TUM Department of Informatics
Informatics 2017
Facts and Figures – Studying at TUM Department of Informatics

Germany’s Leading Department of Informatics
In the subject ranking for “computer science” the Shanghai Ranking and the QS World University Rankings by Subject have assessed the TUM Informatics as being the top Department of Informatics in Germany for several years now.

Best Career Opportunities for TUM Graduates
In the worldwide “Global Employability University Ranking 2017” the TUM holds the 8th place as the only German university among the 25 worldwide leading universities, in the assessment of graduates by international enterprises.
## Informatics 2018

### Facts and Figures – Studying at TUM Department of Informatics

#### Germany’s Leading Department of Informatics

The subject ranking for Computer Science of the Shanghai Ranking and the QS World University Rankings by Subject have assessed the TUM Informatics as being the top Department of Informatics in Germany for several years in a row.

#### Best Career Opportunities for TUM Graduates

In the worldwide Global Employability University Ranking 2018 the TUM holds the 6th place as the only German university among the 25 worldwide leading universities in the assessment of graduates by international enterprises.

### Success

- Number of Habilitations: 2 (Academic Year 2018/19)
- Number of Completed Doctorates: 68 (Academic Year 2018/19)
- Graduates: 930 (Academic Year 2017/18) 143 Female

### Close cooperation with industry

#### Number of Habilitations

- Male: 37
- Female: 5

#### Number of Completed Doctorates

- Male: 345
- Female: 63

### Studying in Munich

QS Best Student City Ranking 2018: In a worldwide comparison, Munich places 6th among the top study locations.

### INTERNATIONAL

- Total Students: 5986
- Male: 4815
- Female: 1171
- International Students: 36.9%

### INTERNATIONAL MOBILITY

- Total new/going students: 5
- TUM Informatics students participating in exchange programs: 164
- TUM Informatics students studying at TUM informatics: 2018/19
- TUM Informatics students in exchange programs: 2018/19

### INTERNATIONAL STUDENTS

- Male: 2208
- Female: 1765
- International students: 40.0%

### NEW ENROLMENTS AND STUDENTS

- First-year Students: 1765
- Male: 443
- Female: 36.9%

### MSc Study Programs

- Bioinformatics
- Computational Science and Engineering
- Data Engineering and Analytics
- Informatics
- Informatics: Games Engineering

### BACHELOR

- Informatics: 751
- Informatics: Games Engineering: 154
- Information Systems: 273
- Bioinformatics: 76

### MASTER

- Informatics: Data Engineering and Analytics: 77
- Informatics: Games Engineering: 412
- Information Systems: 33
- Bioinformatics: 71
- Automotive Software Engineering: 18
- Biomedical Computing: 10
- Robotics, Cognition, Intelligence: 174
- Computational Science and Engineering: 52
- Informatics Part Time: 19 / 65 %%

### DAAD’s 2018/19 comparative figures

No other Department of Informatics in Germany has more students using the Erasmus+ exchange program to study abroad.

### QS World University Rankings by Subject

- The subject ranking for Computer Science of the Shanghai Ranking and the QS World University Rankings by Subject have assessed the TUM Informatics as being the top Department of Informatics in Germany for several years in a row.

### Informatics Part Time 50 % / 66 %

- 19 / 9
- 43 Informatics (Postgraduate Non-Degree Program)

### Gottfried Wilhelm Leibniz Prize Winners

- IEEE Computer Pioneer Award Winners: 2
- Alexander von Humboldt Professors: 2
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IN.TUM Management Board. (Photo: A. Heddergott/TUM)
Editorial

The Technical University of Munich (TUM) is among the leading technical universities in Europe. TUM is highly committed to excellence in research, education, technology transfer, and entrepreneurship. Interdisciplinary, international, and intersectoral collaboration are of high priority, as well as support of young scientists and equal opportunities. In 2006, TUM was among the first three universities in Germany to be awarded the status of a “University of Excellence” in the framework of the German Excellence Initiative, and this status got renewed in 2012. A core component of TUM’s successful concept was the introduction of a sophisticated three-level evaluation system, with an institutional evaluation of each department about every eight years. TUM’s Department of Informatics (IN.TUM) underwent this process in 2017, with a self-report as a main pillar. This brochure has been compiled from that report, and it now provides a unique and to-date overview of our department.

Our department’s evaluation coincided with the celebration of “50 Years of Informatics in Munich”. Since 1967, when the first Informatics courses and the respective study program were offered at TUM, Informatics has seen a breathtaking development – in science, industry, and society. From its “Is-this-really-a-discipline?”-kind of beginning, Informatics has evolved into a rich, pace-making, and technology-driving scientific domain, with both its own research agenda and numerous close links to most other disciplines – from science and engineering via life sciences and medicine up to social sciences and the humanities. This rise of the field is also reflected by our department’s development: starting from a few professorships, getting the status of a department in 1992, moving to Garching campus in 2002, and seeing a continuous growth with 42 professors today – a dozen more to come within the next two years. There can be no doubt: Informatics at TUM has been and is extremely fortunate, concerning the economic and political context as well as, in particular, the strong support by the university board and our fellow departments. We are very grateful for that. Moreover, we are very happy that we do have a lot to give back to our university and environment, being today a very attractive, visible, and successful department of TUM as well as one of the leading informatics departments in Germany and Europe that also earned an excellent reputation world-wide.

From the very beginning, IN.TUM chose a modern and lean organizational and governance structure, with all resource and budget management as well as all services being organized at the department level through highly competent and efficient central units. Today, we consider this model even more important, since it provides us with an utmost degree of flexibility, which is crucial when the funding mechanisms get more short-term and volatile as well as, hence, less predictable.

Our primary strategy has always been to be a comprehensive informatics department that can deliver answers and solutions to the upcoming big and urgent questions and problems, as well as the necessary experts educated for that in the best possible way. That’s why our answer to “either-or”-kind issues (research vs. top-level and broad education; basic vs. applied research; deepening in focus areas vs. opening towards upcoming topics; core informatics vs. all the bridges to other disciplines) has always been a clearly pronounced “both-and”.

clusters will have a positive effect on both internal collaboration and attractiveness for potential external partners.

Actually, networking and collaboration have always been strengths of IN.TUM. This holds for joint activities with other departments; participation in TUM-wide measures; collaboration with local non-university research institutions (Fraunhofer, Max-Planck, Helmholtz, Leibniz Supercomputing Center); close relations to a large variety of companies, from start-ups to global players, and covering a broad landscape of industry branches; consulting to public and private leadership; and, last but not least, research partnerships with renowned academic partners, nationally and internationally.

Concerning teaching, for our currently about 5,400 bachelor’s and master’s students, we offer four bachelor’s (Informatics, Informatics: Games Engineering, Information Systems, Bioinformatics) and nine master’s programs (the above four, plus Computational Science & Engineering (CSE), Biomedical Computing, Automotive Software Engineering, Robotics – Cognition – Intelligence, Data Engineering & Analytics). Furthermore, IN.TUM participates in or coordinates six elite programs in the framework of the Elite Network Bavaria (Bavarian Graduate School of Computational Engineering, Technology Management, Software Engineering, Finance & Information Management, TopMath, Data Science). While there are good reasons for a limitation at the bachelor’s level (Games Engineering has been the only addition in the last decade – and it is a huge success story), we see a bigger need for variety at the master’s level, mainly due to internationalization and interdisciplinarity. Both dimensions have always been at the top of IN.TUM’s agenda. Concerning the first, just take CSE completely taught in English (since 2001), the English track in the Informatics master (since 2008), or the Germany-wide highest Erasmus exchange numbers as examples. Concerning interdisciplinarity, CSE pioneered as a program jointly offered by seven departments, and Data Engineering & Analytics is part of the first new, TUM-wide Integrative Study Program on Big Data.

Numbers keep increasing: Since the “double Abitur class” in 2011, this trend has been somewhat overwhelming, leading us to more than 1,000 new bachelor’s and almost 1,000 new master’s students last fall. While this is a challenge, we see our societal mandate, and we are enthusiastic about so many young people taking a smart decision. IN.TUM pioneered in introducing aptitude & eligibility testing (including individual interviews) in 2002, and we managed to reduce drop-out rates significantly by that (roughly speaking, we obtained a complete about-face – from one out of three arriving after five years to one out of three having dropped out during 3+2 years). And IN.TUM actively participated in TUM’s very successful “two-in-one” program in 2011, offering an ambitious turbo program during the summer for a direct start in the third semester to the last class with nine years of secondary school.

While we feel well positioned in terms of internationalization, cross-disciplinary collaboration, and support of young researchers (the latter through the Center for Doctoral Studies in Informatics and its Applications (CeDoSIA), our Departmental Graduate Center in the framework of TUM Graduate School), we clearly see deficits concerning the gender issue. While there are a couple of pioneering activities beyond the normal (such as “Kinderzimmer”, the “Informatik-Forum Frauen”, or a formalized raise of importance of gender and diversity in the recruitment processes), this topic needs our ongoing further attention.

Life on campus has always been an issue in Garching. Several measures taken – such as the department’s annual Summer Party, the weekly “Game Night” organized by our Departmental Student Council, or the sports facilities next to our building – as well as more upcoming events – have enhanced and will continue to enhance campus life and attractiveness. And we are looking forward to a further enrichment of our
One of the biggest assets of IN.TUM today is the excellent climate of mutual respect and esteem, of a highly collaborative spirit throughout faculty, staff, and students, and of an always constructive way of directing possibly diverging interests towards consent. This provides the ground on which our research, teaching, and technology transfer activities can flourish – and the indicators of our performance, ranking positions, and our overall success show that they have been doing so and continue to do so. Thus, we consider IN.TUM to be in excellent shape.

Of course, there are challenges – due to the “big numbers issue”, but also due to structural changes such as the introduction of the pioneering TUM Faculty Tenure Track (TT) system in 2012. However, it has always been the strength of our university and department to address challenges in an active and creative way and to identify and implement solutions. Actually, this is – besides vivid involvement in start-up activities – what the “entrepreneurial” stands for. And IN.TUM has always been pivotal – with its research, its education, its output of next-generation leaders, inside and outside academia, and through the overall impact of its agenda. Given the high dynamics of our discipline, the essence of IN.TUM’s strategy can only be and, hence, is to be prepared, instead of defining rigid plans. We feel prepared, and we are therefore looking ahead with great confidence as well as scientific and technological curiosity – great times for informatics!

Garching, March 2019

Hans-Joachim Bungartz, Dean
The Technical University of Munich (TUM) was founded in 1868 to educate the engineers urgently needed for the ongoing industrialization. Hence, next year, our university will celebrate 150 years of breathtaking developments. Today, TUM is one of Europe’s top universities, highly committed to excellence in research, education, technology, and entrepreneurship. Throughout its agenda, interdisciplinary, international, and intersectoral collaboration are of high priority, as well as support of young scientists and equal opportunity. In 2006, TUM was among the first three universities to be awarded the status of a “University of Excellence” in the framework of the so-called German Excellence Initiative (“Exzellenzinitiative des Bundes und der Länder zur Förderung von Wissenschaft und Forschung an deutschen Hochschulen” – ExIni), and this status got renewed in 2012. In the last years, TUM has been repeatedly ranked as first university in Germany in the Shanghai Ranking.

Other rankings such as the THE World University Ranking confirm TUM as the leading technical university in Germany and place TUM under the top four in Europe.

Reflecting its fundamental mission to serve society, TUM is committed to progress and innovation in all fields of science that promise sustainable improvement in how people and society live. Hence, building on its traditional strengths in science and engineering, TUM’s portfolio has been continuously widened. Today, TUM has 14 departments, the recent integration of the Bavarian School of Public Policy (HfP) with TUM’s corresponding and 14th department, TUM School of Governance, being the latest extension. TUM’s departments cover a wide range of research and teaching topics in natural sciences, engineering, life sciences and medicine, education and economy as well as technological issues in social sciences and politics.
The departments are complemented by several Integrative Research Centers (IRCs) that bundle expertise across departments, perform interdisciplinary research, and contribute to excellence in teaching. The Institute for Advanced Study (IAS) creates an unrivaled environment for selected outstanding scientists at different levels of seniority – guest researchers or TUM faculty – to conduct their top-level research. Interactions between science, technology, and society are in the focus of the Munich Center for Technology in Society (MCTS), while the Munich School of Engineering (MSE) as well as the Munich School of BioEngineering (MSB) address highly relevant and cross-disciplinary topics such as energy research or bio- and biomedical engineering.

TUM’s total budget is 1,329 Mio € (2016, including the university hospital) that mainly consists of a subsidy of 606.2 Mio € from the state of Bavaria, a gross third party funding of 285 Mio € and a self-generated income of 437.8 Mio €. In the winter term 2016/17, 40,124 students have been enrolled in 172 study programs. Encompassing 545 professors the total staff employed is 10,103 working in 411 buildings, mainly located at three larger sites in the Munich area: “Stammgelände” in Munich where several departments and TUM’s central administration reside, the dynamically growing Garching Campus concentrating science and engineering, and Weihenstephan Campus specializing on life sciences. And TUM continues to expand, the TUM Campus Straubing for Biotechnology and Sustainability being the latest member of the TUM family.

In particular, two innovative components have been established in the context of ExIni and TUM: In 2009, TUM Graduate School (TUM GS) was launched as the TUM-wide umbrella for all doctoral education. In a sophisticated balance of a TUM-wide frame and disciplinary variety, TUM GS appropriately promotes structured training for doctoral candidates and allows them to acquire valuable additional qualifications that help them shaping their careers – whether academic, in industry, or as entrepreneurs. TUM GS is the only one of its kind in Germany thanks to its comprehensive, university-wide format, and its rich program offers. Also as a forerunner in Germany, TUM started the TUM Faculty Tenure Track System in 2012 that offers early independence and career perspectives to outstanding talents.
Highly promising young scientists are appointed as assistant professor (W2) with prospects for performance-based promotion to a permanent associate professorship (W3) and, outstanding achievements at the highest international level given, further advancement to a full professorship (W3*). So far, 85 professors have been appointed within this Tenure Track System.

Currently, TUM is again heavily involved in the renewal of the Excellence Initiative, the so-called Excellence Strategy. Among the various new boundary conditions, three are of particular relevance: the reduction to two funding lines (Excellence Clusters and Excellence Universities), the prolongation of the funding cycles from five to seven years, and the admittance to the competition for the Excellence University label only upon successful acquisition of two Excellence Clusters.

Beginning of April, TUM submitted ten draft proposals for Excellence Clusters, among which are several joint proposals with partner universities.
2 Development of the Department of Informatics

2.1 History

The way to an independent Department. 1967 was the birth year of academic Informatics in Munich: For the first time, a lecture using the term “Informatics” was offered at TUM by F. L. Bauer. Even before, the compute system PERM, developed by H. Piloty and R. Sauer, and first programming languages such as ALGOL 60, coined by F. L. Bauer and K. Samelson, had been highly visible milestones in the development of what would later be called “Informatik”, a newly created word in German. In English, the term “Computer Science” was and still is common, but increasingly replaced by the term “Informatics”. Having started as an optional specialization in “Information Processing” for mathematics students, the new kid on the block soon got the status of a minor in “Informatics”, and in 1972, “Informatics” achieved an independent status as a full diploma study program at TUM. Afterwards, the emancipation of informatics continued – with the foundation of its own institute within the Department of Mathematics, later, of Mathematics and Informatics, and, finally, with the independent Department of Informatics, IN.TUM, in 1992.

After 1970, the building up of informatics faculty took shape, with M. Paul, J. Eickel, and R. Bayer taking the first three chairs dedicated to informatics, and with F. L. Bauer and K. Samelson joining the new field with their chairs. In the following, pioneering work went on: Already in 1978, a computer network with one of the first UNIX licenses in Germany and an Ethernet coupling was operated; the first software-oriented computer network lecture as well as the first software engineering lecture were offered, and one of the first large decentralized workstation computer systems was introduced. Of course, collaboration always played a major part: with our emerging sister institutions at Ludwig-Maximilians-University Munich (LMU) and Munich University of the Armed Forces (UniBW), with industry, with other departments and disciplines, but also and in particular with the Leibniz Computing Center (LRZ, later Leibniz Supercomputing Center) of the Bavarian Academy of Sciences and Humanities, which had been established already in 1962 as the central IT service unit for the academic institutions in Munich – a strategic decision that pointed the way and should turn out to be crucial for many future developments in Munich and Bavaria.

Consolidation and further growth. By 1992, when IN.TUM was founded, there were 12 and soon 14 chairs in informatics. By the end of the 1990s, IN.TUM had got five additional chairs, and this extension was mainly driven by new emerging applications – the so-called “Bindestrich-Informatiken”; here Medical Informatics and, in particular, Business Informatics or Information Systems. Concerning the latter, by the way, TUM did not follow the more common trend to place Information Systems in the Business School, but integrated it into IN.TUM as a strategic decision. The further growth of IN.TUM was driven by special programs, endowed chairs, and also the Rudolf-Mößbauer Professorships that TUM introduced in the framework of the Excellence Initiative.

In 2002, the Departments of Mathematics and Informatics moved from downtown Munich to the Garching campus. With the subway connection being completed in 2006, the campus lost most of its remote flavor. Since then, a lot of measures have been taken to increase campus life, and the opening of Galileo, the new “center” of the campus, will mark another highlight. In the meantime, not astonishingly, space has become an issue again, and since several years now, IN.TUM has been using remote facilities again, for example in Garching Hochbrück.

Today, IN.TUM is one of the largest departments at TUM as well as one of the largest informatics departments in Germany. With a student population
of close to 5,400, a broad offer of bachelor’s and master’s programs, and a very international and interdisciplinary education profile, IN.TUM is well prepared for the future.

Garching Campus, building of the Departments of Mathematics and Informatics. (Photo: Fabian Schmich)

Opening of the FMI building, with former Bavarian Prime Minister Edmund Stoiber. (Photo: FACES by FRANK)

2.2 Strategy & goals

Positioning. 50 years after the first visible steps of informatics education in Munich and at TUM, our department is in a very good shape. All common indicators underline that. We managed to attract excellent faculty at all career stages, advanced or entering our TT system, and we managed as well to avoid points of fracture in phases of a change of generation; the attractiveness of our study offers keeps growing: after having surpassed the beginners numbers of the “double Abitur class” year 2011 last autumn, the application numbers predict another increase for the upcoming academic year, both at bachelor’s and master’s level; the output of doctoral graduates is between 90 and 100 per year; both reputation and third party funding are at very healthy levels; and although the 9th place worldwide in the current THE ranking surely should not be over-estimated, it adds another piece of evidence to the overall picture. IN.TUM has also strengthened its position within TUM – a fact which is reflected by our President’s statement of informatics being a lead discipline of a modern technical university.

Structure & Organization. As depicted in the previous section, the first 50 years of informatics in Munich as well as the first 25 years of IN.TUM have seen a continuous growth, which reflects the breathtaking development of our field in that period. We preserved our structure of “one department – one institute” and our organization with central service units, although it is not always easy to keep such a system scalable. However, the advantages of that system in terms of efficiency, flexibility, ability to act, avoidance of internal friction, and generating critical mass are still obvious and predominant. While this organizational structure shall not be changed, IN.TUM gave itself some structure for our research and introduced 13 “research clusters” – to bundle activities, to make competences visible internally and externally, etc.

Governance. The core of our governance structure is given by law: Department Council, Dean, Vice Dean, and Dean of Studies. Concerning governance beyond that core frame, IN.TUM introduced its present structure in 2010. It is based on “all-faculty instruments” (a retreat twice a year, a Faculty Meeting (“Informatik-Kaffee”) every two weeks during lecture periods); an internal advisory body (the Structural Planning Commission, developing long-term policies and strategies for issues such as new fields, new positions, etc.); the Management Board (the actual “cabinet”, consisting of Dean, Vice Dean, Dean of Studies, Managing Director, Chief Executive Director, and all Deputy Directors for the various responsibilities (HR, Finance, Space & Buildings, IT Infrastructure, Public Relations, and Student Services) and meeting every two to four weeks); as well as several sub-committees.
Strategy – core elements. We consider education and teaching as the core component of our societal mandate. This in mind, and aiming at the best possible student population, our aptitude and eligibility testing has turned out to be crucial, and it continues to be so. At all levels, we want to deliver next-generation leadership for academia, industry, or society. Besides highest standards and broad offerings in teaching, student services also contribute to top conditions of study and, therefore, are of high priority. Striving for excellence in research, in terms of high quality and high impact, is a must for IN.TUM, and this comprises several dimensions, such as high-quality publications, citations, and research projects – both in core informatics as well as in interdisciplinary settings. Another priority is on tight relations to the non-academic sector: industry, society, government, concerning research, development, or consulting. In terms of technology leadership, IN.TUM wants to drive and shape, instead of just participating. This entails that we won’t go for each and every topic, but it is the department’s understanding to have the portfolio to tackle the relevant questions and to deliver solutions, and our structural planning incorporates flexibility and emerging opportunities as key components – we want to be prepared, rather than defining rigid plans. Finally, variety is a core strategy for IN.TUM – in terms of study offers, research fields, general activities, gender, and internationalization. IN.TUM has always benefitted from that openness.

2.3 Participation within TUM

Today, IN.TUM is among TUM’s biggest and most successful departments. The ongoing or upcoming developments due to the digital change will further increase the relevance of informatics and place our department in an even more prominent role – a part which can only be played in a collaborative way.

A first mean of interaction are secondary or affiliate department memberships, which strengthen cross-departmental relations both in a scientific and in a strategic way. Among the active faculty, 12 members of IN.TUM are an affiliate member of overall five other departments (EI, MA, ME, WI, WZW), while currently 13 active faculty from overall seven other departments (AR, EDU, EI, GOV, MA, ME, WI) are affiliate members of IN.TUM.

Moreover, there are various joint programs, research projects, or other activities with our fellow departments – the following incomplete list shall just give a few prominent examples:

- AR (Architecture): support of the IT of the “NS Dokumentationszentrum”;
- BGU (Civil, Geo, and Environmental Engineering): Elite Program Bavarian Graduate School of Computational Engineering (BGCE); industry-funded consortium TUM Living Lab Connected Mobility;
- CH (Chemistry): Elite Program Exploring Quantum Matter; ELPA projects and library;
- EDU (Education): tutor training;
- EI (Electrical and Computer Engineering): SFB/ CRC 89 Invasive Computing; Center for Digital Technology and Management (CDTM); Excellence Cluster Cognition for Technical Systems (CoTeSys); Franco-German Academy of Industry of the Future; industry-funded consortium CAR@TUM;
- GOV (Governance): involvement in its implementation and recruiting;
- MA (Mathematics): Elite Program TopMath; Big Data master's programs; SPP/PP 1648 Software for Exascale Computing;
- ME (Medicine): involvement in several SFB/CRCs; Medical Informatics initiative Data Integration for Future Medicine (DIFUTURE); ZD.B professorship Intelligent Knowledge Extraction in Medicine; Research Center TranslaTUM; Global Health initiative;
- MW (Mechanical Engineering): Master's Program Human Factors Engineering;
- PH (Physics): involvement in Excellence Clusters Origin and Structure of the Universe (Universe) and Munich Center for Advanced Photonics (MAP);
- WI (Management): Information Systems programs;
• WZW (Life Sciences): Bioinformatics programs; new Elite Program Big Data in Life Science (in preparation); Proteomics Database project.

Some examples of multi-lateral activities are the Munich Center for Advanced Computing (MAC, with BGU, CH, EI, MA, and MW), the international master’s program Computational Science and Engineering (CSE, with BGU, CH, EI, MA, MW, and PH), the TUM-KAUST strategic partnership (with BGU, CH, MA), the SFB/CRC 768 Managing Cycles in Innovation Processes (with EI, MW, and WI), or the new GK/RTG Algorithmic Economics and Operations Research (AdONE, with MA and WI).

Concerning TUM-wide measures and institutions, it has to be mentioned that IN.TUM contributes to several of TUM’s big corporate collaborations, for example with Audi, BMW, GE, and Siemens. Furthermore, IN.TUM is actively involved in TUM CREATE in Singapore, in the International Graduate School of Science and Engineering (IGSSE), in the whole portfolio of the Institute for Advanced Study (IAS), the Munich School of Engineering (MSE), the Munich School of Bioengineering (MSB), and Ferienakademie, to give just a few examples. With respect to the IAS, IN.TUM has hosted 14 fellows in the various lines (Hans Fischer, Hans Fischer senior, Rudolf Diesel, Carl von Linde) so far, cf. Figure 2. Finally, IN.TUM has continuously contributed to TUM leadership, cf. Section 2.9.

2.4 Development of research

The department’s research strategy has always been that of a comprehensive informatics department able to deliver answers and solutions to the upcoming big and urgent scientific, economic, and societal questions and problems –
### Table 1: TUM IAS fellows with IN.TUM affiliation

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Host</th>
<th>Type of Fellowship</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bergemann Dirk</td>
<td>Yale University, USA</td>
<td>Bichler / Brandt</td>
<td>Hans Fischer Senior Fellow</td>
<td>2014</td>
</tr>
<tr>
<td>Biros George</td>
<td>The University of Texas at Austin, USA</td>
<td>Bungartz</td>
<td>Hans Fischer Fellow</td>
<td>2012</td>
</tr>
<tr>
<td>Bromberg Yana</td>
<td>Rutgers University, USA</td>
<td>Rost</td>
<td>Hans Fischer Fellow</td>
<td>2014</td>
</tr>
<tr>
<td>Bronstein Michael</td>
<td>Intel Perceptual Computing, Università della Svizzera italiana, Tel Aviv University, Switzerland/Israel</td>
<td>Cremers</td>
<td>Rudolf Diesel Industry Fellow</td>
<td>2017</td>
</tr>
<tr>
<td>Chang Angel</td>
<td>Princeton University, USA</td>
<td>Nießer</td>
<td>Hans Fischer Fellow</td>
<td>2018</td>
</tr>
<tr>
<td>Cremers Daniel</td>
<td>TUM, Germany</td>
<td>-</td>
<td>Carl von Linde Senior Fellow</td>
<td>2017</td>
</tr>
<tr>
<td>Friebe Michael</td>
<td>IDTM GmbH, Germany</td>
<td>Navab</td>
<td>Rudolf Diesel Industry Fellow</td>
<td>2012</td>
</tr>
<tr>
<td>Guibas Leonidas</td>
<td>Stanford University, USA</td>
<td>Nießer</td>
<td>Hans Fischer Senior Fellow</td>
<td>2018</td>
</tr>
<tr>
<td>Hager Gregory D.</td>
<td>The Johns Hopkins University, USA</td>
<td>Navab</td>
<td>Hans Fischer Senior Fellow</td>
<td>2014</td>
</tr>
<tr>
<td>Hegland Markus</td>
<td>Australian National University, Australia</td>
<td>Bungartz</td>
<td>Hans Fischer Senior Fellow</td>
<td>2010</td>
</tr>
<tr>
<td>Kirsch Alexandra</td>
<td>University of Tübingen, Germany</td>
<td>Beetz</td>
<td>Carl von Linde Junior Fellow</td>
<td>2010</td>
</tr>
<tr>
<td>Mehl Miriam</td>
<td>Universität Stuttgart, Germany</td>
<td>Bungartz</td>
<td>Carl von Linde Junior Fellow</td>
<td>2010</td>
</tr>
<tr>
<td>Muscholl Anca</td>
<td>Université Bordeaux, France</td>
<td>Esparza / Chakraborty</td>
<td>Hans Fischer Senior Fellow</td>
<td>2015</td>
</tr>
<tr>
<td>Punta Marco</td>
<td>Université Pierre et Marie Curie, France</td>
<td>Rost</td>
<td>Carl von Linde Junior Fellow</td>
<td>2009</td>
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<tr>
<td>Schröder Peter</td>
<td>California Institute of Technology, USA</td>
<td>Westermann</td>
<td>Hans Fischer Senior Fellow</td>
<td>2009</td>
</tr>
<tr>
<td>Spiegelberg Gernot</td>
<td>Siemens AG, Germany</td>
<td>Knoll</td>
<td>Rudolf Diesel Industry Fellow</td>
<td>2010</td>
</tr>
</tbody>
</table>

As well as, of course, to deliver the well-educated people necessary for that. And IN.TUM has been quite successful with that strategy. While "comprehensive" has to be seen against the background of our embedding into a technical university as well as of its specific local context (comprising our fellow Departments of Mathematics and of Electrical and Computer Engineering, but also the informatics departments of LMU and of UniBW), IN.TUM’s research variety has been growing since its early years. The first extensions aimed at strengthening core informatics with its consolidating or, at that time, still emerging branches. The second wave reflected the increasing relevance of informatics research in other fields and focused on classical “Bindestrich-Informatiken”, such as information systems and bioinformatics. The recent development, still characterized by ongoing growth, is more multi-faceted, with both deepening (the focus on data engineering and analytics, e.g.) and broadening (the new professorship Digital Technologies in Society, e.g.) effects. This also takes into account that a significant part of all modern research is integrated and multi-disciplinary, and takes place rather on the bridges than on the islands. Hence, IN.TUM’s research is coined by both its own initiatives and agenda and its active participation in joint activities, as elaborated in the previous section.

We are convinced that, also in research, there cannot be any “either-or” – concerning theoretical foundations or applications, concerning core informatics or enabling activities, or concerning the various funding sources (DFG, federal ministries, Bavarian ministries, EU, industry, or
2. Development of the Department of Informatics

Others). Within the framework of TUM Graduate School, our Graduate Center CeDoSIA deliberately carries *Informatics and its Applications* in its title. IN.TUM’s research footprint comprises both core informatics milestones – take the early SFB/CRC 49 *Programming*, the leading role in genesis and development of the field of Software Engineering, the SFB/CRC 342 *Methods and Tools for the Use of Parallel Computer Architectures*, the GK/RTU *PUMA – Program and Model Analysis*, or the initiative for several Priority Programs as examples – and a couple of cross-disciplinary collaborative research activities with IN.TUM leadership (the EU Flagship Project *Human Brain Project*, DFG’s Priority Program *Scalable Data Management for Future Hardware*, or DFG’s strategic Priority Program *SPPEXA – Software for Exascale Computing*, to give just two examples). In the framework of the Excellence Initiative, IN.TUM significantly contributes to the research program of the IGSSE and the IAS, is involved in Excellence Clusters (Universe, MAP), and had a co-leadership role in the Excellence Cluster *Cognition for Technical Systems* (CoTeSys). In the running Excellence Strategy (ExStra) application process, IN.TUM researchers are involved in four cluster proposals by TUM (among which two with a (co-)spokesperson role) and one cluster proposal by LMU. Moreover, there is a long list of cooperations with industry, for example with Siemens in the framework of the Center for Knowledge Interchange, with GE in the framework of the TUM-GE partnership, with Audi within INI.TUM, with Intel (*Munich Multicore Initiative*, *Intel Parallel Computing Center*) and nvidia (*CUDA Development Center*), or with BMW, Siemens Healthcare, SAP, and many more.

In 2016, after an intense discussion process, IN.TUM decided to structure its research activities into 13 research clusters as a dynamic topical frame: (1) *Algorithms & Complexity*, (2) *Algorithmic Economics & Operations Research*, (3) *Computer & Communications Architecture*, (4) *Data Engineering & Analytics*, (5) *Digital Biology & Medicine*, (6) *Distributed & Mobile Computing*, (7) *Extreme Scaling*, (8) *Formal Methods*, (9) *Human-centered Engineering*, (10) *Robotics*, (11) *Security, Safety*, *Risk Management*, (12) *Software Engineering & Information Systems*, (13) *Visual Computing*. This is not meant as a rigid organizational corset, but as a living and evolving agenda also including colleagues from other departments. Actually, first extensions are already under discussion, such as the explicit inclusion of Artificial Intelligence. We are convinced that the establishment and further development of these clusters will have a positive effect on both internal collaboration and attractiveness for potential external partners.

Finally, IN.TUM’s track record in terms of prizes, awards, and ranking positions also underlines our strong position on the national and international informatics stage.

2.5 Development of teaching

Today, IN.TUM offers four bachelor’s as well as nine master’s programs, and we offer or are involved in six elite master’s programs, with an overall student population of about 5,400. It all started 50 years ago.

The first lecture in informatics was held in 1967, and five years later, TUM’s diploma program *Informatics* started. The following years were characterized by a consolidation of the curriculum, based on the three pillars theoretical, practical, and applied informatics, the further evolution (including the re-shaping of the fundamental mathematics courses), and an ongoing diversification of the field. As a next landmark, a first experimental bachelor’s degree program was installed in 2000 in parallel to the diploma program, and together with a switch to examinations alongside with the courses. In the same year, the internet bubble and the Green Card discussion in Germany confronted the department with a first peak in the number of beginners, resulting in 1,200 students participating in the introductory course “Informatics I”.

In 2001, new course programs *Information Systems, Computational Science and Engineering*,
Development of the Department of Informatics and Bioinformatics were established. Each of these programs is offered in cooperation with other departments, due to our strong belief that higher education in Informatics requires a strong interaction with other disciplines. As an answer to the high drop-out rates of beginners – a general nuisance of all technical study programs in Germany resulting in frustrated students and waste of valuable lifetime and university resources – IN.TUM pioneered in installing university aptitude/eligibility testing ("Eignungsfeststellungsverfahren" – EFV) in 2002, which effectively reduced the drop-out rate from up to 60% to around 30% in the following years.

Already in 2005, the Bologna transition to the bachelor/master system was completed for all study programs offered by the department. After the burst of the internet bubble, in particular in the years 2005 to 2009, we generally experienced a low in the number of beginners. Various countermeasures were taken: A tailored school program was installed; at the master's level, our main program Informatics was systematically opened for international applicants ("English Track"). This internationalization at the master's level can be considered as the counterpart of the extensively used exchange programs for bachelor’s students. And new attractive master’s programs, Robotics – Cognition – Intelligence, Biomedical Computing, and Automotive Software Engineering were established.

In 2011, due to the switch in Bavaria from nine years of secondary school to eight years only, universities were confronted with a double age-group of beginners. The situation was even severed as, in the same year, the compulsory military service was abandoned. IN.TUM reacted by actively participating in the “TUM two-in-one” program, by exceptionally offering an extra study track starting already in the summer term as well as a fast track during the summer break in order to enable ambitious students to catch up with the beginners from 2010. Additionally, the new bachelor’s study program Informatics: Games Engineering was installed. Since then, this study program has been rounded up by providing a consecutive master’s program Informatics: Games Engineering in 2014 and, finally, a master’s program Data Engineering and Analytics in 2016 as our contribution to the new Integrative Study Program (ISP) Big Data offered by TUM.

In order to assure conformance with the Bologna requirements, in 2007, the department started program accreditation for the bachelor's and master's programs in Informatics, which was approved by ASIIN in 2009. Currently, all bachelor's and master's programs are continuously monitored by the quality management installed at TUM within the system accreditation.

Since 2011, the number of beginners both at the bachelor’s and the master’s level has steadily and significantly increased. Taking the number of students, we are currently the largest Informatics department in Germany and the second-largest department of TUM. Interestingly, the number of beginners in the master’s programs is close to the number of bachelor’s beginners. This effect is certainly due to our attractive research portfolio and our continuous internationalization efforts.
Figure 3: First-year students in bachelor’s and master’s programs per year (summer + winter term) at IN.TUM.

Figure 4: Students in diploma, bachelor’s and master’s programs (per winter term) at IN.TUM.
Figure 5: Graduates in diploma, bachelor’s and master’s programs per academic year (winter + summer term) at IN.TUM.
3 Research

Over the last two decades, informatics was faced with the development that more and more application domains changed dramatically by the adoption of information technology. This opened up new challenges for informatics research in collaboration with a variety of application domains, and gave opportunities for the department to grow. Further growth opportunities emerged by the strong growth in the number of students. IN.TUM used this opportunity for growth by adopting a balanced strategy that on the one hand emphasized continuity in maintaining strength in the core informatics disciplines, while at the same time using opportunities for covering new research areas with new professor positions in application domains such as Medical Image Computing and Bioinformatics.

The goal of IN.TUM is to cover all relevant research directions in informatics. The department also aims at having a broad range of impact, addressing academic and also industrial relevance of its research. While some research groups aim equally for academic and industrial impact, others emphasize one over the other.

3.1 Research Clusters

Concept and role of the research clusters

The research clusters are not departmental units, but rather bring together the research activities of individual groups working on specific topics. They are a means of fostering collaboration within IN.TUM, but also of supporting collaboration with research groups of neighboring TUM departments, linking to engineering, natural sciences, economics, and medicine, and boosting exchange with the outside.

Professors can be members of more than one research cluster. The research clusters have been created in a bottom-up process, reaching their consolidated format in 2017. It is expected that additional members, in particular from other TUM departments, are going to be integrated into the current build-up phase.

The following 13 research clusters have been established:

1. Algorithms & Complexity
2. Algorithmic Economics & Operations Research
3. Computer & Communication Architectures
4. Data Engineering & Analytics
5. Digital Biology & Digital Medicine
6. Distributed & Mobile Computing
7. Extreme Scaling
8. Formal Methods
9. Human-centered Engineering
10. Robotics
12. Software Engineering & Information Systems
13. Visual Computing

In the following, for each cluster, we provide its agenda and its current members. Instead of listing all related project activities, we illustrate the ongoing research by presenting selected highlight projects in detail.

1 Algorithms & Complexity

The cluster members pursue a wide spectrum of foundational and applied working directions in algorithms research. The cluster mission is to investigate fundamental algorithmic problems and to develop substantial contributions in terms of concrete algorithmic solutions and underlying design and analysis techniques. Specific research foci include the study of approximation and online algorithms, randomized algorithms as well as parallel and network algorithms. Important algorithmic problems arising in the resource management of computer systems and large networks are examined. A recent line of work addresses the design of energy-efficient algorithms.
Research interests also include the fields of algorithmic game theory and algorithms engineering. On the more applied side, the cluster members explore fundamental algorithmic and complexity issues in computational logic, program and systems verification as well as mathematical optimization, computer vision, and scientific computing.

Cluster Members: Susanne Albers (Coordinator), Michael Bader, Martin Bichler, Felix Brandt, Hans-J. Bungartz, Daniel Cremers, Javier Esparza, Peter Gritzmann (MA), Stephan Günnemann, Ernst Mayr, Tobias Nipkow, Harald Räcke, Helmut Seidl.

Selected projects:

Algorithmic Performance Guarantees: Foundations and Applications (APEG); ERC Advanced Grant. This project builds on the algorithm research of Susanne Albers. The goal of APEG is to significantly advance the state of the art in the field of algorithmic performance guarantees. The project will improve algorithmic techniques in the areas of online algorithms, approximation algorithms, and algorithmic game theory. Moreover, it will apply these techniques to solve basic and long-standing open problems. The research agenda encompasses a host of classical and timely topics such as (a) resource allocation in computing environments, (b) data structuring, (c) graph problems, with relations to Internet advertising, (d) complex networks, and (e) massively parallel systems.

Energy-Efficient Scheduling; project within the DFG SPP 1736 Algorithms for Big Data. The project investigates algorithmic techniques for energy savings in hardware environments, thereby supporting the processing of big data sets at the systems level. It focuses on the technique of dynamic speed scaling and develops algorithms for the realistic scenario that a processor has a finite set of discrete speed levels. The theoretically oriented work is complemented by thorough experiments. A specific project goal is to bring algorithmic results closer to practice.

Degree Bounds for Gröbner Bases of Important Classes of Polynomial Ideals and Efficient Algorithms; project within the DFG SPP 1489 Algorithmic and Experimental Methods in Algebra, Geometry and Number Theory. Buchberger introduced Gröbner bases in order to solve problems of polynomial algebra algorithmically. The membership problem for ideals is to decide whether a given polynomial is member of a given ideal. The goal of the project is to find interesting cases where the membership problem is provably easier than the general case and thus possibly better tractable in practice. New and exact complexity results have been achieved for the membership problem in general polynomial ideals as a function of the dimension of the ideal.
Research of the cluster focuses on the analysis and optimization of economic processes in general. Aim is to develop models, algorithms, and economic mechanisms for the improvement of social welfare. Topics include the analysis and design of economic mechanisms with multiple decision makers (auctions, matching, voting, etc.), the design of algorithms to solve managerial resource allocation and scheduling problems, and the analysis of data in the context of predictive analytics. Game-theoretical as well as algorithmic properties of economic mechanisms are analyzed, and their performance is evaluated in the lab and in the field. The work is rooted in combinatorial optimization, game theory, mechanism design, and social choice theory, but also requires tools and techniques from algorithm design and complexity theory. While these areas have been separate academic disciplines in the past, much recent research at the intersection of informatics, mathematics, management science, and economics combines respective methods to design new types of economic mechanisms. Examples include new types of combinatorial auction mechanisms for the allocation of spectrum licenses or other private or public assets, new optimization techniques for kidney exchanges, and stable matching algorithms for course assignment at universities. All these examples consider computational aspects, as well as incentives and strategies of multiple decision makers to achieve globally optimal solutions. The cluster includes a combination of internationally recognized experts in algorithms, game theory, mechanism design, and experimental economics, who have contributed to theory, but also to a variety of important and challenging real-world problems.

Cluster Members: Martin Bichler (Coordinator), Susanne Albers, Felix Brandt, Peter Gritzmann (MA), Rainer Kolisch (WI), Ernst Mayr, Tobias Nipkow, Harald Räcke.

Selected projects:

DFG Research Training Group Advanced Optimization in the Networked Economy (AdONE). DFG recently approved a new Research Training Group, the Graduate Program AdONE. Due to an increasingly interconnected economy, multiple decision-makers are typically involved in resource control, and large data sets are available allowing for new optimization methods for the efficient use of resources. The Graduate Program conducts research in operations research and management science to develop models and processes that aim at the efficient use of resources through intelligent planning and control.

Design of a Combinatorial Exchange for the Trade of Fishery Access Rights. The project is concerned with the design and development of software for allocation and pricing of fishery shares. The auction rules draw on mathematical programming techniques to solve underlying optimization problems. A formal analysis focuses on economic properties such as robustness against manipulation and fairness of the payment rules.

An Axiomatic and Computational Study of Probabilistic Social Choice. The goal of this project is to investigate the axiomatic properties of probabilistic social choice functions, i.e., functions that aggregate the preferences of individual agents to socially acceptable probabilistic outcomes. Probabilistic social choice is gaining increasing attention in economics and informatics and has many applications in special domains of interest such as random assignment and matching markets.

Dynamic Resource Allocation in Cloud Data Centers. Design and development of algorithms for static and dynamic resource allocation in cloud data centers. The problems require to solve very high-dimensional packing problems. Based on mathematical programming and matrix approximation techniques, allocation problems with hundreds of virtual machines can be solved to near-optimality. A subproject received the INFORMS Design Science Award.
Cluster Members: Georg Carle (Coordinator), Uwe Baumgarten, Arndt Bode, Michael Gerndt, Jörg Ott, Hans-Arno Jacobsen, Wolfgang Kellerer (EI), Wolfgang Utschick (EI), Andreas Herkersdorf (EI), Klaus Diepold (EI).

Selected projects:

CELTIC-Project SENDATE PLANETS: SEcure Networking for a DAIta center cloud in Europe (SENDATE), ProgrammabLe Architecture for distributed NETwork functions and Security (PLANETS). The goal of the SENDATE research program is to provide and demonstrate concepts, mechanisms, and algorithms for secure and flexible Internet infrastructure for Industrial Internet, mobile connected objects, Internet of Things, health applications, and 5G networks. High demands on security, location awareness, service guarantees, flexibility, and latency require a convergence of telecommunication networks and IT as well as distributed data centers, which are placed close to

3 Computer & Communication Architectures

Networked computer systems have to transmit and process increasing quantities of data with the lowest possible latency. Flexible and scalable architectures for communication and virtualization are deployed in “data centers”. More and more paradigms especially crafted for data centers find their way into smaller systems. The Cluster addresses research on energy-efficient and scalable solutions for the transmission, processing and storage of data, drawing ever nearer to physical limits. Internet communication should make it possible to access remote objects with a latency near the limit set by the speed of light. Network virtualization enables the decoupling of network functions from hardware and the dynamic distribution of workload. Some of the technologies considered include Software-Defined Networking, Network Function Virtualization, Information-Centric Networking, and Manycore Architectures.

Cluster Members: Georg Carle (Coordinator), Uwe Baumgarten, Arndt Bode, Michael Gerndt, Jörg Ott, Hans-Arno Jacobsen, Wolfgang Kellerer (EI), Wolfgang Utschick (EI), Andreas Herkersdorf (EI), Klaus Diepold (EI).

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Research

Network Functions Virtualization (NFV) in combination with Software-Defined Networking (SDN) form the basis for a secure, flexible, low latency, and locality-aware distributed data center approach to support the upcoming application scenarios. The BMBF-funded project is coordinated by Nokia. Partners include Airbus, Infineon, genua, Fraunhofer AISEC, VTT, F-Secure, and numerous universities.

AutoMon: Autonomic Performance Monitoring.
The goal of the AutoMon project is to increase the robustness of IT infrastructures through a continuous, proactive, and cross-system function and performance monitoring as well as an automated root cause analysis. To this end, we develop processes to automatically link monitoring data on a cross-system basis. These processes will then be implemented on distributed network systems. This allows administrators to receive visually enhanced and meaningful analyses of outages and disruptions. Issues can then be tackled more swiftly and the maintenance cost is reduced. Furthermore, we develop a business intelligence solution which balances cost and gain of outage analyses. AutoMon delivers a well-founded information base to improve organizational and economical decisions in an enterprise. The developed system will be tested and evaluated in practice within the networks of the project partners IBM and Deutsche Bahn.

Data Engineering & Analytics

Database research at IN.TUM is internationally recognized and has cooperations with leading industrial and academic partners. The strength of the TUM Data Engineering and Analytics group lies in its systems-centered work which has produced many prototypes, including HyPer, widely considered the fastest main-memory database system. Its commercialization license was acquired by Tableau, the world’s market-leading provider of
analytical data visualization. To further extend Hyper, Tableau has created a new development center in Munich which was staffed with many TUM graduates. TUM retained the research license for HyPer which is a particularly useful platform for validating innovative research in BigData analytics techniques. The participating research groups (with an estimated 100 researchers) of this cluster cover a broad interdisciplinary spectrum in the field of database systems engineering and in domain-specific analysis. They carry out practice-oriented and application-validated research and development work for the upcoming Big Data era.

**Cluster Members:** Alfons Kemper (Coordinator), Thomas Neumann (Co-Coordinator), Stephan Günnemann, Thomas Runkler, Martin Bichler, Hans-J. Bungartz, Daniel Cremers, Peter Gritzmann (MA), Alois Knoll, Florian Matthes, Björn Menze, Burkhard Rost, Rüdiger Westermann.

**Selected projects:**

**HyPer – A Hybrid OLTP&OLAP High Performance DBMS.** HyPer is a main-memory-based relational database management system (DBMS) for mixed On-line Transaction Processing (OLTP) and OLAP (On-line Analytical Processing) workloads. It is a so-called all-in-one New-SQL database system (as illustrated in the figure below) that entirely deviates from classical disk-based DBMS architectures by introducing many innovative ideas including machine code generation for data-centric query processing and multi-version concurrency control, leading to exceptional performance. HyPer’s OLTP throughput is comparable or superior to dedicated transaction processing systems and its OLAP performance matches the best query processing engines – however, HyPer achieves this OLTP and OLAP performance simultaneously on the same database state. Current research focuses on extending HyPer’s functionality beyond OLTP and OLAP processing to exploratory workflows that are deeply integrated into the database kernel by utilizing HyPer’s pioneering compilation infrastructure.

DFG Emmy Noether project: Robust Data Mining of Large-Scale Attributed Graphs. With the rapid growth of social media, sensor technologies, and life science applications, large-scale complex graphs have become a ubiquitous and highly informative source of information. Examples include review and co-purchase networks, protein interaction networks, or social networks. The goal of this project is to develop and analyze robust data mining techniques for large-scale complex graphs. Since in real life applications, complex graphs are often corrupted, prone to outliers, and vulnerable to attacks, the project focuses on the methods’ robustness properties. The obtained research results will act as a foundation for research and development in areas such as spam and
fraud detection, advanced data cleansing, and recommender systems.

ERC Consolidator Grant CompDB: The Computational Database. This project builds on the database research of Thomas Neumann. The goal of this project is to enable users to perform near real-time analysis and exploration of complex and large databases by exploiting modern hardware. For this purpose it is proposed to develop a computational database system that integrates all data processing tasks from transactional scripts to analytical SQL queries to exploratory workflows – in one system on the same most current (i.e., transaction-consistent) database state. In this sense we want to turn the database system into a comprehensive data science platform.

DFG Priority Program: Scalable Data Management on Modern Hardware. Members of the cluster are involved in the coordination of this new DFG priority program. The priority program aims to develop and evaluate architectures and abstractions for flexible and scalable data management techniques which provide extensibility regarding new data models including processing and access mechanisms for emerging applications, and exploit the features of modern and heterogeneous hardware as well as system-level services.

5 Digital Biology & Digital Medicine

The increasing amount of data that are being acquired, stored, and processed in the life sciences and health sector makes the development of new information technologies one of the key factors for advancing the current state of knowledge in biomedical and health research.

The cluster addresses technologies for extracting and exploiting information from clinical and biological data, e.g., from omics data and related repositories, from medical and biomedical images, or from population-wide health records. The cluster builds models of biological, physiological, or anatomical function using techniques from machine learning and mathematical modeling, together with evidence from large databases. These models are used to advance knowledge about biological processes, and also to inform decisions in clinical routine, e.g., in the interpretation of diagnostic images and health records, or when treating patients in the operating theatre.


Selected projects:

EU collaborative project SOUND: Statistical Multi-Omics Understanding. The project, funded by the EU Research and Innovation Program Personalising Health and Care, aims to create the bioinformatic tools for statistically informed use of personal genomic and other -omic data in medicine, including cancers and rare metabolic diseases. The project consortium comprises bioinformatician-statisticians and physician-scientists.

E:Med Junior Research Alliance mitOmics. The project develops and validates systematic approaches to infer the molecular bases of mitochondrial diseases in individual patients by combining genetics, functional genomics, and statistical causal inference. Project partners include Helmholtz center Munich (Gene center of the LMU) and TUM’s hospital Rechts der Isar.

EU collaborative project EDEN2020: Enhanced Delivery Ecosystem for Neurosurgery. The project aims to develop one-stop diagnosis and treatment of brain disease by delivering an integrated technology platform for minimally invasive neurosurgery. The project includes industrial partners (Renishaw, XoGraph), clinical oncological neurosurgery teams (Politecnico di Milano, and Università di Milano, San Raffaele) and experts in shape sensing (Imperial College London, Universitair Medisch Centrum Groningen).
3 Research

and investigations in theory as well as applied and prototypical solutions are ongoing in various fields. Examples are mentioned in the subsequent projects.

Cluster Members: Uwe Baumgarten (Co-Coo rdinator), Jörg Ott (Co-Coo rdinator), Alin Albu-Schäffer, Bernd Brügge, Georg Carle, Claudia Eckert, Wolfgang Kellerer (El).

Selected projects:

Living Lab Connected Mobility: This project is focusing on a variety of mobile services. One part of the project explores a cloud-controlled distributed crowd sensing platform in which individuals as well as service providers can submit sensing requests to a population of devices, comprising, e.g., mobile users, vehicles, and city infrastructure. A cloud-based service orchestrates sensing task allocation taking into account node location, sensing capabilities, load, battery status, and other properties. Another mobile service leverages such as well as static data to provides city trip planning recommendations for groups.

ArchitectuRe for an Internet For Everybody (RIFE): This project develops an architecture for an Internet for everybody, leveraging novel network architecture concepts to further the reach of the Internet to
Developing and remote areas. The project exploits Information-Centric Networking principles as well as delay/disruption tolerance mechanisms to develop networks and services that emphasize locality of information sharing and access. Local surrogates support centrally deployed as well as arbitrary decentralized applications to minimize long distance interactions across the (costly) Internet and keep data and control locally.

**Cooperative Integration Architecture for Smart Mobility (KIA4SM):** Transportation systems address one core aspect of mobility. Cooperative intelligent transportation systems (C-ITS) are supporting many traffic aspects including autonomous driving. Basic functionality for dynamic reconfiguration and software-based migration will be provided by flexible microkernels supporting appropriate scheduling of flexible sets of tasks including powerful checkpoint-restore mechanisms.

**7 Extreme Scaling**

Extreme scalability of algorithms and solutions is a key computational challenge. It is the door-opener for Exascale Computing and Big Data, and thus key to novel data-driven science, engineering, economy, and society. Scalability challenges exist in the management, storage, analysis, fusion, and processing of huge amounts of data, in the extreme simulation of phenomena and processes in computational science and engineering, and in the visualization of research data in general, stemming from simulations, experiments, sensors, etc.

The "Extreme Scaling" cluster’s mission is to shape and drive the methodology, algorithms, tools, and software to enable extreme-scale applications and solutions on high performance computing and data platforms. It exploits the close connection of IN.TUM to the LRZ, as one of Europe’s Tier-0 supercomputing sites.
Cluster Members: Michael Bader (Coordinator), Arndt Bode, Hans-J. Bungartz, Michael Gerndt, Thomas Huckle, Daniel Cremers, Claudia Eckert, Stephan Günnemann, Alfons Kemper, Björn Menze, Thomas Neumann, Jörg Ott, Burkhard Rost, Nils Thuerey.

Selected projects:

Munich Center of Advanced Computing (MAC): The project was funded 2009–2014 by the State of Bavaria, TUM, and KAUST and combined 11 interdisciplinary projects on advanced computing. It lead to more than 30 PhD degrees, which were all achieved with IGSSE, TUM’s International Graduate School for Science Engineering, in which MAC serves as one of IGSSE’s strategic focus areas.

SPPEXA: DFG’s Priority Program 1648 Software for Exascale Computing addresses fundamental research on High-Performance Computing (HPC) software that efficiently exploits the ubiquitous massive parallelism offered by current and future HPC platforms. The priority program was co-initiated and is coordinated at IN.TUM. Running from 2013–2019 it comprises 17 collaborative research projects in Germany and (since 2016) in France and Japan.

SuperMUC: LRZ’s Tier-0 supercomputer SuperMUC combines two 3-PFLOPS systems installed and drives record-setting HPC research in a multitude of applications. Key achievements of IN.TUM include the worldwide largest molecular simulation (4.1 trillion Krypton atoms, 0.6 PFLOPS on the full SuperMUC phase 1) or the first simulation of the multi-physics rupture process of the 2004 Sumatra earthquake (simulation with 100 billion unknowns; running 13.9 hours at nearly 1 PFLOPS on the full SuperMUC phase 2).

8 Formal Methods

The cluster members develop theories, algorithms, and tools for the specification, design, verification, and testing of software systems. They conduct research on theorem proving, model-checking, abstract interpretation, and testing. This includes foundational contributions to automata theory, semantics, computational logic, concurrency theory, game theory, and computer algebra. Application areas include automotive and avionics software, power grids, autonomous cars, robotic systems, and pure mathematics.

Cluster Members: Tobias Nipkow (Coordinator), Matthias Althoff, Javier Esparza, Jan Kretinsky, Ernst Mayr, Alexander Pretschner, Harald Räcke, Helmut Seidl, Lawrence Paulson (Cambridge University).

Selected projects:

Formal Proof of the Kepler Conjecture: 400 years ago Kepler conjectured that the face-centered cubic packing of congruent spheres is the densest possible. In 1998 Hales (Univ. of Pittsburgh) announced the first proof. It contained large amounts of unverified computer computations. Dissatisfied with his own proof, Hales started the Flyspeck project to verify his proof in a theorem prover. Flyspeck required 20 person years, was completed successfully in 2014 and is the largest
Research

A mathematical proof ever checked by a computer. A significant part of the proof was verified at IN.TUM with the help of the theorem prover Isabelle.

Checking procedures were speeded up by orders of magnitude as a result of PARSEC and are being incorporated into the most popular probabilistic model checker PRISM.

**XML**: A core functionality of XML processors is the transformation of a tree-structured document into a string. One of the simplest models of such tree-to-string transformations is the deterministic top-down tree transducer. For more than 35 years it has been an intriguing open question whether or not equivalence of such transducers is decidable. In 2015, Seidl, Maneth (Univ. of Edinburgh) and Kemper (TUM Mathematics) succeeded in answering this question affirmatively. This result is remarkable in that the corresponding decision procedure has been obtained by transferring techniques from program verification and abstract interpretation. The key technical point consists in proving that equivalence, when it holds, can always be certified by means of inductive invariants of a particular form.

**9 Human-centered Engineering**

The research addresses the design, development, and deployment of computing systems to understand and support users’ activities. Research areas and projects include augmented reality and gamification, collaborative and creative complex problem solving in teams, contextual and social computing, interactive recommender systems, and others. A main goal is to assist the user by services that are tailored towards his/her context and thus improve the user experience, for example in mobile scenarios.

 Cluster Members: Wolfgang Wörndl (Coordinator), Alin Albu-Schäffer, Bernd Brügge, Gudrun Klinker, Alois Knoll, Florian Matthes, Jörg Ott, Burkhard Rost, Peter Struss, Georg Groh.
Selected projects:

**TUM Living Lab Connected Mobility.** This research project was initiated to support the digital transformation in the area of Smart Mobility and Smart City and is funded by ZD.B. Within the subprojects Crowdsourcing and Crowd innovation, Sensing on Demand, Privacy Preserving Proximity Services, and Collaborative and Social Mobility Services particularly the user-centered design of mobility services is addressed to satisfy the users need for a personalized mobility experience as it is already provided by existing mobility services.

**Enable Cluster.** This BMBF-funded interdisciplinary project aims to develop new strategies to promote healthier food choices in different stages of human life. The project cluster consists of interdisciplinary research groups including nutrition science and food engineering. Scientists from IN.TUM contribute to the cluster’s work in investigating sociotechnical systems for healthy nutrition of adolescents and young adults using feedback mechanisms and gamification elements, educative social games or mobile food recommender systems with modern sensor devices and user interface concepts.

10 Robotics

The cluster develops autonomous robots and their interfaces to humans. It focuses on computer science aspects of robotics, in particular on machine vision, artificial intelligence, and machine learning for planning and perception, on cognitive and physical human-robot interaction, motion and task planning, autonomous navigation, and formal verification of autonomous systems software. The cluster furthermore has a strong expertise in robot design and control, neuroscience, and biomechanics. We pursue robotics research through an interdisciplinary approach and in direct collaboration with the Departments of MW, EI, and ME.

Through its applications, the cluster addresses major societal challenges. Securing and increasing welfare by continuously raising the productivity of work is the most obvious benefit of robotics. Robots, in a broader understanding, provide substantial support also in medicine and healthcare and help addressing the problems of our aging society as well as of logistics and future transportation.

**Cluster Members:** Alin Albu-Schäffer (Coordinator), Matthias Althoff, Darius Burschka, Daniel Cremers, Gudrun Klinker, Alois Knoll, Nassir Navab.

**Selected projects:**

**ERC Consolidator Grant 3D-Reloaded.** This project builds on the research of Daniel Cremers in the fields of mathematical image processing and pattern recognition. The aim of the project is to create 3-D models of the real world from two-dimensional videos recorded using cameras, for example cell phone cameras. The resulting models could be used, for example, to calculate how much lignite was extracted from a mine over a particular period of time. They could also be used to explore the world’s most remote regions while sitting at a PC and could also enable film viewers to select the perspective from which they see an action. The analysis of the three-dimensional models is another...
of Daniel Cremers’ research interests. In medicine, this technology could enable the reconstruction of organs and the testing of the resulting models for anomalies. The models could also document and analyze the development of motion sequences performed by dancers and gymnasts.

**Neurorobotics in the Human Brain Project.** The Human Brain Project (HBP) is an EU-funded Horizon2020 FET Flagship project that develops a digital ICT-based infrastructure for virtual brain research. A strategic pillar of the project’s research program is the embedding of simulated brains in body models to enable *in-silico* studies of cognition and behavior. The neurorobotics subproject led by Alois Knoll develops the tools and the theory required to connect state-of-the-art large-scale brain simulations to both simulated and physical robot bodies. The ability to study brain models during closed-loop interaction is not only relevant for neuroscience but also enables new directions of research in machine learning and cognitive science. All tools, methods, and robots developed in the subproject are made available through an easily accessible cloud-based simulation environment, the Neurorobotics Platform. To facilitate transfer from the virtual to the real world, the work builds on a track record in the field of biomimetic robotics to build physical robots that enable a seamless transition between the virtual and the physical world.

**ECCEROBOT.** This EU-funded project built a new kind of robot: an anthropomimetic robot. Instead of just copying the outward form of a human, it copies the inner structures and mechanisms, bones, joints, muscles, and tendons, and thus has the potential for human-like action and interaction in the world.

**ERC Marie-Curie Project Sustainable manufacturing through Advanced Robotics Training in Europe (SMART-E).** This European doctoral training network aims to prepare the next generation of leading experts in advanced robotics to secure a sustainable manufacturing sector in Europe. A special focus of this project conducted by Matthias Althoff and Alois Knoll is the development of modular robots that can be adapted to the current task at hand. To make this an industrially viable solution, the robot reprograms itself after assembly
to provide a push-button approach. In addition, techniques are developed to find optimal configurations from given modules and to ensure safe operation using formal methods.

**HORSE (Smart integrated Robotics system for SMEs controlled by Internet of Things based on dynamic manufacturing processes).** The project aims to develop a new, flexible model of smart factory which facilitates the smooth collaboration of humans, robots, and machinery, in order to improve production efficiency. The specialty of this project is that, via middleware, one can plan the entire production process from the meta-level down to the individual workcell. Thus, using the framework provides immediate and significant added-value to the manufacturing company without the need for costly re-engineering of the whole production line. This is an amazing savings.

11 Security, Safety, Risk Management

The cluster addresses research of technologies, methods, and models for developing trustworthy, safe and resilient cyber-physical systems (CPS) and services, including interactions with human users. Combining the different expertise of the cluster members covering formal modelling, as well as system architectures, networking, services engineering, business processes, and human interaction, the cluster is able to explore new research directions to tackle security, safety, and risk management in CPS. For instance, theory-based methods are combined with model-oriented approaches from engineering. The cluster explores theoretical approaches in order to precisely capture, ensure, and verify the security features (Security and Safety) from CPS, as well as observe them during their runtime. New security architectures and system services are designed, which are based on mathematical methods and approaches from engineering. This should enable privacy maintenance during data collection and use, or even allow one to recognize anomalies in behaviour early on and with higher precision. Moreover, the cluster investigates methods and models for securing software for (safety-critical) cyber-physical systems throughout their entire lifecycle.

The goal of the cluster is to make the results for security-relevant application domains (such as autonomous driving, networked production, or networked healthcare) useable. Specific protection measures for privacy are also taken into account. Due to the crosscutting nature of security and risk the cluster closely cooperates with other clusters.

**Cluster Members:** Claudia Eckert (Coordinator), Matthias Althoff, Uwe Baumgarten, Georg Carle, Javier Esparza, Jens Grossklags, Helmut Krcmar, Florian Matthes, Jörg Ott, Alexander Pretschner, Helmut Seidl, Peter Struß.

**Selected projects:**

**SIBASE.** This BMBF-funded project develops a modular system of standardized, interlocked security components for embedded systems in hardware and software, in order to provide longterm security. A tool for the modeling and analysis of security requirements at the software architecture and design levels, based on the Unified Modeling
Language, is being developed. Symbolic execution is used for the analysis of safety characteristics of C/C++ software at source code level. Additionally, a tool is being developed for the automatic recognition of weaknesses that could be misused for Remote Exploits or Privilege Escalation Exploits.

**IUNO.** In this BMBF-funded project, novel techniques are developed to defend against the emerging threats of the Internet of Things (Industry 4.0). Within IUNO novel security techniques e.g. new anomaly detection algorithms, new security analysis methods and new Virtual Machine Introspection (VMI) based control techniques are developed and evaluated using real world scenarios.

**ForSEc.** This BMBF-funded project addresses complex and adaptive attacks that overcome standard defensive countermeasures. The project tackles this challenge using a synergy of three phases in security: (1) Preparedness, (2) Response, and (3) Recovery, Auditing, and Forensics. IN.TUM research focuses on security monitoring on ARM devices and anomaly and intrusion detection under resource constraints.

**Scalable Distributed Data Usage Control Across Layers of Abstraction and Systems.** This DFG-funded project is part of the Priority Program 1496 Reliably Secure Software Systems. In the project, solutions for run-time enforcement or at least the detection of violation of usage control requirements were developed.

**Living Lab Connected Mobility.** This project funded by ZD.B addresses privacy preserving mobile services for user-generated IoT sensing tasks, exploiting unikernel-based virtualization for isolation and controlled information sharing (almost) all the way to sensing nodes.

**Scalable and Secure Infrastructures for Cloud Operations (SSICLOPS).** This EU-funded project addresses a high-performance private cloud infrastructure that allows flexible scaling through federation with other private clouds without compromising their service level and security requirements. This includes secure transport protocols for inter-data center communications and for cloud access. The project explores security leveraging multipath communication and contributes to the development of the protocol QUIC.

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![Diagram of Secure VM, Lazy Loader (LL), and Guest](image)

**Diagram:**

- **Secure VM:**
  - **Preselector (PS):** locate executable pages, map page to module
  - validate codepages

- **Run-time Verifier (RV):** load trusted context, apply and check dynamic modifications, validate page contents

- **Lazy Loader (LL):**
  - load trusted module, load dependencies, apply static modifications
  - check whitelist

- **Trusted whitelist:** contains trusted reference binaries

- **Introspection:**

- **Guest:**

**Code validation for modern OS kernels.**
12 Software Engineering & Information Systems

The cluster focuses on the engineering aspects of IT systems, their development, and their role and how embedded they are in their technical, socio-technical, economic, legal, and application-related contexts. The involved research groups combine theory-based research methods with questions in practice. The cluster members jointly aim at increasing the quality of software-intensive systems and their effective and efficient exploitation for specific application domains. Application domains include Enterprise Architecture Management and Social Software Engineering. In all domains, there exist recurring errors, which can be historically identified. In the safety area many techniques help to identify potential errors or a potential defective system behavior. The security area uses related techniques. We investigate how the knowledge regarding typical recurring and anticipated errors can cost-effectively increase the quality of systems.

Cluster Members: Florian Matthes (Coordinator), Bernd Brügge, Anne Brüggemann-Klein, Helmut Krcmar, Alexander Pretschner, Martin Bichler, Alfons Kemper, Burkhard Rost, Helmut Seidl.

Selected projects:

Lexalyze. The project focuses on the development of synergies between legal science and informatics. Addressing all areas of law – legislation, jurisprudence, and contract design –, the aim is to align and prepare the most recent insights in both disciplines in order to enable a successful transfer of knowledge. The project seeks to implement a bi-directional interdisciplinary knowledge transfer. Whereas former projects have merely been uni-directional efforts of legal scientists with an interest in informatics or vice versa, we now aim to establish a fundamental discourse between legal scientists from LMU and information scientists from IN.TUM, all of whom are at the forefront of the methodological discourse in their respective fields of expertise. This interdisciplinary discourse will be accompanied and furthered by cooperating scientists from other institutions as well as by several partners in different practice areas of law and informatics.

SocioCortex. Social information management involves multiple users collaborating in the design and creation of information. More than 10 years of research and cooperations with industry partners in this area revealed recurring problems and solution patterns. Therefore, social information management systems share a common set of general capabilities and features. The project integrates those features and exposes them as services to its applications. In this way, domain-specific applications built upon the SocioCortex platform benefit from proven solution patterns for prevalent social information management problems.

SocioCortex platform.

13 Visual Computing

This cluster targets research on novel algorithms and innovative systems for the acquisition, analysis, and synthesis of visual data. This vibrant field encompasses many areas of informatics, mathematics, and physics, and it represents a key component in fields ranging from autonomous
driving, interactive virtual worlds and visual film effects to data analysis tasks in many areas of science and engineering.

A particular emphasis of the ongoing research projects lies on deep learning for data classification, completion, physics-based simulation, and sensor-based reconstruction. In addition, the cluster members target computer-aided model and image synthesis, and interactive graphical representations of visual data. Major challenges are with respect to the ever-growing size and complexity of the data to be handled, and the time constraints that are more and more often imposed in practical applications.

**Cluster Members:** Rüdiger Westermann (Coordinator), Nils Thuerey, Matthias Niessner, Daniel Cremers, Darius Burschka, Hans-J. Bungartz, Thomas Huckle, Gudrun Klinker, Björn Menze, Burkhard Rost.

**Selected projects:**

**Gottfried Wilhelm Leibniz Prize and ERC Consolidator Grant 3D Reloaded:** Daniel Cremers has been awarded the Leibniz Prize of the German Research Foundation (DFG) in 2015. His research aims to endow machines with the ability to analyze and interpret visual data. With the project 3D Reloaded, Cremers will develop algorithms for 3D reconstruction from standard and RGB-D cameras, algorithms for 3D shape analysis, and shape priors for 3D reconstructions.

**ERC Advanced Grant SaferVis and ERC Proof of Concept Grant Vis4Weather:** SaferVis challenges the status quo in visual data analysis with innovative ideas for next-generation technology that provides uncertainty visualization as a core methodology. Vis4Weather builds on previous projects by Rüdiger Westermann, SaferVis and research in the transregional Collaborative Research Center "Waves to Weather". It aims to study the potential of an operational use of meteorological data visualization at weather centers and the potential of such visualization tools for training forecasters, decision makers and researchers in 3D ensemble analysis.

**ERC Starting Grant realFlow:** Virtualization of Real Flows for Animation and Simulation: The project builds on previous research by Nils Thuerey, and aims to improve the simulation of physical processes and, above all, develop new algorithms to generate accurate simulations with high efficiency. It is planned to create a repository containing previously-calculated simulations and video recordings of the behavior of real fluids. This repository will be used to synthesize flows with high resolution details that cannot easily be captured by regular numerical schemes.

Completion of incomplete scanned geometry using deep learning algorithms.
3.2 Participation in large research initiatives

In the following, we list participations of IN.TUM faculty in larger collaborative research programs. It is characteristic for IN.TUM that our focus is on collaborative initiatives with other partners (within and outside TUM; interdisciplinary, international, or intersectoral).

Large European Projects

The Human Brain Project. The Human Brain Project (HBP) is an EU-funded Horizon2020 FET Flagship project that develops a digital infrastructure for virtual brain research. This infrastructure is based on six ICT platforms for neuroinformatics, brain simulation, high performance analytics and computing, medical informatics, neuromorphic computing, and neurorobotics. The technical development of these platforms is coordinated by Alois Knoll who is a member of the project’s directorate. He also was involved in the original development of the concept of the EU’s FET flagship projects. Research in the HBP is organized in twelve subprojects including the neurorobotics subproject led by Alois Knoll.

The European Coordination Hub for Open Robotics Development (ECHORD++). This EU-funded project coordinated by Alois Knoll aims to strengthen the knowledge transfer between scientific research, industry, and users in robotics and to stimulate their cooperation. It has a runtime of five years and funds small-scale research projects (called experiments), public end-user driven technological innovation and established robotics innovation facilities (open labs providing state-of-the-art robotic hardware and software as well as scientific and technical support). The term ECHORD-like structure is now a standard in EC terminology for similar types of cascade funding. The project was the impetus for introducing Digital Innovation Hubs.

EU collaborative project SOUND: Statistical Multi-Omics Understanding. In this project, Julien Gagneur from the research cluster Digital Biology & Digital Medicine collaborates with ETH and University Hospital Zurich, University of Cambridge, the National Center for Tumor Diseases, the European Molecular Biology Laboratory in Heidelberg, and TUM’s hospital Rechts der Isar in the area of personal genomic data in medicine.

FETHPC in Horizon 2020: Within the FET PROACTIVE call “Towards Exascale High Performance Computing”, members of the research cluster Extreme Scaling participate in the two projects READEX and ExaHyPE, that contribute to the European exascale strategy. While READEX develops a tools-aided methodology to improve energy-efficiency of extreme-scale applications, ExaHyPE will deliver an exascale-ready engine to realize grand challenge simulations that can be modelled via hyperbolic conservation laws.

Excellence Clusters

Munich Center for Advanced Photonics (MAP). Led by LMU and TUM, and with partners from the Max-Planck-Institute for Quantum Optics, the Helmholtz Center Munich, and UniBW, the MAP excellence cluster was successful in the first two rounds of the German Excellence Initiative, and is being funded by the DFG for the years 2006-2019. Focusing on the development of compact brilliant X-ray sources using ultrafast lasers, the cluster projects also explore advanced biomedical imaging modalities using this new type of X-ray source, along with the investigation of cost-effective particle therapy approaches. Nassir Navab and Tobias Lasser from IN.TUM are involved in the imaging projects with research on image reconstruction and visualization techniques.

Cognition for Technical Systems (CoTeSys). As part of the first round of the German Excellence Initiative, TUM was successful with its proposal for a cluster in the area of cognitive robotics and embedded cognition, which was funded by the DFG for the
years 2006-2015. The project, which was coordinated by Martin Buss (EI), had IN.TUM participants Alois Knoll, Bernd Radig (em. 2009), Daniel Cremers, Nassir Navab, Gudrun Klinker, Darius Burschka, and Michael Beetz. It was partly built on past collaboration between EI and IN.TUM in the context of the SFB 453 High-Fidelity Telepresence and Teleaction. The cluster also included LMU, DLR, UniBW, and other departments from TUM. While the research yielded in numerous joint research activities and joint publications, unfortunately, the proposal for a continuation of the cluster did not succeed in the second round of the Excellence Initiative which started in 2012.

**DFG Collaborative Research Centers**

Collaborative Research Center Imaging for Selection, Monitoring, and Individualization of Cancer Therapies (SFB 824, since 2009). The CRC aims at improving the success of cancer therapies with the help of imaging. The development of new molecular imaging methods, in particular imaging probes and optical methods suitable for clinical translation, facilitates better tumor detection at an early stage and better prediction of treatment success, while providing objective and quantitative assessment of treatment results. The consortium is interdisciplinary with partners from the university hospitals of TUM and LMU as well as the Helmholtz Center Munich. Coordination is by Markus Schwaiger from ME, with Nassir Navab from IN.TUM participating.

Collaborative Research Center Managing Cycles in Innovation Processes – Integrated Development of Product Service Systems Based on Technical Products (SFB 768, since 2008). The CRC consists of 14 subprojects at three departments engaging problems, which emerge during the innovation process. Focus of the research is the implementation and use of elements of complex solutions, nowadays typically consisting of a combination of product- and service-components, so-called product-service-systems. The components are subject to development-, manufacturing- and life-cycles of varying length, which are provided by different functional divisions. Availability and maturity of technologies, changes of competences, financial cycles at capital markets or of investments and write-offs as well as changes of customer demands represent external influences on the company. In contrast, the associated business processes underlie different cycles in research and development, manufacturing, logistics, finance, service, and recycling, which are mutually affecting each other as well. Coordination is by Udo Lindemann and Birgit Vogel-Heuser from MW, with Helmut Krcmar from IN.TUM participating.

Collaborative Research Center High-Fidelity Telepresence and Teleaction (SFB 453, 1999-2010). Telepresence is achieved if the human operator of a technical system is provided with the impression of actually being present in a remote environment. Teleaction emphasizes that the operator is not only present passively, but also able to interact actively with the remote environment. Goal of the project was to overcome barriers between the local operator and the remote environment. Barriers are formed, e.g., by spatial distances, inaccessible environments, and scaling tasks, as present in minimal invasive surgery or micro assembly. In addition to visual and auditory information, the haptic modality plays an important role. The haptic sense comprises tactile (pressure, temperature, roughness, and vibration), and kinesthetic information (proprioception, forces). Coordinator was Martin Buss from EI, with Alois Knoll and Gerd Hirzinger from IN.TUM participating.

Transregional Collaborative Research Center Waves to Weather (TCRC 165, since 2015). The project aims to build the scientific basis of a new generation of weather forecasting systems. The research center addresses a broad range of tools, including numerical models with detailed treatment of cloud processes and aerosols, and ensemble forecasts with sophisticated statistical postprocessing to describe uncertainty. Improved insight will be gained through the development of new interactive visualization methods, that will enable rapid
exploration of forecast ensembles to identify the sources and evolution of uncertainty in meteorologically significant features. This interdisciplinary project includes Geosciences, Mathematics, Informatics, Systems and Electrical Engineering. Spokesperson is George Craig from LMU. From IN.TUM, Rüdiger Westermann participates.

Transregional Collaborative Research Center Invasive Computing (InvasIC, TCRC 89, since 2010). The project investigates dynamic resource management for invasive applications from highly parallel chip multiprocessors up to state-of-the-art supercomputers. The goal is to provide optimized execution and resource usage while maintaining a high level of predictability. In HPC, this research will lead to the productive development of evolving applications based on MPI and OpenMP as well as to a system-level resource management beyond the current static space sharing approach. Hans-Joachim Bungartz, Michael Bader, and Michael Gerndt from IN.TUM and Andreas Herkersdorf from EI participate.

DFG Priority Programs

Priority Program 2037 Scalable Data Management on Modern Hardware. Members of the cluster Data Engineering & Analytics (Alfons Kemper and Thomas Neumann) co-coordinate together with Kai-Uwe Sattler (Ilmenau) und Jens Teubner (Dortmund) this new DFG priority program. It aims to develop and evaluate architectures and abstractions for flexible and scalable data management techniques which provide extensibility regarding new data models for emerging applications. Currently used database concepts and systems are not well prepared to support emerging application domains such as eSciences, Industry 4.0, Internet of Things, or Digital Humanities: From a user’s perspective flexible domain-specific query languages or at least access interfaces are required; novel data models for these application domains have to be integrated; consistency guarantees which reduce flexibility and performance should be adaptable according to the requirements; and the volume and velocity of data caused by ubiquitous sensors have to be mastered by massive scalability and online processing. At the same time current and future hardware trends such as many-core CPUs, co-processors like GPU and FPGA, novel storage technologies like NVRAM and SSD as well as high-speed networks provide new opportunities.

Priority Program 1914 Cyber-Physical Networking. The program is motivated by cyber-physical applications such as telemedicine, smart production, and infrastructure systems. In such systems feedback control loops are closed over the communication channel imposing real-time requirements on the communication system. Predictably low latency is generally a desirable property, however, it challenges concurring requirements for high reliability, spectral and energy efficiency of the communication system in particular in wireless communication. The program aims to develop the theoretical basis for the paradigmatic change from throughput- to real-time-oriented communication for networked control systems. Two members of the research cluster Computer & Communication Architectures participate in the program, Georg Carle with the project Measurements for Composable Performance Models of Cyber-Physical Network Components, and Wolfgang Kellner (EI) with the project Optimal Co-Design of Wireless Resource Management and Multi-Loop Networked Control.

Priority Program 1835 Autonomous Learning. The program aims to develop a system-theoretical framework for cooperative traffic involving automated automobiles. For information retrieval, cooperating interacting automobiles not only consider the sensor information onboard the vehicle but also analyze communicated information from sensors of other automobiles. For full use of the information, robust fusion methods are investigated that consider the individual quality of the information due to latencies, spatio-temporal uncertainties, and possibly cyclic information flows. Based on the perception of the current traffic situation, the
future behavior and trajectories of other traffic participants shall be predicted. This topic involves methods to anticipate the movement of people and vehicles as well as methods ensuring that others may anticipate one’s own behavior. Based on the perceived and predicted traffic scenes, planning strategies for cooperative trajectories shall be investigated. Cooperatively interacting automobiles aggregate their knowledge in a collective data and information base and provide this information to the traffic community. Matthias Althoff participates with the project *ColnCiDE: Cooperative and Intrinsically-Correct Control of Vehicles in Diverse Environments*.

**Priority Program 1736 Algorithms for Big Data.**
The program addresses the developments in the area of Big Data, where information is accumulating at an exponential rate. At the same time, we often face poor scale-up behavior from algorithms that have been designed based on models of computation that are no longer realistic for big data. The program aims to improve the situation by providing computational models better suited for recent hardware developments and technological challenges, and by developing a toolbox of improved algorithms and data structures for big data sets. Susanne Albers is among the initiators of the program and participates with a project on energy-efficient scheduling.

**Priority Program 1648 Software for Exascale Computing (SPPEXA).** The program addresses fundamental research on the various aspects of HPC software, which is particularly urgent against the background that we are currently entering the era of ubiquitous massive parallelism with many-core processors and their assembly to systems beyond $10^7$ processing units. The following research areas are addressed: computational algorithms, system software, application software, data management and exploration, programming, and software tools. TUM participants include Hans-Joachim Bungartz (coordinator) from IN.TUM and Barbara Wohlmuth from MA.

Priority Program 1593 *Design for Future – Managed Software Evolution*. This program aims to develop fundamentally new approaches in software engineering with a determined focus on long-living software systems. New foundations, methods, and tools are needed to be able to develop “forever young software”, which maintains its initial functionality and quality and is even continuously improved during the whole lifetime. A new paradigm will be established where development, adaptation, and evolution of software and their platforms, on the one hand, as well as operation, monitoring, and maintenance, on the other hand, are no longer separated but integrated. One aim is to define meta-models for preserving and accessing the knowledge provided and gained during the system development process. Furthermore, methods and process models, as well as suitable infrastructures, have to be provided to comprehensively support the integration of software development and evolution. Bernd Brügge participates with the project *Continuous Usage- and Rationale-based Evolution Decision Support*, and Manfred Broy with the project *Model-Driven Evolution Management for Microscopic Changes in Automation Systems*.

**Priority Program 1527 Autonomous Learning.**
The program aims to develop novel foundations of autonomously learning systems, targeting concepts and methods which go beyond existing machine learning methods, towards systems that autonomously explore an unknown environment and develop appropriate representations. Core aspects of autonomous learning are the autonomous choice of parameters, representations and features for learning, the autonomous collection of data, i.e., exploration and active search to accelerate learning instead of learning from static data sets, the autonomous development of appropriate representations, including hierarchies, and the incremental abstraction of stimuli, internal representations, and actions. Daniel Cremers and Rudolph Triebel participate with the project *Efficient Active Online Learning for 3D Reconstruction and Scene Understanding*, Alois Knoll with the project...
Active exploration in the high-dimensional data of an artificial skin, and Michael Beetz (since 2012 with University of Bremen) with the project Autonomous Learning for Bayesian Cognitive Robotics.

Priority Program 1496 Reliably Secure Software Systems. The view of IT security has been dominated by the border between a supposedly trustworthy inner world and a potentially hostile outer world. Consequently, many classical security mechanisms, e.g., firewalls, access controls, and cryptography, focus on securing these borders. However, due to networking, mobility, and dynamic extensibility, a more sophisticated view of security is needed. The program first aims to develop precisely defined (and, thus, verifiable) security properties. A subsequent goal is the development of analysis methods and tools that target the reliable verification of security properties of systems. A further goal is to develop concepts for understanding and certifying security aspects even in complex software systems. Within this priority program, Tobias Nipkow participates with the topics of interactive and automatic verification of qualitative and quantitative methods of information flow analysis, and on security type systems and deduction, Helmut Seidl with secrecy and information flow in shared document bases, and Alexander Pretschner with system-wide data-driven usage control across layers of abstraction.

Graduate Schools and Research Training Groups

Research Training Group Advanced Optimization in the Networked Economy (AdONE). A new Research Training Group approved by the DFG is the new Graduate Program AdONE. Due to an increasingly interconnected economy, multiple decision-makers are typically involved in resource control, and large data sets are available allowing for new optimization methods for the efficient use of resources. The Graduate Program conducts research in operations research and management science to develop models and processes that aim at the efficient use of resources through intelligent planning and control. Participants from IN.TUM are Martin Bichler and Susanne Albers.

Research Training Group PUMA (Programm- Und Modell-Analyse). PUMA started in July 2008. A second period of funding by DFG, PUMA-2, was granted in Summer 2012. PUMA-2 started in January 2013. PUMA brings together the four fundamental approaches of program and model analysis, namely, type systems, theorem proving, model-checking, and abstract interpretation. Its goal is to develop new analysis techniques through cross-fertilization. The new methods should prototypically be implemented and be evaluated on selected analysis problems of software-intensive systems. PUMA has been initiated by IN.TUM faculty Javier Esparza, Alois Knoll, Tobias Nipkow, Andrey Rybalchenko, and Helmut Seidl, with further participation of Birgit Vogel-Heuser from MW and Martin Hofmann from LMU.
4 Teaching

4.1 Strategy

IN.TUM holds one of the top positions, both in research and teaching, in terms of size, thematic breadth, scientific reputation, networking with industry, innovation through spin-offs, and embedding in the international science landscape. We aim to set national and international standards in all phases of academic education from bachelor’s and master’s degree to doctoral and postdoctoral qualification – with regard to quality, diversity, internationalization, and preparation for the different career paths of our graduates. This also means to timely identify new topics within the field of Informatics and also at the interplay with other subjects. We try to take them up in a determined way, and to provide tailored innovative teaching and studying formats for them.

IN.TUM offers programs for all kinds of career paths – in academia (at universities, universities of applied sciences, or non-university research institutions), in the IT industry as well as in virtually all other sectors of economy. There, our graduates may serve as employees, as founders of start-up companies, or as self-employed persons. The department faces the large and growing demand for IT experts both within Germany and abroad, and does not see its duty only in the qualification of small scientific elites. This means a clear commitment to the bachelor’s education at a large scale, to an adequate range of content, especially at the master’s, but also at the bachelor’s level, to the development of training courses for life-long learning, to internationalization, and to a self-evident anchoring of gender and diversity in all relevant processes. The latter two issues will be extensively discussed in Section 2.8.

4.2 Portfolio

IN.TUM currently offers four bachelor’s and nine master’s study programs, which are accompanied by a participation in six elite or honors programs.

Bachelor’s programs

All bachelor’s programs take three academic years and start in the winter term. So far for admission, applicants have to undergo an aptitude test. Generally, the teaching language is German with only some courses taught in English. Included into all study programs is instruction in social and communicative skills and competences, by solving problems in teamwork and as team leaders. All students are encouraged and supported to spend some time abroad. For that a mobility window is generally provided in the fifth term. The broad interdisciplinary character of all bachelor’s programs constitutes a basis for life-long learning. The final bachelor’s thesis is often involved in a running research project or performed in close cooperation with business companies. With our bachelor’s programs, the students achieve sound and internationally approved degrees.

Informatics

The bachelor’s program Informatics is the central bachelor’s program of our department. It provides core competences which can later be deepened by the various applications and specializations in the wide range of career paths within Informatics. It provides deepened practical skills in design and implementation of software systems, in understanding networked hardware and their operating systems, and the management of data. It builds up fundamental knowledge of the mathematical foundations of Informatics and provides the basis for conceptual and algorithmic problem solving. The program enables graduates in their later jobs to adopt new methods and technology rapidly and flexibly. An integral part
of the training are hands-on lab courses, and a seminar.

In addition to knowledge in Informatics, students get to know about applications of Informatics by choosing a minor. Most popular minors are Economics, Medicine, and engineering disciplines such as Mechanical or Electrical Engineering. Also, Mathematics can be chosen. In the third academic year, students can focus on individual main areas and select specialized lectures out of the huge variety of areas offered by the department such as Software Engineering, Databases, Artificial Intelligence and Robotics, Computer Graphics and Image Understanding, Computer Architecture, Distributed Systems and Networks, Formal Methods and their Applications, or Algorithms and Scientific Computing.

The bachelor’s program *Informatics: Games Engineering* conveys comprehensive knowledge on games technologies. Students get acquainted with up-to-date and trend-setting technologies like Game Engine Design, Computer Graphics, Simulation, Interaction, Social Games, Artificial Intelligence, Usability, and User Experience. Students participate in gaming projects each term.

The graduation in the bachelor’s program *Informatics: Games Engineering* allows direct access to jobs in the gaming industry as well as conventional companies investing in games-related technology. As the curriculum makes only minor compromises in the education of core skills in Informatics and Mathematics, graduates may also enter an ordinary Informatics career. The bachelor’s degree in *Informatics: Games Engineering* is the basis of the respective master’s program, but may also serve as the basis for other advanced master’s programs offered by IN.TUM.

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**Informatics: Games Engineering**

Computer games are getting more and more versatile: Players undergo virtual situations, try different strategies, develop new ideas, and cooperate or compete. In doing so, the interchange of ideas via computer and new ways of get-together are important as well. But games do not only aim at entertainment: they also are helpful in learning social or professional expertise, trying new technologies, and overcoming cultural barriers. Therefore, profound knowledge in Informatics is essential for developing games, for understanding these new technologies, and for using them effectively in the games area. The games market is booming. Under the keyword “Serious Games”, game concepts are increasingly used in industry such as automotive, aerospace, and plant engineering, medicine, banking and finance, and management.

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**Figure 6:** Student numbers for the bachelor’s program *Informatics*. (Source: IN.TUM)

**Figure 7:** Student numbers for the bachelor’s program *Informatics: Games Engineering*. (Source: IN.TUM)

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![Gaming equipment.](image)
Information Systems

Today, almost all business processes are supported by IT systems. Accordingly, companies need experts that are able to understand, manage, and develop business software. Graduates of Information Systems combine economic and Informatics aspects by modeling business processes and developing software for business applications.

The mission of Information Systems is to address the social, technical, and economical aspects in designing innovative concepts and networks of value creation, and to link the perspectives of the producer and the user in development, operating, and maintenance of business software. The education is in close cooperation with companies and administration, supports entrepreneurship, and provides transfer of knowledge from academia to practice.

During six terms, the theoretical and practical foundations of Information Systems are conveyed. Students concentrate on Informatics, Economics, and Mathematics. The program is inherently interdisciplinary. In practical tutorials, software labs, and seminars the acquired theoretical knowledge is utilized. In the last academic year the gained knowledge can be applied practically in projects with leading companies.

The bachelor’s program prepares the students for a career in particular in the area of IT services and consultancy. Additionally, TUM supports entrepreneurial business ventures. Furthermore, the program provides the foundation for the master’s program Information Systems.

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<th>Year</th>
<th>Completed applications</th>
<th>First-year students</th>
<th>Graduates</th>
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<td>2015</td>
<td>403</td>
<td>186</td>
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<tr>
<td>2016</td>
<td>467</td>
<td>209</td>
<td>92</td>
</tr>
</tbody>
</table>

Figure 8: Student numbers for the bachelor’s program Information Systems. (Source: IN.TUM)

Bioinformatics

Bioinformatics uses the algorithmic knowledge of Informatics to solve molecular biological, biochemical, or medical problems. Graduates work on the relationship and the evolution of different species by comparing the genomes of organisms. Furthermore, they analyze the structure of complex macro-molecules like proteins, and their interactions. Thus, graduates of the program Bioinformatics contribute to the better understanding and controlling of life processes and their dysfunctions or diseases. These tasks usually generate huge amounts of data that have to be managed efficiently. Therefore, in Bioinformatics scientists assemble appropriate databases integrating the various information but taking little storage and allowing fast, practical access to the data.

The bachelor’s program introduces the foundations of Informatics, Mathematics, Biology, Chemistry, Biochemistry, and the most important bioinformatical methods. In lab courses students apply the gained knowledge on concrete examples, and in seminars they practice giving talks, doing research, and writing scientific papers.
First, the students get a profound basic education in Informatics (e.g., programming, algorithms and data structures, automata and formal languages), in Mathematics (Combinatorics, Algebra, Analysis, Stochastics), and in natural sciences (Biology, Chemistry, and Biochemistry). In Bioinformatics courses the students get acquainted with the basic methods (e.g., sequencing of genomes or prediction of protein structures and functionality).

The second part of the bachelor's program introduces databases and strengthens the bioinformatical knowledge that is especially important in algorithmic methods for processing protein-sequences and for analyzing biological networks.

<table>
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<tr>
<th>Year</th>
<th>First-year students</th>
<th>Graduates</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>42</td>
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<td>2013</td>
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<td>30</td>
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<tr>
<td>2016</td>
<td>64</td>
<td>24</td>
</tr>
</tbody>
</table>

Figure 9: Student numbers for the bachelor's program Bioinformatics. (Source: IN.TUM)

**Master's programs**

All master's programs take two academic years. For admission, applicants have to participate in an aptitude test. Master's programs run by IN.TUM alone can all be studied in English. These are Informatics, Informatics: Games Engineering, and Data Engineering and Analytics. The master's programs Computational Science and Engineering and Biomedical Computing can only be studied in English. In German, but with large English portions, are the master's programs Information Systems, Bioinformatics, Robotics, Cognition, Intelligence, and Automotive Software Engineering. With the exception of Biomedical Computing and Computational Science and Engineering, which accept beginners only in the winter term, all master's programs admit students both in summer and winter. The master's programs Informatics, Informatics: Games Engineering, Information Systems, and Bioinformatics are programs that can be chosen as immediate continuations of the corresponding bachelor's programs. Switching between subjects is possible, but may require bridging courses.

**Informatics**

In the era of information society, none of today's well established sciences can do without data processing. In most disciplines information technology is the key to scientific progress and is the basis for developing new products and services. Therefore, qualified experts are urgently needed.

The master's program Informatics is research-oriented and enables students to work independently according to high academic standards. It qualifies students for a PhD, for leading software development projects, and for executive positions in business and management.

Targeting German as well as international students, the master's program Informatics is almost entirely taught in English and can be completed in four terms. It is a consecutive degree course of study based on a prerequisite bachelor's degree in Informatics, Computer Science, or Computer Engineering. After having acquired the basics of Informatics in previous studies, students can now specialize and benefit from the wide spectrum of courses and research topics offered at TUM. The program offers much freedom of choice and allows to focus studies on preferred areas of interest.

Students of the master's program Informatics can specialize by choosing from the most important areas in Informatics, Software Engineering, Databases and Information Systems, Artificial Intelligence and Robotics, Computer Graphics and Image Understanding, Computer Architecture, Distributed Systems and Computer Networks, Formal Methods and their Applications, or Algorithms and Scientific Computing.
Students will attend lectures, lab courses and seminars, and will carry out research projects in these areas. By participating in software development projects and in an interdisciplinary project in a chosen minor subject, students will improve their communication skills in a specific area of application and practice the use of methods in Informatics. Additionally, the curriculum covers soft skills courses, e.g., seminars on business planning, management skills, communicative ability and intercultural communication.

Modern Games Engineering combines fundamental concepts of Informatics, Physics, and Mathematics in due consideration of hardware-specific aspects. The master’s program equips students with the technical skills and knowledge required to design and realize the technical infrastructures underlying modern computer games, to transfer their skills and knowledge to new application domains, and to eventually discover ways to integrate computer games technologies into other research and application areas as well as into everyday life. The research-oriented master’s program allows students to structure their studies towards their preferred sub-areas of interest in the particular area of Games Engineering. Besides the mandatory courses (such as image synthesis and two lab-courses in Games Engineering), it offers several areas of specialization such as computer-graphics and animation, computer vision and intelligent image processing, game-theory and algorithmic economics, internet models, technologies and applications, autonomous systems, modern database systems, numerics and simulation as well as hardware-related programming.

Informatics: Games Engineering

Interact, play, explore – by means of interactive computer game technologies! This is the spirit of this master’s program Informatics: Games Engineering, which acknowledges the growing impact of interactive computer games technologies in our society. It is settled in a booming industry, far exceeding the classical game market, rushing towards new applications of interactive computer games technologies for problem-solving, education and training as well as movie entertainment. Informatics: Games Engineering is an international and interdisciplinary field of science. A master’s degree in this field enables students to work and to pursue research in a multitude of different application domains worldwide.

Games Engineering deals with the theoretical foundations of interactive computer games technologies and their technical realization through software and heterogeneous computing devices, multi-sensory interfaces, and display systems.

Information Systems

As companies nowadays operate their business processes based on IT systems, experts are needed who are able to understand and design complex business software. Graduates of the master’s program Information Systems are able to link business-management and IT aspects in developing information systems and business processes. Accordingly, there is a huge demand for these graduates in growth sectors like IT services, software ventures, and consulting.
The program prepares for leadership in economy and provides good job and income possibilities for beginners.

In four terms, students gather profound knowledge and methods for solving challenging tasks of practical operative importance. Compared to similar study programs, IN.TUM emphasizes the Informatics expertise in design, development, and management of complex IT systems, in combination with economical expertise and the preparation for leadership.

The program is inherently interdisciplinary. The main focus is the core area of Information Systems, Economics, and Informatics. Informatics contributes courses in Software Engineering, Databases, and Distributed Systems. Mandatory subjects of Information Systems are Information and Knowledge Management, Business Analytics, and CIO Business Game. Economics provides Management Accounting, Operations Management, and Technology and Innovations Management.

Students are getting prepared for job profiles like Chief Information Officer, Chief Technology Officer, or IT consultant. In a CIO business game and in a lab developing software they get hands-on experience.

<table>
<thead>
<tr>
<th>Year</th>
<th>Completed applications</th>
<th>First-year students</th>
<th>Graduates</th>
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<tbody>
<tr>
<td>2012</td>
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<tr>
<td>2013</td>
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<tr>
<td>2016</td>
<td>239</td>
<td>122</td>
<td>78</td>
</tr>
</tbody>
</table>

Figure 12: Student numbers for the master’s program Information Systems. (Source: IN.TUM)

Bioinformatics

The Bioinformatics master’s program in Munich represents a major stronghold of advanced Bioinformatics. LMU and TUM are offering this master’s program jointly. Students can directly benefit from a broad selection of courses that are partially offered at both universities. Based on algorithmic Informatics knowledge, Bioinformatics solves open molecular biological, biochemical, and medical questions. During four terms, the students specialize choosing courses from a wide range of topics in Bioinformatics, Informatics, Mathematics/Statistics, and Molecular Biology/Biochemistry. Examples are Algorithmic Bioinformatics, Sequence Analysis, Systems Biology, Structural Bioinformatics, Cheminformatics, DNS Sequencing, Databases and Data Mining, Project Management, Software Engineering, Statistics, Structural Biology, Genetics / Genomics, Evolutionary Biology, Biochemistry, Biotechnology. Graduates may either continue with academic research or work in companies, e.g., in genomic applications or by participating in the development of new pharmaceuticals.

<table>
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<tr>
<th>Year</th>
<th>First-year students</th>
<th>Graduates</th>
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<tbody>
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<tr>
<td>2016</td>
<td>18</td>
<td>16</td>
</tr>
</tbody>
</table>

Figure 13: Student numbers for the master’s program Bioinformatics. (Source: IN.TUM)

Computational Science and Engineering

Computational Science and Engineering (CSE) is the multidisciplinary field of computer-based modeling, simulation, and data exploration for studying scientific phenomena and engineering applications. Modeling and simulation help to validate theory, and make it possible to analyze scenarios that would otherwise be too time-consuming, expensive, or dangerous to study by experiment. Data exploration helps to turn numbers into insight – which is especially challenging in times of Big Data. The increasing quest for higher levels of detail and realism does not only
require enormous computational capacities, but also advanced programming skills, sophisticated models, as well as efficient numerical, visualization, and data analysis methods. Traditional programs in Informatics, Mathematics, or Engineering, often do not offer an education that meets all of these requirements.

As an interdisciplinary course, the CSE program is based on three pillars: Applied Mathematics (especially numerical analysis), Informatics, and applications in science and engineering. In Applied Mathematics, CSE teaches skills in mathematical modeling and numerical analysis. In Informatics, CSE focuses on efficient numerical algorithms, their (parallel) implementation, and the exploration of the results via visualization or, for instance, data mining. The scientific and engineering applications cover a huge range of temporal and spatial scales, from the simulation of molecular dynamics to computations in astrophysics. For this reason, HPC plays an important role in CSE. Due to its strong focus on engineering and scientific applications, CSE is not to be confused with a Computer Science or Informatics program. Talented students interested in pure Computer Science or Informatics are encouraged to apply to the Informatics master’s program at TUM.

The spectrum of applications in science and engineering covers various fields of high industrial relevance. These include computational fluid dynamics, computational structural mechanics, computational physics / chemistry / electronics, and computational methods in bioscience, as well as fields related to Informatics, such as 3D visualization and imaging in medicine. We also encourage the study of stochastic methods (for example, for financial applications). Our academic offer increases constantly, incorporating subjects from many different TUM departments.

<table>
<thead>
<tr>
<th>Year</th>
<th>Completed applications</th>
<th>First-year students</th>
<th>Graduates</th>
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<tr>
<td>2016</td>
<td>307</td>
<td>50</td>
<td>34</td>
</tr>
</tbody>
</table>

Figure 14: Student numbers for the master’s program Computational Science and Engineering. (Source: IN.TUM)

Master’s course on Soft Skills.

Graduates from the elite master’s program BGCE.

Biomedical Computing

The master’s program Biomedical Computing (BMC) aims at motivated above-average students holding a bachelor’s degree in Informatics, Mathematics, Physics, Electrical Engineering, or related subjects. Focusing on biomedical image computing and computer assisted interventions, BMC allows students to get introduced to medical data acquisition and management, medical terminology as well as physics of medical imaging. Furthermore,
students get familiarized with medical image processing, visualization, advanced user interfaces, and computer-aided medical solutions.

During the first term, all students take mandatory fundamental medical science and technology courses. Remaining credits for the first term are filled with complementary courses that depend on the student’s previous education. Informatics or Computer Science majors can choose from advanced courses in Mathematics, whereas Mathematics and Physics majors can select from a set of Informatics courses. In the second and third terms, students are taking additional mandatory courses related to medicine and visual computing. Missing credits can be earned by attending courses from a list of general-interest lectures. Students can acquire practical experience by participating in lab courses and in a clinical project. The fourth term is intended for the completion of the master’s thesis.

**Biomedical Computing** focuses on bridging the gap between Informatics and Medicine. The possibilities for a clinical project and several newly created courses by the Medical School provide students with a unique understanding of medical problems in imaging, interventions, and diagnosis. Many events take place in the hospitals of our Medical School to provide students with a proper insight into clinical routine. Only this understanding can foster innovative thinking from an engineering perspective.

### Automotive Software Engineering

Software-based and cross-linked components in cars have been getting increasingly important in the last three decades. They make cars safer, more comfortable, and more user-friendly. Their development requires a fundamental change in the process of development. The strong dependencies between the different components lead to new requirements on Software & Systems Engineering. A limiting factor in the car industry is the lack of highly qualified, skilled persons that are able to design and implement the novel processes and methods. This master’s program addresses this high demand for engineers in the industry who are able to design and optimize processes and systems in highly complex cross-linked real-time settings. The program does not only qualify for jobs in the automotive industry but also in aerospace industry, in the automation of technical processes, and the construction of embedded systems of all kinds.

During four terms, students broaden their knowledge in Informatics, Mechatronics, Electrical and Information Technology, and Business Administration. Techniques for programming and modeling are acquired together with familiarity with tools and processes as much as needed for implementing software intensive systems during practical car development. Visiting lecturers from companies complement the syllabus of instruction and give practical experience.

The master’s program **Automotive Software Engineering** is both research-oriented and practical, and splits into topics from Software Engineering, automotive topics, and soft skills like organization and management. Students can emphasize individual key aspects in the master’s thesis, lab courses, and seminars.

<table>
<thead>
<tr>
<th>Year</th>
<th>Completed applications</th>
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<td>2015</td>
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<td>29</td>
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<tr>
<td>2016</td>
<td>87</td>
<td>36</td>
<td>20</td>
</tr>
</tbody>
</table>

Figure 15: Student numbers for the master's program *Biomedical Computing*. (Source: IN.TUM)
Robotics, Cognition, Intelligence

Robotics is in flux: In the past, industrial robots were mainly automating the manufacturing process, but today they have captured many areas of life. In the past they had to be operated by experts; today everybody can do this: they are vacuum cleaning at home or mowing the lawn. Even more: humans and robots are cooperating closely together without separating walls. Tomorrow, they will be part of everyday life and of the human body. Already today wearable robots serve as walking frame in form of an exoskeleton for disabled persons.

Because the boundary line between man and robot obliterates, the developers of robots face new challenges. Robots have to be able to react autonomously and adaptively to unexpected situations. Therefore, modern robots must be able to learn automatically.

The master’s program Robotics, Cognition, Intelligence establishes the foundation to participate in this fascinating development. The graduates are much asked for in research and industry – e.g. in aerospace, microelectronics, consumer electronics, medical engineering, and automotive engineering.

During four terms, students get experts in robotics accessing the broad course and research offering of the TUM. Students attend classes in Informatics, Electrical, and Mechanical Engineering. Theoretically and practically, students get to know systematic tools for developing robots, and learn to deal with robots in practice based on many technical real life platforms. In addition to classical robot control, students are engaged in cognition, image processing, and artificial intelligence. Students learn methods in signal processing, sensor data evaluation and fusion, and programming. Students work on concepts of behavior and machine learning and man-robot interaction. The courses are close to applications and to modern trends: e.g., TUM researchers are cooperating with partners from industry in technologies for autonomous driving.

### Table: Student numbers for the master’s program Robotics, Cognition, Intelligence

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<thead>
<tr>
<th>Year</th>
<th>Completed applications</th>
<th>First-year students</th>
<th>Graduates</th>
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<tbody>
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<td>2013</td>
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<tr>
<td>2016</td>
<td>54</td>
<td>15</td>
<td>18</td>
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</table>

### Figure 16: Student numbers for the master’s program Automotive Software Engineering. (Source: IN.TUM)

### Table: Student numbers for the master’s program Automotive Software Engineering

<table>
<thead>
<tr>
<th>Year</th>
<th>Completed applications</th>
<th>First-year students</th>
<th>Graduates</th>
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<tr>
<td>2014</td>
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</tr>
<tr>
<td>2015</td>
<td>125</td>
<td>65</td>
<td>27</td>
</tr>
<tr>
<td>2016</td>
<td>134</td>
<td>72</td>
<td>23</td>
</tr>
</tbody>
</table>

### Figure 17: Student numbers for the master’s program Robotics, Cognition, Intelligence. (Source: IN.TUM)

Humanoid robot. (Source: IN.TUM, copyright Terra Mater, Christian Grund List Grid)
Data Engineering and Analytics

Data are a key resource in present and future economic developments. Revolutionary insights can be extracted from data by means of exploration, analyses, and engineering, and the world is reacting with impressive impulses and creative ideas. Industry is pushing towards data guided decisions, while entrepreneurship flourishes with ever new tidbits of knowledge extracted from data.

In this context, the two TUM master's programs Mathematics in Data Science and Data Engineering and Analytics create the unique opportunity for an in-depth study of Data Science and Data Engineering. Both programs provide the fundamentals in Data Engineering and Data Analysis. Data Engineering and Analytics specializes on techniques for the engineering of systems that enable the exploration and analysis of vast amounts of data.

Data Science and Data Engineering require skills and knowledge from multiple disciplines. This prompted the Departments of Mathematics and Informatics to jointly contribute to a new Integrative Study Program Data Science. Integrative Study Programs constitute a novel instrument offered by TUM to allow multiple departments to create innovative study programs by sharing their respective expertises.

Lectures on advanced database technology, distributed systems, IT security, machine learning, and scalable programming methods are provided by IN.TUM. Statistics, mathematical representation of large and high dimensional data sets, their dimensionality reduction, and their classification to mine meaningful information, cryptography and optimization are taught by the Department of Mathematics.

The Integrative Study Program Data Science offers two different master's programs. Students who want to focus on the mathematical aspects are encouraged to apply for Mathematics in Data Science whereas students who are interested in the Computer Science/Informatics perspective should apply for Data Engineering and Analytics.

<table>
<thead>
<tr>
<th>Year</th>
<th>Completed applications</th>
<th>First-year students</th>
<th>Graduates</th>
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<tbody>
<tr>
<td>2016</td>
<td>49</td>
<td>15</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 18: Student numbers for the master's program Data Engineering and Analytics. (Source: IN.TUM)

4.3 Interdisciplinary teaching activities

Informatics is inherently interdisciplinary. To a certain extent, this becomes apparent in the organization of our bachelor's programs, but is even more central in all our dedicated master's programs, some of which even have shared examination committees with other departments. As an example of a particularly innovative teaching format, we refer to the Interdisciplinary Project in an application subject of master's students in Informatics (see below).

Export

Informatics contributes fundamental technology and background skills which are crucial for virtually every other discipline. Currently, Informatics can be chosen as a minor subject or specialization area only in the bachelor's programs Management and Technology, Mathematics and Engineering Science, as well as for various programs offered by EDU. For several other disciplines, we provide introductory courses.

TUM School of Management

IN.TUM provides dedicated courses “Introduction to Informatics for Management and Technology” as well as “Information Management for Digital Business Models”. Informatics also supports various WI study programs by admitting WI students to regular Informatics courses. For example, the Informatics beginners’ course “Introduction to Informatics I” has seen around 250 Management
and Technology students each year. Likewise, the courses “Introduction to Software Engineering” and “Fundamentals of Databases” have seen around 200 Management and Technology students each in each year.

Mathematics

For MA, we provide the mandatory courses of a minor subject Informatics. Various elective modules of Informatics are also available for master's students of MA. The master's program Mathematics in Science and Engineering requires a full minor subject in Informatics. The course “Introduction to Informatics”, e.g., has about 70 to 100 Mathematics students, while the course “Fundamentals of Algorithms” has about 50 to 80 students from MA.

Munich School of Engineering

To the mandatory course program of the MSE bachelor's program, IN.TUM contributes the mandatory courses on programming, software engineering and databases, and as elective courses “Geometric Modeling and Visualization”, “Embedded Networked Systems” and “Systems Engineering”. For the specialization, a wide spectrum of courses from Informatics may be chosen.

TUM School of Education

Within the bachelor's program Science Education with emphasis on Mathematics and Informatics for Secondary Schools, IN.TUM provides the required modules in Informatics. The same holds true for the complementary teaching subject Informatics within the program Vocational Education both at the bachelor's and master's level.

Other Exports

Basic know-how in Informatics is also provided for WZW. For EI, we offer a course on “Algorithms and Data Structures”. For PH, we provide a course “Scientific Programming”. A letter of intent to admit students to courses has also been signed for MW. A similar letter for GOV is in preparation.

Import

Import from other disciplines is crucial when interdisciplinarity is to be taken serious. For training interdisciplinary thinking, bachelor's students in Informatics take up minor subjects. As minor subjects may be chosen Mathematics, Mechanical Engineering, Electrical Engineering, Economy, or Medicine. A minor subject in Politics is conceivable. Bachelor's students in Information Systems naturally are exposed to courses from Management and Technology, and bachelor's students in Informatics: Games Engineering are encouraged to do joint projects with the HFF (Hochschule für Film und Fernsehen). Common to all bachelor's programs are mandatory support electives as offered by the Carl von Linde Academy, the TUM Language Center, the Munich Center for Technology in Society, by WI or EDU.

An innovative project format of the master's program Informatics is the “Interdisciplinary Project in an Application Subject”. Such projects may be offered by any TUM department, different from Informatics. The task assigned to the students is to acquire enough background knowledge of the application domain to communicate with the given end user, to understand the posed problem and to engineer a solution.

An overview of the interdisciplinary exchange of teaching activities at the bachelor's level for the major bachelor's programs in Informatics is given in the following diagram.
4.4 Special offers: elite, double-degree, and part-time studies

IN.TUM is involved in six elite study programs within the Elite Network of Bavaria. While the participation in TopMath (by MA) and Data Science (by LMU) is through individual faculty, the involvement in the other programs is stronger and goes up to coordination (in case of BGCE).

BGCE

The Bavarian Graduate School of Computational Engineering (BGCE), coordinated by IN.TUM, consists of the three basic programs Computational Mechanics and Computational Science and Engineering (CSE) at TUM, and Computational Engineering (CE) at the Friedrich-Alexander-Universität Erlangen-Nürnberg. By its innovative concept of teaching, the BGCE program has developed to an essential pillar of training in Computational Engineering in Bavaria, also compared with other international programs.

For its students, BGCE provides a deep understanding of the interrelations in Computational Engineering – from multi-core processors to simulation software, from mathematical modeling to fast numerical algorithms, from parallel programming to exploration and analysis of large data sets, from the physical background of challenging simulation tasks to the optimization of technical systems and processes and the analysis of related uncertainties. So BGCE contributes significantly to the necessary qualification for dealing innovatively with future tasks.

FIM

Since its introduction in 2004, the elite program Finance and Information Management (FIM) has emerged as a great success story: In addition to the Universität Augsburg, the Universität Bayreuth and TUM, other national and international scientific and business partners constitute this unique and individual study program. Within the Elite Network of Bavaria, FIM is the only full-time business
master’s program. Furthermore, the high reputation of FIM is also demonstrated by the excellent position in the nationwide CHE Master Ranking of 2008/2009, 2011/12, and 2014/15 of the newspapers “Die Zeit” and “Handelsblatt”, in which FIM was ranked 1st in all categories.

Software Engineering

In the winter term 2006/2007, the Department of Applied Informatics at the Universität Augsburg and the Departments of Informatics at TUM and LMU started a joint elite master’s program Software Engineering.

The program aims to educate an elite for the cutting-edge areas of Software Engineering. The graduates of this study program have proven not only to be able to face the challenges of ambitious software projects, but also to be actively involved in the development of tomorrow’s solutions.

This is the first elite study program in Software Engineering in Germany. Post-graduate students of this program are facing opportunities for their careers in science or industry which are hardly to achieve otherwise. Many of the graduates have pursued a PhD and/or are involved in successful start-ups.

Technology Management

Informatics also participates in the interdisciplinary study program Technology Management offered by the Center for Digital Technology and Management (CDTM), which has been designed as an add-on program for highly talented students, mainly of Informatics, Electrical and Computer Engineering and Business Studies. The curriculum, which is integrated into the regular university studies, focuses on technology management and entrepreneurship in the international environment of fast moving industries such as telecommunications, information technology and new media.


From the recent evaluation report of Technology Management. (in German)
The curriculum is geared towards a career in high technology management. In a mandatory core curriculum, students work in an interdisciplinary and international environment. Team- and practice-oriented courses focus on technology trends, product development, and entrepreneurship. In a term abroad, students gather the skills to succeed in international and cross-functional settings. Courses are oriented to provide skills necessary for extraordinary managerial challenges.

Lectures are not only designed to provide a solid basis in business and engineering, but also to allow students to tailor their studies according to their specific needs. For students aspiring careers at the intersection of management and technology, the program offers an education that closely reflects the realities of modern markets.

Double-degree master’s programs

Since 2004, IN.TUM has offered double-degree programs for the master’s program in Informatics – currently with seven partner institutions, namely: KTH Stockholm, Telecom ParisTech, Eurecom Nizza, Al Akhawayn University Ifrane (AUI), Georgia Institute of Technology Atlanta (GIT), Tomsk Polytechnic University (TPU), Ecole Polytechnique Paris (EP). All follow the same scheme: one year at the home university, one year at the host university, a common master’s thesis and the possibility to transfer 30 credits in both directions. All in all, students have to gain at least 150 Credits (without transfer) in order to get two master’s degrees. We see that some partnerships are symmetric in the exchange, especially with Telecom ParisTech and Eurecom Nizza. We send more students to KTH than we receive, and we receive a lot more students from AUI and TPU than we send. The contract with GIT includes tuition fees to be paid for TUM students. We send more students to KTH than we receive, and we receive a lot more students from AUI and TPU than we send. The contract with GIT includes tuition fees to be paid for TUM students. As a consequence, only very few TUM students use this opportunity. EP is a new master’s partnership with no experience yet. Double-degree programs turned out to be very time-consuming to administer and coordinate and cannot be done on the side. Therefore, we will carefully review these partnerships to concentrate our efforts on those which are fruitful for both sides.

Part-time studies

In summer 2014, IN.TUM has introduced a part-time master’s program in Informatics. The full-time master’s program in Informatics is very flexible, meaning that it offers a framework within which students may freely choose courses by respecting only certain constraints. This simplified the task of introducing part-time study variants where students are allowed to study with a reduced load, of 50% or 66%. Neither were new courses introduced, nor are courses scheduled in the evening or at the weekends. Students attend the regular courses of the full-time program. It has turned out that this model fits for quite a large number of students. In summer 2017 around 55 students are enrolled in the part-time program. Most of the students work besides their studies, as employee or as entrepreneur. They have flexible working times so that our lean concept of part-time studies fits them well. Although the administration of this part-time program requires a significant effort – mainly due to the respective functionalities of the campus management system TUMonline currently still missing – we plan to continue this program as it is highly successful.

4.5 Aptitude testing

With the rapid increase in the number of first-year students around the year 2000, the number of study drop-outs rose to more than 60 percent. This made it clear that many of the first-year students apparently had wrong expectations about studying in general or about the subject or were not well suited for the specific demands of the Informatics study programs at TUM. In order to counter this development, IN.TUM was one of the first departments in Bavaria to successfully implement an aptitude testing procedure for the diploma program in Informatics. Later, this procedure was transferred to all bachelor’s programs.
Aptitude testing in the bachelor’s programs

The aptitude test is organized in two stages. In the first stage, applicants are immediately admitted to the study program, if their final school grades are good enough that they can be expected to successfully complete their studies. In the second stage, the remaining applicants are invited to the department for a selection interview with a professor and a research assistant. The interview takes into account the applicant’s motivation, realistic expectations of the demands of the study program, the ability to abstract, logical and system-oriented thinking as well as communication skills.

In winter 2016/17, 775 applicants were directly admitted to the bachelor’s programs Informatics, Informatics: Games Engineering, and Information Systems in the first stage. 836 applicants were invited to a selection interview. Of the 622 candidates who took part in the interview, 455 were admitted (73%).

Since the introduction of aptitude testing in Informatics, the drop-out rate has dropped to less than 30%. Although IN.TUM thus has had very good experience with aptitude testing, in the bachelor’s program in Informatics, for legal reasons, this procedure must be given up in the future to be replaced with some procedure of study-oriented non-binding recommendation.

Aptitude testing in the master’s programs

The master’s programs of IN.TUM receive an ever increasing number of applications from all over the world. In order to ensure the sufficient qualification of the first-year students in the master’s programs, aptitude testing is mandatory in all programs. The evaluation procedure is organized in two stages, similarly to the evaluation procedure at the bachelor’s level. The first stage takes into account the comparability of the previous bachelor’s degree with the corresponding program at the TUM, a motivation letter, an essay on a given topic as well as the grade in the bachelor’s degree. A committee consisting of a professor and a research assistant decides whether the candidate is directly admitted, rejected or invited to an interview.

In 2016 (summer term plus winter term), 1039 applicants were admitted in the first stage, 452 were rejected, and 187 were invited to an interview. Of the 173 applicants who took part in the interview, 119 were admitted (69%). Due to aptitude testing, the drop-out rates of our master’s programs are negligible.
4.6 Administrative support

The large number of students as well as the considerable number of distinct study programs has made it inevitable to centralize the management of study affairs. Therefore, in 1999 a dedicated office for academic programs was founded.

Organizational structure of the Academic Programs Office

The Academic Programs Office is centrally responsible for the organizational and administrative support of teaching, the organization of the aptitude tests, the examination management, the quality management, the academic study advising, and the internationalization in study and teaching. It is, on the one hand, the executive body of the examination boards for virtually all IN.TUM study programs. On the other hand, it supports the Dean of Studies in her/his organizational and administrative tasks. A special role is played by the master’s programs Computational Science and Engineering and Robotics, Cognition, Intelligence which own, based on their interdisciplinary structure, their own examination boards, which nonetheless are supported by the Academic Programs Office.

Organigram of IN.TUM's Academic Programs Office.
Management and development of study programs

The secretaries of the examination boards within the Academic Programs Office are responsible for the preparation and implementation of the decisions of the examination boards. They advise the students on examination matters, especially, in difficult study situations (illness, failed exams). They trigger the examination office to issue notifications, diplomas, and certificates for the students.

The secretaries of the examination boards are assisted in their work by clerks, who, e.g., answer questions of students in their back offices or in the front office (Infopoint). They process applications of all kinds and final theses, monitor deadlines, and record results in TUMonline.

For each study program, there is a responsible professor as well as a coordinator (research assistant) outside the Academic Programs Office who are responsible for ensuring the course offer and the development of the respective program. At the examination boards, they may request changes in the permissible elective modules or cause necessary changes to the academic and examination regulations. They are administratively supported by the respective secretary of the examination board.

Academic study advising

IN.TUM is keen on providing excellent services for its students. For that reason, the front office Infopoint has been installed for immediate support. Moreover, a team of two academic advisors is available for students every day of the week for solving more intricate study-related problems. In order to provide students with the best possible advice concerning their future academic careers, the department employs advisors who themselves have studied Informatics or a related subject at a university and participate in the department’s teaching. Accordingly, they have deep insights into the academic culture and also into the course programs offered at TUM. They are deeply involved in the development of the study programs and include the student’s perspective into the departmental discussion. One of the main challenges in the last years has been to support the large number of international students in the master’s program Informatics.

Resource management (rooms, time slots, matching)

IN.TUM offers more than 500 courses per study year. Time slots for mandatory courses are planned centrally to ensure that students are able to participate in all necessary courses of their study program in time. The timetables of some study programs have to be planned in cooperation with other departments at TUM (e.g., Information Systems) and also with LMU (e.g., for the Bioinformatics programs).

Due to the shortage of lecture rooms on the Campus Garching of TUM, all lectures which are expected to be attended by more than 70 students are also planned centrally. Thus, care is taken that no lecture room is blocked by a course which could take place in a smaller room.

Furthermore, the allocation of the large lecture halls must be negotiated with the other TUM departments at Campus Garching. Due to the massive growth of enrollments in the past years, IN.TUM had to rely on other departments’ rooms to realize its current lecture program.

The allocation of rooms to large exams is calculated by the MOSES system which is jointly used by most of the TUM departments. This ensures that exams which are mandatory in a study program do not overlap, and that rooms are used in an optimal way. Participants in exams must be seated at sufficient distance from one another to prevent cheating. To keep this quality despite the large number of exams at TUM and despite the large number of participants in some exams, the department is currently forced to conduct exams also in evenings and on Saturdays.
In most study programs it is mandatory for students to participate in one seminar course and one practical course. Students are matched to offered courses by a tailored software system developed at IN.TUM to fulfil our specific requirements and to realize the matching in a way as satisfying as possible.

4.7 Controlling and quality management

In 2007, IN.TUM started the accreditation process according to the Bologna requirements and decided to get its bachelor’s and master’s degree programs in Informatics accredited by the German accreditation organization ASIIN. The request was submitted in 2008 and in 2009 both degree programs were accredited. Ever since then the department kept improving its quality management (QM) approach and implementation.

QM: Panel of Study Affairs

One major step was the establishment of a Panel of Study Affairs (Studienkommission) at IN.TUM in 2012. Announced by the Department Council, its minimum members are the Dean, the Dean of Studies, the Vice Dean of Studies, a third representative of the professors, the head of the Academic Programs Office, the assistant to the Dean of Studies, an academic student advisor, a representative of the scientific staff, the Gender Equality Officer, and three student representatives. The Panel of Study Affairs is concerned with everything which affects study and teaching, should be discussed by all four groups (professors, scientific staff, members of the Academic Programs Office, and students), is not a primary task of the examination boards or cannot be discussed in the appropriate depth in the Departmental Council or the examination boards. The Panel of Study Affairs plays a central role in the departmental quality management, as it reviews the evaluations of courses as well as study programs and supervises taken measures for improvement. The panel is involved in designing of new degree programs and the discussion of planned amendments to the statutes of existing programs. All matters concerning tuition fees and tuition fee substitution funds, on the other hand, remain in the hand of the departmental Quality Circle. As a permanent committee of the Department Council, the Panel of Study Affairs has planning, advisory, and recommending function only. It receives orders for the preparation of recommendations from the Department Council, and it also may submit self-initiated proposals to the Department Council.

QM: Integration into TUM’s quality management.

On 14 May 2014, TUM was system-accredited by the Swiss Center of Accreditation and Quality Assurance in Higher Education (OAQ) until September 2020. For being accredited, degree programs have to pass TUM’s internal QM assessment procedures. Therefore, IN.TUM adapted its own QM implementation to the TUM-wide QM system in 2014, which comprises the following six areas of application within academic and student affairs:

(1) the faculty appointment procedure,
(2) the design of new degree programs,
(3) their implementation,
(4) their evaluation, refinement, and/or cancellation,
(5) professional development programs for TUM personnel, including instructional methodology training for teaching staff,
(6) and the reporting system.

Whereby, items (2) to (4) constitute the core element of TUM’s optimization measures, the degree program life cycle. Accredited bachelor’s and master’s degree programs must receive renewed approval or update every five years.

QM: Collaboration with student representatives.

As students are seen as active co-producers and customers of higher education at TUM, they are not only organized in the TUM Student Council and departmental student councils but also incorporated in the degree program life cycle at various stages.
With regard to IN.TUM, student representatives are, e.g., to be found in the examination boards, the Panel of Study Affairs, the Quality Circle, the TUM Senate and Board of Trustees, the Academic Affairs Board (VL) and the Academic Affairs Council (PL). Therefore IN.TUM works in tight cooperation with the Departmental Student Council.

**QM: Introduction of new study programs.** The idea for a new degree program may be conceived by any member of the department. It must be broadly discussed by all stakeholders, in particular, the experienced members from the Academic Programs Office, the Dean of Studies, the Dean himself as well as the assembly of all professors. Given that a broad consensus has been reached, the official TUM process for creating a new study program is initiated. In general, the department is reluctant to enlarge the variety of degree programs. Still, the department considers it important to provide timely responses to exciting new developments in economy, science, or society. For that reason, it has created as one of the first Informatics departments in Germany a bachelor’s as well as a master’s program Informatics: Games Engineering, and also decided to take up the challenge of big data by installing the new master’s program Data Engineering and Analytics.

**QM: Supervision of study programs.** During the implementation of a new degree program a program director is appointed. The program director is in charge of ensuring that the targeted qualification profile of prospective students and the envisaged goals are achieved as stated in the study program documentation. To support this effort, the continuous improvement process applies to every study program within the department. The implementation of the quality management process in the department is based on the integration of several measures for monitoring and steering the life cycle of the department’s degree programs. An essential part of quality control is the evaluation of all lectures given by IN.TUM lecturers as well as the related tutorials. The set of questions used in the lecture surveys were developed together with the survey unit of the departmental student council and were reviewed by the Panel of Study Affairs and the TUM Academic and Student Affairs Office (HR SL) to ensure that all relevant questions are included and comply with the TUM evaluation guidelines. These lecture surveys are conducted and analyzed by the departmental student council every term. Since winter term 2016/17 seminars and practical courses get also evaluated. Only such courses are not evaluated where an anonymized analysis of the gathered data is not possible. Before the end of the lecture period, lecturers are encouraged to discuss...
the results with their students and tutors and implement improvements where required. A shortlist of the results of all lectures is prepared for the Dean of Studies for a possible follow-up discussion with the lecturers. This shortlist is also discussed at the subsequent meeting of the Panel of Study Affairs for possible improvements. Measures to be taken in case of alarming results include a justification against the Dean of Studies followed, perhaps, by pedagogical coaching or recommendations of courses offered by ProLehre or the Language Center.

Another essential part of quality control is the evaluation of each degree program and of its study conditions at least every two years. The results are forwarded to the Panel of Study Affairs and the respective program director for evaluation. In addition, the second alumni survey is planned at the graduation ceremony 2017. Also additional data including key figures, feedback management, etc. have to be taken into account by the Panel of Study Affairs. In accordance with TUM's QM system the degree program evaluations lead to varying degrees of recommendations of modifications and/or improvements from the Dean of Studies and/or the Panel of Study Affairs and/or the respective program director and require the approval by the Department Council. Those modifications can be at module or degree program level. In case that the scientific or economic perspectives have changed or the attractiveness for students shrinks, a comprehensive program redesign or even termination of a degree program may be taken into account. All this happens in close cooperation with the HR SL and the quality management at university level.

4.9 Innovative teaching and learning concepts

Teaching and experimenting with innovative forms of teaching have always been a keen interest of IN.TUM. The various elite master's programs in which IN.TUM is involved can be considered as playgrounds for all kinds of innovative teaching formats. In 2015, Gudrun Klinker received the Bavarian Award for Excellence in Teaching for designing and realizing outstanding teaching formats within the study program Informatics: Games Engineering. In 2017, the same prize will be awarded to Angelika Reiser for her life-long contributions to improving not only teaching itself, but also study programs and the whole life-cycle of students and, in particular, international students. Subsequently, we list example activities to improve teaching and learning environments.

MOOCs. The chair of Bernd Brügge has developed a new Massive Open Online Course (MOOC) about software engineering essentials. The course is designed as bridge course for incoming master's students. It teaches the topics in the style of explanation videos, coupled with interactive exercises: multiple-choice quizzes, drag and drop quizzes test the students’ understanding of the taught concepts, while modeling and programming exercises test that students can apply the learned knowledge practically. A new automated assessment system evaluates the students’ solutions automatically and provides feedback. Students can submit their solution multiple times...
and know immediately whether their solution meets the correctness criteria. Instant messaging is used to improve the communication between students, teaching assistants, and instructors.

MOOC technology has also been tried out by Daniel Cremers for a lecture on Autonomous Navigation for Flying Robots with over 40,000 registered students. MOOCs, however, are best suited for introductory material only. Therefore, Cremers has produced Youtube videos for his lectures “Variational Methods for Computer Vision” (around 50,000 views) and “Multiple View Geometry” (around 70,000 views).

While MOOC lectures often are very short (most have a total speaking time of 5 hours), the Youtube videos are full lectures (4 hours a week). They are very well received by the TUM students (who use them to recap a particular class at their own speed or to rehearse for the exam). In addition, the large number of views and frequent emails indicate that they are hugely popular well beyond TUM.

iLab. The iLab didactical concept, developed at the chair of Georg Carle, is a blended learning methodology combining offline and online phases, individual and teamwork, and lecture, self-studies, and practical hands-on in teams of two. The iLab concept is currently applied in two different iLab courses at TUM that run in parallel (iLab – build your own Internet, iLab – you set the focus). It is also running at the University of Tübingen. The iLab didactical concept is built around a customized open source eLearning solution.

Since 2004, the system has been continuously developed. More than 1,000 students have already participated in iLab courses. They acquired knowledge about computer networks and distributed systems. From the beginning the student feedback has been extremely positive.

A survey of students that participated in the iLab and had finished their university studies years ago resulted in multiple feedbacks that the iLab content would still be remembered and that it would be very well applicable in the daily industry work.

Lecture recording. Since 2000, the group of Helmut Seidl has experimented with lecture recording. Their insight is that the best technology for recording is that which requires the least effort by the lecturer. In order to be platform-independent, they decided for a screen-capturing approach based on the VNC protocol resulting in small recordings. Automated post-processing is provided to identify new pages and to make the pixel stream searchable for key words. A different approach based on html technology has been developed by the group of Hans Schlichter. Bernd Brügge produced recordings of his lectures on topics from software engineering for iTunes U.

Generally, lecture recording currently is the de facto standard for all very large lectures offered by Informatics. In order to support this service for lecturers without specific technological ambition, the RBG has installed default recording infrastructure in all major lecture halls used by the Informatics faculty.

TUMexam. TUMexam is a system for supporting (large) written examinations: It includes the creation of seating plans, participants lists and protocols, and allows the automatic recording of marking results by means of image recognition. Various assessment methods and bonus systems with freely adaptable grades keys are supported. As a result, lists can be imported directly into TUMonline. The scanned examinations can then be made available to the students as a PDF via a feedback system (tumexam.de), which replaces the classical post-examination review. The system has been developed since spring 2015 at the chair of Georg Carle. In autumn 2016 the online feedback system was developed, which replaced the complicated upload of examinations in Moodle. In the last few months the support of the KKK (Karpfinger-Klausur-Konzept) has been integrated for compact mathematics tests.
In the last winter term, more than 4,000 written examinations at four TUM departments used TUMexam, of which around 3,600 also used the online feedback (retakes not included). Thanks to the online post-examination reviewing, the students have the maximum transparency of the marking without the need of their presence, including the possibility to indicate marking errors. These are digitally post-processed and fully documented in the PDF version of the test.

**Demo Day.** In connection with the study program *Informatics: Games Engineering*, IN.TUM has started in 2011 to organize a Demo Day event in the last week of each term. Students from all Informatics study programs use the opportunity to demonstrate and discuss their achievements of the past term to the public. This event is well received by fellow students, teachers, friends, and visitors from industry, politics, and press. The event allows students to practice presentation skills and obtain feedback. These presentations are complementary to academic talks in seminars. They may take the form of one-minute pitches, poster presentations, or live demonstrations, and thus are highly interactive.

4.10 Extra support for prospective and current students

**Preparatory classes.** For the bachelor’s beginners, IN.TUM together with the departmental student council offers a preparatory class as “Mathematics for Informatics Students” lasting 8-9 days. The beginners get to know the Campus Garching and, e.g., library, mensa, and IT environment, and participate at showcase lectures and tutorials. The beginners learn to know each other, and come in contact with representatives of the department.

As not all beginners participate in this preparatory class, at the beginning of both the winter and summer terms, the departmental student council organizes the *Study Introduction Days* (*SET: Studieneinführungstage*) for first-year students of the bachelor’s and master’s programs. All events are accompanied by social meetings in the evening to learn about Munich and Garching.

**School programs.** The main objectives of the IN.TUM school programs are to enhance the study skills at the interface between school and university and to promote special groups such as young women or school students from upper vocational schools. School students and groups of school students are invited to visit the department. Typically, they are offered to visit showcase lectures, to participate in dedicated workshops, and to get in touch with students and lecturers. Additionally, dedicated programs such as holiday programs for
4 Teaching

girls and young women, the Pupils' Academy of Serious Gaming, and the hands-on lab ITüpferl.

The effectiveness of the school programs are scientifically evaluated and the findings presented at appropriate conferences. IN.TUM cooperates with other educational institutions and teachers.

**Early studies.** Ten years ago in 2007, the department established the program Schueler.IN.TUM. This early study program targets talented school students in the greater Munich area in their final years before graduation (Abitur) and offers them to attend lectures in Informatics at TUM. The early study program is endorsed by the Ministry for Education. Thus, school directors are allowed to release students from regular school activities in order to accommodate their university studies.

In their first term, these students attend the lecture “Introduction to Informatics” and the accompanying lab course for a total of 12 credits. This challenging entry lecture lays the foundation for further elective courses that can be freely chosen from the undergraduate curriculum, such as “Discrete Structures”, “Foundations of Databases”, “Foundations of Algorithmus and Data Structures”, etc.

The obtained credits of the early study courses can be transferred into credits of a regular study program at TUM – thereby often shortening the duration of the succeeding bachelor’s studies.

By this measure, the objective is to strengthen diversity by motivating female school students to enroll in the program. Also, talented school students should be proven first-hand that Informatics is not only useful, but challenging and exciting.

**MINT.** IN.TUM also participates in the TUM MINT program in the summer term. The program offers a term of orientation to help beginners in identifying the study program which suits them best.

4.11 Mentoring and support programs

IN.TUM is particularly concerned with gifted and highly qualified students. For these, mentoring and several dedicated programs are offered. Attending intensive courses, getting an early start into research, or collaborating with students from different departments, establishing a network for future careers, coaching from an experienced professor are just examples. A complete list can be found at www.in.tum.de/en/mentoring.

**Gems of Informatics.** Part of the department’s program for gifted students is a course “Gems of Informatics 1-4” which is offered in the first 4 terms. It is designed for particularly keen and gifted students who are identified via their grades and are invited personally. At the same time the course is open for all students. The aim of the course is to bring students into contact with research topics early on in their undergraduate studies. There is no fixed syllabus and the lecturers can choose particularly exciting or fun topics to capture the imagination of the students. The format is often a mixture of lecture, seminar, and laboratory course, depending on what is most suitable for the topic at hand. An outstanding alumnus of this series of courses is Bernhard Häupler, who (when at MIT) won the 2014 ACM-EATCS Doctoral Dissertation Award of Distributed Computing and is now assistant professor at Carnegie Mellon University.

**best.in.tum.** IN.TUM promotes the best two percent of its students by this dedicated program for students of the department. Participation is independent of the participation in other programs and without obligation for the promoted students. The promotion shall confront the best students with open and challenging issues in Informatics. Advice is provided concerning the studies, a forum for discussion is offered, and in some cases even a desk space is organized at IN.TUM. By means of excursions to companies and research institutes the members of best.in.tum get in touch with future employers in an early stage of their studies.
Currently, the program has more than 120 members, thereof 25% female students.

**National Scholarship Program.** Both TUM students and partners in industry share in the benefits of the National Scholarship Program (*Deutschlandstipendium*). Besides providing financial support, it enables talented students to tap their potential and puts industrial partners in contact with highly-qualified specialists and leaders of tomorrow early on. The main coordination and the application is organized by the TUM coordinators. IN.TUM supports the selection process of applicants and is involved in the fund raising of future sponsors.

In the last terms, the applications from students in Informatics increased as well as the number of scholarships. In the last selection round, students in Informatics received the highest number of scholarships compared to other departments.

**Junge Akademie.** TUM: Junge Akademie is the TUM’s program for encouraging exceptionally talented and dedicated students who are interested in interdisciplinary topics and want to reach positions of responsibility in the modern society. The support initiative aims to confront the most promising students with open and particularly difficult problems at an early stage and provide them with all relevant know-how to solve such issues.

The application process and the supervision of the program is coordinated by TUM. IN.TUM is involved in the application process, and also encourages students from *best.in.tum* to apply for TUM: Junge Akademie as well.
5 Governance and Human Resources

5.1 Governance and organization

The core of IN.TUM’s governance structure is given by law (Bayerisches Hochschulgesetz, BayHSchG, and Verordnung über abweichende Regelungen vom Bayerischen Hochschulgesetz an der TUM, VOTUM) and extended by the constitution of TUM (Grundordnung der TUM, GOTUM): Department Council, Dean, Vice-Dean(s), and Dean of Studies. According to these regulations, this core has the decision competence and all responsibilities within the department.

Concerning governance beyond that core frame, IN.TUM introduced its present structure in 2010 with minor adaptations in 2018. The number of professors of the department increased from 16 at the time of the establishment in 1992 (only first memberships counted) to 30 in 2009. Therefore, the former governance organization was no longer effective enough. After a broad discussion in the winter term 2009/2010, IN.TUM has given itself a new, firm organization.

Today, after 8 years of operation and a further increase in the number of professors to 42 (as of July 2018), it can be said that the new governance organization has proven to be very effective. This means, e.g., that actions and decisions can be taken faster. Also transparency and information have increased, e.g. because minutes are provided for all relevant meetings. Our governance structure is based on “all-faculty instruments” allowing for a broad participation of IN.TUM faculty, on a lean management structure around the Management Board, and on a number of commissions to ensure the involvement of all relevant groups (faculty, staff, students).

IN.TUM governance.
Department of Informatics

Department Council, Dean, Vice Deans, Dean of Studies, and Department Board

IN.TUM is headed by the Dean and the Vice Dean. They are responsible for the management of the department. The Dean of Studies and the Vice Dean of Studies support them in all affairs related to studies. A further Vice Dean with responsibility for all affairs related to research is on the way to be established. The Dean, the Dean of Studies, and all Vice Deans constitute the Department Board.

Decisions of fundamental academic importance (e.g. installation of new professorships, acceptance of doctorates and habilitations, structure and strategy of study programs) are taken by the Department Council. The Department Council consists of the Dean, the Vice Deans, the Dean of Studies, the Gender Equality Officer, and elected representatives of the professors (6), the scientific staff (2), the non-scientific staff (1), and the students (2). The Dean chairs the Department Council, which meets typically six to eight times a year.

Professorships

The department currently comprises 25 chairs with altogether 42 professors. There are full professorships (Chairs), associate professorships, and assistant professorships. In addition there is a small number of award-winning postdocs, summarized as TUM Junior Fellows, who also have the right to supervise dissertations according to the statutes of the TUM.

Institute of Informatics

Institute Council, Executive Directors, Managing Director, and Institute Board

All chairs and professorships of the department are organized in a single institute, the Institute of Informatics. All fundamental non-academic decisions are taken by the Institute Council, which consists of all tenured Professors of the institute.

This Institute Council elects six Executive Directors for the areas Human Resources, Finance, Space and Building, IT-Infrastructure, Student Services, and Communication and Public Relations from its members.

At the operational level, a Managing Director, also elected by the Institute Council from among the scientific staff, assists the deans and the executive directors with a large power of authority. He heads the Dean’s Office and the Service Offices of the department.

Important decisions such as the permanent employment of scientists or the allocation of department functions are taken by the Institute Council, whereas most everyday decisions are delegated to the Institute Board, which consists of all Executive Directors and the Managing Director.

Management Board
(Erweiterte Fakultätsleitung)

Department Board and Institute Board form the Management Board, which is responsible for coordination and decision-making in the affairs of the department and the institute. It is headed by the Dean, who is responsible for invitation, agenda, and the follow-up of the proposed resolutions. Keeping record is the responsibility of the Managing Director. The minutes are publicly available to the faculty. The meetings take place every 2 weeks.

Faculty Meeting (Professorium)

The full-time professors (W3, W2, W2-TT, C4, C3) as well as the affiliate members of the department, the adjunct professors, the adjunct teaching professors, and the junior research group leaders meet regularly during the lecture period. This Faculty Meeting is a forum for consultation and discussion. It supports the decision-making bodies of the department in their decision-making through the opinion-forming process taking place there. The frequency of the meetings, the content design (e.g. tech updates, reports from Department Board, Institute Board, and
Management Board), as well as the minutes are given by the dean in a timetable each term.

Faculty Retreat (Professorenklausurtagung)

Once a term, IN.TUM holds a 1-2-day closed workshop, in which the Faculty Meeting participates together with the Managing Director, the head of the Academic Programs Office, and additional guests as appropriate. The Dean informs about relevant activities and decisions and the commissions report about their work.

Structural Planning Commission (Strukturplanungskommission, SPK)

The Structural Planning Commission is meant to discuss and develop a long-term strategy for all kind of structural issues of the department, e.g., of the employment policy. This commission elects a chairperson from its members who reports to the Dean. The term of office of the members of the Structural Planning Commission ends with the Dean’s office.

Panel of Study Affairs (Studienkommission)

The Panel of Study Affairs, headed by the Dean of Studies, is concerned with everything that affects study and teaching, that should be discussed by all four groups: professors, scientific staff, members of the Academic Programs Office and students, and that is not a primary task of the examination boards or cannot be discussed in appropriate depth in the Department Council or the examination boards. The Panel of Study Affairs plays a central role in the departmental quality management, as it reviews the evaluations of courses as well as study programs and supervises measures taken for improvement. For that reason also the Gender Equality Officer is member of this panel. As a permanent committee of the Department Council, the Panel of Study Affairs has planning, advisory, and recommending function only. For more details see Section 2.4.

Quality Circle (Studienzuschusskommission)

The department initiated its Quality Circle as planning commission to decide how to use the tuition fees introduced in 2007. In October 2013, tuition fee substitution funds (state compensation for abolishing these fees) were introduced which, as the tuition fees, are dedicated to improvements of the conditions for studying and teaching. The Quality Circle is in charge of the implementation of measures and the allocation of the respective departmental budget. It is headed by the Dean of Studies, for more details see Section 2.4.

Panel of Financial Affairs (Haushaltssitzung)

The Executive Director of Finance organizes two meetings per year on budgeting, planning, and forecasting (BP&F) in addition to a report about third party funding presented at the two annual Faculty Retreats. The budgeting is organized along cost centers (e.g., IT, public relations, office supply) with colleagues responsible for the budget of these cost centers. In the BP&F meetings, the cost center representatives report their plans, and the group discusses and then develops recommendations on the allocation of the overall budget provided by the university.

Research Commission (Forschungskommission)

The department initiated the creation of 13 research clusters, described in detail in Section 2.3. Headed by the Research Commissioner, the coordinators of the research clusters form the Research Commission, which has the task of aligning the activities and the reporting of the research clusters. The Research Commissioner informs twice a year at the occasion of the Faculty Retreat on the activities of the Research Commission. In the future, a further Vice Dean is planned for this responsibility.
Commissioners (Beauftragte)

For various other responsibilities, e.g., library, privacy protection, colloquium, the Dean, or in some cases such as for diversity and gender, the Department Council, appoints further representatives of the faculty.

5.3 Human Resources

Professorships

In 2012 TUM introduced Germany's first Tenure Track System – TUM Faculty Tenure Track. New appointments as Tenure Track (TT) assistant professorships are the entry level for young talents. Initially, a TT assistant professor receives a temporary W2 contract for six years with an option for tenure. After a successful evaluation, the assistant professor is promoted to the associate professor level with a permanent W3 contract. Besides these professors, IN.TUM has classical associate professors (W2/C3) as well as full professors (W3/C4) with a chair, who have entered the department by appointment (cf. Figure 28).

<table>
<thead>
<tr>
<th>Org-Id</th>
<th>Denomination of chair</th>
<th>Professor (Emeritus)</th>
<th>Appointed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>Angewandte Softwaretechnik</td>
<td>Prof. Bernd Brügge (Manfred Paul)</td>
<td>1997</td>
</tr>
<tr>
<td>I2</td>
<td>Sprachen und Beschreibungsstruktufn in der Informatik</td>
<td>Prof. Helmut Seidl (Jürgen Eickel)</td>
<td>2003</td>
</tr>
<tr>
<td>I3</td>
<td>Datenbanksysteme</td>
<td>Prof. Alfons Kemper (Rudolf Bayer)</td>
<td>2004</td>
</tr>
<tr>
<td>I4</td>
<td>Software &amp; Systems Engineering</td>
<td>Prof. Alexander Pretschner (Manfred Broy)</td>
<td>2012</td>
</tr>
<tr>
<td>I5</td>
<td>Wissenschaftliches Rechnen</td>
<td>Prof. Hans-Joachim Bungartz (Christoph Zenger)</td>
<td>2004</td>
</tr>
<tr>
<td>I6</td>
<td>Robotics, Artificial Intelligence and Real-time Systems</td>
<td>Prof. Alois Knoll (Hans-Jürgen Siegert)</td>
<td>2001</td>
</tr>
<tr>
<td>I7</td>
<td>Algorithms and Complexity</td>
<td>Prof. Javier Esparza (Wilfried Brauer †)</td>
<td>2007</td>
</tr>
<tr>
<td>I8</td>
<td>Netzarchitekturen und Netzdienste</td>
<td>Prof. Georg Carle (Eike Jessen †)</td>
<td>2008</td>
</tr>
<tr>
<td>I9</td>
<td>Computer Vision and Artificial Intelligence</td>
<td>Prof. Daniel Cremers (Bernd Radig)</td>
<td>2009</td>
</tr>
<tr>
<td>I10</td>
<td>Computer Architecture and Parallel Systems</td>
<td>Prof. Martin Schulz (Arndt Bode)</td>
<td>2017</td>
</tr>
<tr>
<td>I11</td>
<td>Connected Mobility</td>
<td>Prof. Jörg Ott (Johann Schlichter)</td>
<td>2015</td>
</tr>
<tr>
<td>I12</td>
<td>Bioinformatik</td>
<td>Prof. Burkhard Rost</td>
<td>2009</td>
</tr>
<tr>
<td>I13</td>
<td>Application and Middleware Systems</td>
<td>Prof. Hans-Arno Jacobsen</td>
<td>2011</td>
</tr>
<tr>
<td>I14</td>
<td>Theoretische Informatik</td>
<td>Prof. Susanne Albers (Ernst Mayr)</td>
<td>2013</td>
</tr>
<tr>
<td>I15</td>
<td>Graphik und Visualisierung</td>
<td>Prof. Rüdiger Westermann</td>
<td>2002</td>
</tr>
<tr>
<td>I16</td>
<td>Informatik-Anwendungen in der Medizin</td>
<td>Prof. Nassir Navab</td>
<td>2003</td>
</tr>
<tr>
<td>I17</td>
<td>Wirtschaftsinformatik</td>
<td>Prof. Helmut Krcmar</td>
<td>2002</td>
</tr>
<tr>
<td>I18</td>
<td>Decision Science &amp; Systems</td>
<td>Prof. Martin Bichler</td>
<td>2003</td>
</tr>
<tr>
<td>I19</td>
<td>Software Engineering betrieblicher Informationssysteme</td>
<td>Prof. Florian Matthes</td>
<td>2002</td>
</tr>
<tr>
<td>I20</td>
<td>Sicherheit in der Informatik</td>
<td>Prof. Claudia Eckert</td>
<td>2008</td>
</tr>
<tr>
<td>I21</td>
<td>Logik und Verifikation in der Informatik</td>
<td>Prof. Tobias Nipkow</td>
<td>2011</td>
</tr>
<tr>
<td>I23</td>
<td>Sensorbasierte Robotersysteme und Intelligente Assistenzsysteme</td>
<td>Prof. Albu-Schäffer</td>
<td>2013</td>
</tr>
<tr>
<td>I25</td>
<td>Data Science and Engineering</td>
<td>Prof. Thomas Neumann</td>
<td>2017</td>
</tr>
<tr>
<td>I27</td>
<td>Robotics Science and System Intelligence (Joint Appointment EI/IN)</td>
<td>Prof. Sami Haddadin</td>
<td>2018</td>
</tr>
</tbody>
</table>

Figure 28: Full professorships (chairs, W3/C4) at IN.TUM.
Mechanical Engineering. Currently (as of June 2017), IN.TUM has 39 professorships (grades full professorships/chairs, associate professorships, and assistant professorships). Chair I23 is associated to DLR (lead by Albu-Schäffer).

The development in the number and type of professorships in the past 10 years is shown in Figure 35. With the introduction of the Tenure Track (TT) program in 2012, two new categories have been created, namely the W3 associate (cf. Figure 29) and the TT W2 assistant professor (cf. Figure 31).

The traditional W2 and C3 professorship (cf. Figure 30), and C4 professorships, are going to fade out with the retirements of the professors holding them.

<table>
<thead>
<tr>
<th>Org-Id</th>
<th>Denomination</th>
<th>Professor</th>
<th>Appointed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I15</td>
<td>Physics-based Simulation</td>
<td>Prof. Nils Thürey</td>
<td>2018</td>
</tr>
<tr>
<td>I24</td>
<td>Cyber Trust</td>
<td>Prof. Jens Großklags</td>
<td>2017</td>
</tr>
</tbody>
</table>

Figure 29: Associate professorships (W3) at IN.TUM.

<table>
<thead>
<tr>
<th>Org-Id</th>
<th>Denomination</th>
<th>Professor</th>
<th>Appointed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I5</td>
<td>Hardwarenahe Algorithmm und Software für Höchstleistungsrechnen</td>
<td>Prof. Michael Bader</td>
<td>2011</td>
</tr>
<tr>
<td>F13</td>
<td>Vernetzte Rechensysteme</td>
<td>Prof. Uwe Baumgarten</td>
<td>1994</td>
</tr>
<tr>
<td>I18</td>
<td>Algorithmische Spieltheorie</td>
<td>Prof. Felix Brandt</td>
<td>2010</td>
</tr>
<tr>
<td>I11</td>
<td>Programmierung und Anwendung verteilter Systeme</td>
<td>Prof. Anne Brüggermann-Klein</td>
<td>1994</td>
</tr>
<tr>
<td>I6</td>
<td>Informatik mit Schwerpunkt Telerobotik</td>
<td>Prof. Darius Burschka</td>
<td>2005</td>
</tr>
<tr>
<td>I10</td>
<td>Architektur paralleler und verteilter Systeme</td>
<td>Prof. Hans Michael Gerndt</td>
<td>2000</td>
</tr>
<tr>
<td>I5</td>
<td>Informatics / Scientific Computing</td>
<td>Prof. Thomas Huckle</td>
<td>1995</td>
</tr>
<tr>
<td>I16</td>
<td>Erweiterte Realität</td>
<td>Prof. Gudrun Klinker</td>
<td>2000</td>
</tr>
</tbody>
</table>

Figure 30: Classical associate professorships (W2/C3) at IN.TUM.

<table>
<thead>
<tr>
<th>Org-Id</th>
<th>Denomination</th>
<th>Professor</th>
<th>Appointed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I6</td>
<td>Cyber-Physical Systems</td>
<td>Prof. Matthias Althoff</td>
<td>2013</td>
</tr>
<tr>
<td>I12</td>
<td>Computational Biology</td>
<td>Prof. Julien Gagneur</td>
<td>2015</td>
</tr>
<tr>
<td>I3</td>
<td>Data Mining and Analytics</td>
<td>Prof. Stephan Günnemann</td>
<td>2016</td>
</tr>
<tr>
<td>I7</td>
<td>Formal Methods for Software Reliability</td>
<td>Prof. Jan Kretinsky</td>
<td>2017</td>
</tr>
<tr>
<td>I16</td>
<td>Bildbasierte biomedizinische Modellierung</td>
<td>Prof. Björn Menze</td>
<td>2013</td>
</tr>
<tr>
<td>I9</td>
<td>Dynamic Vision and Learning</td>
<td>Prof. Leal-Taixé Laura</td>
<td>2018</td>
</tr>
<tr>
<td>I15</td>
<td>Visual Computing</td>
<td>Prof. Matthias Nießner</td>
<td>2017</td>
</tr>
</tbody>
</table>

Figure 31: Tenure track assistant professorships (W2) at IN.TUM; S. Günnemann, B. Menze, and M. Nießner have been appointed in the so-called Rudolf Mößbauer program of TUM at IAS.
Affiliate memberships in and from other TUM departments

A considerable number of professors of other departments own an affiliate membership in IN.TUM and vice versa, reflecting the intense collaboration of IN.TUM with other TUM departments (cf. Figure 32).

### TUM Distinguished Affiliated Professors

The honorary title *TUM Distinguished Affiliated Professor* is awarded to leading international scientists at other universities who have significantly advanced a scientific area and developed long-term collaborations with their colleagues at TUM. This title is conferred by the President with approval by

<table>
<thead>
<tr>
<th>First membership in / affiliate membership in</th>
<th>Electrical and Computer Engineering / Informatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Uwe Baumgarten</td>
<td>Prof. Kurt Antreich (retired)</td>
</tr>
<tr>
<td>Prof. Arndt Bode (retired)</td>
<td>Prof. Klaus Diepold</td>
</tr>
<tr>
<td>Prof. Georg Carle</td>
<td>Prof. Jörg Eberspächer (retired)</td>
</tr>
<tr>
<td></td>
<td>Prof. Georg Fäber (retired)</td>
</tr>
<tr>
<td></td>
<td>Prof. Andreas Herkersdorf</td>
</tr>
<tr>
<td></td>
<td>Prof. Wolfgang Kellner</td>
</tr>
<tr>
<td>Informatics / Mathematics</td>
<td>Mathematics / Informatics</td>
</tr>
<tr>
<td>Prof. Felix Brandt</td>
<td>Prof. Roland Bulirsch (retired)</td>
</tr>
<tr>
<td>Prof. Hans-Joachim Bungartz</td>
<td>Prof. Jürgen Richter-Gebert</td>
</tr>
<tr>
<td>Prof. Daniel Cremers</td>
<td>Prof. Peter Gritzmann</td>
</tr>
<tr>
<td>Prof. Javier Esparza</td>
<td>Prof. Karl-Heinz Hoffmann (retired)</td>
</tr>
<tr>
<td>Prof. Thomas Huckle</td>
<td>Prof. Michael Ulbrich</td>
</tr>
<tr>
<td>Prof. Ernst W. Mayr (retired)</td>
<td></td>
</tr>
<tr>
<td>Prof. Christoph Zener (retired)</td>
<td></td>
</tr>
<tr>
<td>Informatics / Medicine</td>
<td>Medicine / Informatics</td>
</tr>
<tr>
<td>Prof. Björn Menze</td>
<td>Prof. Klaus A. Kuhn</td>
</tr>
<tr>
<td>Prof. Nassir Navab</td>
<td></td>
</tr>
<tr>
<td>Informatics / Management</td>
<td>Management / Informatics</td>
</tr>
<tr>
<td>Prof. Martin Bichler</td>
<td>Prof. Joachim Henkel</td>
</tr>
<tr>
<td>Prof. Helmut Krca</td>
<td>Prof. Rainer Kolisch</td>
</tr>
<tr>
<td>Informatics / Life Sciences</td>
<td>Life Sciences / Informatics</td>
</tr>
<tr>
<td>Prof. Burkhard Rost</td>
<td></td>
</tr>
<tr>
<td>Informatics / Education</td>
<td>Education / Informatics</td>
</tr>
<tr>
<td></td>
<td>Prof. Maria Bannert</td>
</tr>
<tr>
<td></td>
<td>Prof. Peter Hubwieser</td>
</tr>
<tr>
<td>Informatics / Architecture</td>
<td>Architecture / Informatics</td>
</tr>
<tr>
<td></td>
<td>Prof. Frank Petzold</td>
</tr>
<tr>
<td>Informatics / Governance</td>
<td>Governance / Informatics</td>
</tr>
<tr>
<td></td>
<td>Prof. Simon Hegelich</td>
</tr>
<tr>
<td></td>
<td>Prof. Jürgen Pfeffer</td>
</tr>
</tbody>
</table>

Figure 32: Affiliate memberships.
the TUM Extended Board of Management and the TUM Senate. TUM Distinguished Affiliated Professors become members of the departments putting forth their nominations. Joint appointments of several faculties are possible.

TUM Distinguished Affiliated Professors at IN.TUM are:

- Prof. Dr. Lawrence C. Paulson, professor of Computational Logic at the University of Cambridge. His appointment in 2006 documents his long-term and close collaboration with IN.TUM and specifically with the Theorem Proving Group. The most visible outcome of this joint work is the theorem prover Isabelle.

- Prof. Dr. Dr. h.c. August Wilhelm Scheer. He was appointed in 2011 for his pioneering work in Information Systems especially in modelling data, processes, and performance, his achievement as an entrepreneur, his impressive work in connecting science, business and politics and for his commendable patronage. Since then, he has been intensively involved in the department's Graduate Center.

Former professors

A timeline of all professorships at IN.TUM since the very beginning of Informatics at TUM in 1967 is given in the appendix.

<table>
<thead>
<tr>
<th>Org-Id</th>
<th>Professor</th>
<th>Area of expertise</th>
<th>Appointed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I4</td>
<td>Prof. Dr.-Ing. Dr.-Ing. e.h. Hans-Hermann Braess</td>
<td>Technologiemanagement</td>
<td>1992</td>
</tr>
<tr>
<td>I4</td>
<td>Prof. Dr.-Ing. Ernst Denert</td>
<td>Software Engineering</td>
<td>1991</td>
</tr>
<tr>
<td>I10</td>
<td>Prof. Dr. Friedrich Hertweck</td>
<td>Rechnernetze, Betriebssysteme, Parallelrechner</td>
<td>1973</td>
</tr>
<tr>
<td>I6</td>
<td>Prof. Dr.-Ing. Gerhard Hirzinger</td>
<td>Robotik</td>
<td>1991</td>
</tr>
<tr>
<td>I4</td>
<td>Prof. Dr. Karl-Rudolf Moll</td>
<td>Informatik-Management</td>
<td>1996</td>
</tr>
<tr>
<td>I8</td>
<td>Prof. Dr.-Ing. Peter Müller-Stoy</td>
<td>Rechnerarchitektur</td>
<td>1990</td>
</tr>
<tr>
<td>I5</td>
<td>Prof. Dr. Frank Jenko</td>
<td>Computational Physics</td>
<td>2018</td>
</tr>
<tr>
<td>I9</td>
<td>Prof. Dr.-Ing. Walter Proebster</td>
<td>Computertechnik und -netze</td>
<td>1995</td>
</tr>
<tr>
<td>I7</td>
<td>Prof. Dr. Thomas Runkler</td>
<td>Maschinelles Lernen</td>
<td>2011</td>
</tr>
<tr>
<td>I4</td>
<td>Prof. Dr.-Ing. Dr.h.c. multi. Heinz Schwärtzel</td>
<td>Informatik</td>
<td>1991</td>
</tr>
<tr>
<td>I9</td>
<td>Prof. Dr. Carsten Steger</td>
<td>Bildverstehen</td>
<td>2011</td>
</tr>
</tbody>
</table>

Figure 33: Honorary professors at IN.TUM.
6 Infrastructure and Facilities

6.1 Room resources

The building of the Departments of Mathematics and Informatics (FMI) is located on the Garching campus at Boltzmannstrasse 3. This building is equipped with a small canteen, open from 7am to 7pm. The part of the building that is occupied by IN.TUM consists of rooms for teaching, for researchers and technical assistance, and for the administration: Dean's Office, Academic Programs Office, Service Offices for Personnel, Student Assistants, Finance, and Space, IT Unit RBG, and the Departmental Student Council. Because of the growth of the department, it was necessary to relocate parts of the department and establish satellites located (1) in Parkring 13 as well as (2) Schleissheimerstrasse 90a, both located in Garching-Hochbrück.

The vast majority of both research and teaching in informatics takes place in the main building, newly built in 2002. There are 3 large lecture halls seating 550, 98, and 98, respectively, and several smaller classrooms seating 10 to 40 students. In parts, these rooms are also used for labs and are therefore not entirely devoted to tutorials or smaller lectures. Further teaching takes place outside the building in other departments (predominantly Mechanical Engineering and Chemistry because of the large existing lecture halls), and in the interim building with two large lecture halls close to the main building. In cases where one large single lecture hall cannot seat all students, we regularly perform live video streaming in other lecture halls on campus. Students use the library and single special rooms to study individually and often express the desire for more private space of this kind, which has been taken up by the university’s management in deciding to build a new building on campus exclusively for students’ purposes.

With the exception of two groups, or subgroups of the department that have been relocated to Garching-Hochbrück, all researchers’ offices are located in the main building. Room allocation is administered by the department itself on the grounds of a “breathing” system: space is dynamically allocated based on need, and equally dynamically retracted if necessary. To this end, we have agreed on the minimum space that different employees are entitled to, based on their area of work (e.g., technicians tend to need more space) and also seniority. Using the number of full-time equivalent (FTE) persons employed within one group, which is provided by the Service Office for Personnel, we compute the space that each group is entitled to on a monthly basis, according to the allocation formula decided by IN.TUM. On these grounds, space is dynamically reassigned when needed. We see the major challenge to be the avoidance of fragmentation.

The growth of the department made it necessary in the past to turn former meeting rooms into offices, and to drastically reduce the number of rooms for exclusive use by student assistants. Given the growth of our department, we are happy to observe that this compactification has made it possible to only split off comparatively small parts of the department to other locations. In the future, we will need to sustain these satellites; we will need to relocate students’ individual learning activities to the above-mentioned student building as well as the
newly built building for Electrical and Computer Engineering; we are currently also working on acquiring external funding to extend our main building (see Section 3.5.2).

6.2 Academic administration (Servicebüros)

The two Departments of Informatics and Mathematics have service offices, some of them even jointly for both departments, in which administrative tasks of the departments are bundled centrally for all chairs of the department (23 in Informatics, 17 in Mathematics).

The following service offices are organized by task areas:

- **Academic Programs Office** (SB-S-IN and SB-S-MA),
- **Service Office for Personnel** (SB-P, jointly for Informatics and Mathematics),
- **Service Office for Student Assistants** (SB-Z, jointly for Informatics and Mathematics),
- **Service Office for Finance** (SB-F-IN and SB-F-MA),
- **Service Office for Space** (SB-R, jointly for Informatics and Mathematics).

The service offices SB-P, SB-Z and SB-R cover all administrative tasks in the respective areas of both departments. SB-S-IN and SB-S-MA as well as SB-F-IN and SB-F-MA cover all administrative tasks from their areas, but they work closely together and are also located spatially adjacent.

The department-wide or the cross-department bundling of these tasks offers, among other things, the following advantages:

- greater competence and experience of service workers,
- ‘economy of scale’ with simultaneous proximity to the ‘customers’,
- uniform processes and software systems throughout the department resp. both departments,
• simple interfaces between departments and central administration of TUM,
• improved compliance with external regulations and guidelines (TUM, laws, etc.),
• lower licensing and training costs as well as bundling of know-how in the use of relevant software systems (SAP, TUMonline, etc.),
• optimized use of staff and financial resources allocated by the university,
• consequent implementation of the 4-eyes principle,
• reduction of scientific staff with administrative tasks.

**Academic Programs Office (SB-S-IN) in Informatics**

The Academic Programs Office supports the Dean of Studies in all organizational and administrative aspects of teaching, quality management and academic study advising. Moreover, it is centrally responsible for the management of examinations and serves as executive body of the departmental examination boards. Structure and tasks of the Academic Programs Office are described in detail in Section 2.4. In 2016, the SB-S-IN was staffed with a total of about 12.3 full-time equivalent employees across all levels of qualifications.

**Service Office for Personnel (SB-P) in Informatics and Mathematics**

The SB-P deals with all the positions and personnel issues of the scientific staff (about 390 in Informatics and about 160 in Mathematics) and non-scientific staff (about 125 in Informatics and about 40 in Mathematics) of the 40 chairs of both departments in close cooperation with the personnel department of the TUM.

This includes in particular the following processes:

• personnel procedures: Job advertisements and management of applications, new appointments, tariff classifications, onboarding of new employees, administration of absences (vacation, illness, etc.), flexitime administration for non-scientific staff, data collection for the administration of teaching obligations, working time agreements, user agreements with guests, job references, appointments and promotions of officials, administration of annual interviews with employees, administration of dissertations, contract extensions, administration of service end, etc.,
• position mangement: Position planning, position capitalization, position placement, administration of appointment committments, etc.,
• advising the chairs on the application and cost calculation of third party funding projects,
• further activities like remuneration for lectureships, subcontracted works, maintenance of intranet, etc.

The following incomplete table gives just some examples for the number of transactions processed in the SB-P in 2016 (only Informatics without Mathematics):

<table>
<thead>
<tr>
<th>Transactions</th>
<th>Cases in 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>advertisements of vacancies (only non scientific)</td>
<td>24</td>
</tr>
<tr>
<td>applications for employment</td>
<td>441</td>
</tr>
<tr>
<td>new hires</td>
<td>163</td>
</tr>
<tr>
<td>extensions of employment contracts</td>
<td>617</td>
</tr>
<tr>
<td>exits and job references</td>
<td>157</td>
</tr>
<tr>
<td>accounting of positions</td>
<td>772</td>
</tr>
<tr>
<td>vacation events</td>
<td>4,522</td>
</tr>
<tr>
<td>user agreements with guests</td>
<td>385</td>
</tr>
<tr>
<td>lectureships</td>
<td>41</td>
</tr>
<tr>
<td>etc.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 36: Cases processed by SB-P in 2016.

For the described tasks in Informatics 4 full-time equivalent employees are available at the SB-P.

**Service Office for Student Assistants (SB-Z) in Informatics and Mathematics**

The Service Office for Student Assistants, SB-Z, completely handles all administration tasks in connection with student employment contracts for the 40 chairs of both departments.
The SB-Z is responsible for the efficient and correct execution of the following tasks at both departments:

Preparation of student employment contracts, management of personnel files for assistants, verification of the equivalence of foreign degrees, administration and controlling of the relevant funds of the institutes, exchange of data with the "Landesamt für Finanzen" responsible for payroll accounting, and maintenance of all relevant data in the SAP-installation of TUM. In 2016 about 1,700 assistant contracts were processed for both departments with about 3.3 full-time equivalent employees in SB-Z.

Service Office for Finance (SB-F-IN) in Informatics

The Service Office for Finance, SB-F-IN, is a service facility of the department, which manages the efficient use of the budget allocated by the university and the payment transactions and accounting of all third party funded projects at the department. The Department of Mathematics has its own Service Office for Finance, SB-F-MA, with an analogous structure and an analogous task portfolio. Both service offices closely cooperate.

The SB-F-IN is responsible for the efficient and correct execution of the following tasks for all chairs at the department:

- budget management,
- processing of all invoices of the department: internal, TUM internal, and external,
- preparation, booking, and sending of invoices national and international, accounting of donations, control of payment receipts,
- pre- and post-processing of asset accounting and inventory,
- support for dedicated means of professors,
- support for the management of third party projects, establishment of industrial project accounts, establishment of publicly funded project accounts, preparation of intermediate and final use reports for the funding institutions, calculation and execution of the requests for funds in accordance with the specification of the funding institutions and the project managers, compensation and closure of project accounts,
- approval of non-regular special expenses of the department,
- advising the chairs on application for funding and on legal and tax issues,
- support of internal and external revisions.

The number of booking transactions made in SAP is only a small part of the task portfolio of the SB-F-IN, but still it provides at least a certain measure for the efficiency. In 2016, the number of booking transactions in SAP was around 24,700 with 7.1 full-time equivalent employees in SB-F-IN.

Service Office for Space (SB-R) in Informatics and Mathematics

The Service Office for Space, SB-R, organizes the efficient use of the teaching and work space provided by the university and carries all related administrative tasks for both departments such as:

- space allocation to units (space file),
- planning of room allocation,
- administration of room equipment,
- distribution and return of keys and transponders,
- maintenance of key and closing plan,
- administration of telephone accounts (lists, billing and changes),
- copiers (contracts, billing, maintenance),
- support of showcases,
- planning and support of major events,
- support of in-house mail service.

The SB-R handles these tasks for the entire staff of both Departments of Informatics and Mathematics and it is staffed with one employee.
6.3 IT unit RBG (Informatics and Mathematics)

The two Departments of Informatics and Mathematics maintain a joint IT unit, the "Rechnerbetriebsgruppe" (RBG). The RBG, also located in the FMI building, provides both departments with an extensive IT environment, covering the complete range from networks (wired and wireless), operation of a high-availability server infrastructure up to user-centric IT services and client management. Multimedia-related IT services are also part of the RBG's service portfolio, as are services and support in hardware procurement and software licensing. Many IT services provided by the RBG are tailored towards, or even custom-developed according to the specific needs and requirements of research and studies at both departments. In detail, the RBG provides the following service groups and services:

IT infrastructure and IT services

- LAN operation in all buildings used by the two departments (inside the FMI building: all glass fiber-based network – “fiber to the desk”), currently offering 1 Gbit connectivity in every office, 10 up to 40 Gbit connectivity in backbone networks.
- Wireless LAN operation in all buildings used by the two departments (approximately 200 deployed access points, up to 7,500 active devices in the WLAN per day).
- Operation and maintenance of the complete network infrastructure (switches, routers, WLAN-controllers, VPN-servers for high bandwidth tunnels to the external buildings used by both faculties). The network infrastructure offers a high degree of flexibility in provisioning virtual LANs for research groups, projects and teaching activities, with customizable levels of (optionally predefined) security settings and optional VPN access.
- Operation of an uninterruptible power supply (UPS) sufficiently dimensioned to ensure continuous availability of networks, servers, and cooling system, to bridge unanticipated power outages.
- Server housing for hardware operated by chairs and research groups of both departments.
- Operation of a redundant, physically distributed virtual storage network, to which all storage-related services are mapped.
- Operation of a redundant, physically distributed VMware ESX cluster, which currently hosts approximately 700 virtual machines running Linux and Windows Server. Most of the 700 virtual machines are operated by users (researchers) of the two departments. These virtual machines enable users to implement IT services specific to their research or teaching requirements without the need to maintain their own server and/or storage hardware.
- Storage services for chairs and research groups (“home servers”, via NFS and SMB), including automatic backup, and network backup services for client computers.
- Integrated identity-, host-, and network-management, including a local registration authority, to issue and maintain user and server certificates.
- Operation and maintenance of a high availability e-mail system, including sophisticated spam and malware protection and prevention mechanisms.
- Print service for the multi-function copier/printer systems operated at both departments, featuring a fine-grained accounting scheme for print jobs.
- Development and operation of a centrally managed smart client infrastructure to operate approximately 300 client computers running Linux, Windows, or both in combination.
- Operation of an IT help desk (staffed by working students) to provide first-level IT support for all users in both departments.
The given lists outline the most important services the RBG provides primarily for the two Departments, partially also for all departments of TUM. The RBG provides its service portfolio embedded into the framework of IT services available from the LRZ and the IT Service Center (ITSZ) at TUM, and in close coordination with these institutions. Both departments have a number of specific requirements with regard to their IT infrastructure: In contrast to many other departments at TUM these two departments are very much focused towards open source software and operating systems. Consequently, Linux is, to a high degree, the preferred operating system, even for client systems. This in turn requires a specific landscape of IT infrastructure services for Linux systems, which is provided by the RBG.

The RBG is currently in the process of an internal reorganization, which aims at gaining more internal resources to develop user-centered IT services, specifically driven by the needs of researchers and lecturers in Mathematics and Informatics. Examples include general collaboration and project management services to support software development activities, management of software development repositories, or “DevOps” infrastructures for continuous development and delivery of IT systems and services. The IT infrastructure operated by the RBG plays a key role in the ongoing digital transformation process of both departments. In 2016, the RBG was staffed by both departments with a total of about 26 full-time equivalent employees over all levels of qualifications.

6.4 Public relations

In general, it is the job of the Public Relations (PR) staff of IN.TUM to keep the department in communication with certain target groups. With respect to internal communications, this includes groups like bachelor’s and master’s students, doctoral students, and department employees.
PR keeps them informed, either regularly or as needed, about goings on within the department via media like the newsletter “in.tum.quarterly” and the Intranet. Events like our annual Summer Party serve to encourage communication between students and employees and to bring both groups closer together within the department.

In terms of external communications, PR maintains contact with the wider public, the scientific community, industrial partners, funders of research, and the press. To increase the efficiency of PR undertakings, the department works closely with TUM central organizational bodies like the Corporate Communications Center and the Alumni & Career Center. School students, parents, and teachers are attended to by the School-University Interface organization with support from PR.

The goal of PR at IN.TUM is to make sure that the enormous productive capacity of IN.TUM in the fields of research and teaching is portrayed fully and accurately and therefore to continue to increase the department’s recognition and maintain its positive image.

PR contributes to IN.TUM’s ability to apply for external funding. Additionally, it helps to maintain the quality of the ever-increasing number of students at the highest possible level. Maintaining a representation at highly frequented online portals that detail the courses of study offered also falls under the purview of PR, along with the publication of brochures with information on courses of study, maintaining the department website, and overseeing the Facebook page with over 6,000 “friends” as part of the measures to deliver relevant content. In order to inform students about their job prospects after graduation, PR has developed approaches to recruiting and sponsoring. The process of contacting graduates and students is made easier for businesses looking for employees in the IT field through the sponsoring activities undertaken for events like the graduation celebration, Summer Party, Hackathon, and career fairs.

6.5 Show-Lab ITüpferl – Bits@Work

The ITüpferl is an interactive laboratory, a research workshop, and a museum all at the same time, and it is open to visitors to IN.TUM. Whether for alumni, industry partners, scientists, or university/school students – IN.TUM presents modern Informatics research to its visitors in this research workshop. Scientists from a research unit work at the ITüpferl on cutting edge topics and show visitors applications and demonstrations from their research projects. The academic chairs that present their projects change on a yearly basis. This means for example that students have the chance to become familiar with the diversity of research possibilities early on and can more easily decide what sort of research work they would like to do in later terms.

The following groups have been active in the research workshop to date:

- Chair of Applied Software Engineering, B. Brügge,
- Chair of Computer-Aided Medical Procedures, N. Navab,
- KAUST Virtual Arabia Project: A. Bode, H.-J. Bungartz, G. Klinker, E. Rank (BGU), R. Westermann,
- Associate Professorship of Augmented Reality, G. Klinker,
- Chair of Robotics and Embedded Systems, A. Knoll.
The *ITüpferl* also has a museum section on the history of Informatics. The displayed items are mainly from the 70s and 80s and they show, amongst other things, that early concepts in Informatics are still valid today. Exhibited items include an early desktop computer and various generations of hard drives.

Besides a research workshop and a history museum, the *ITüpferl* serves as an interactive laboratory in which groups of visitors can work together. Above all, groups of school students can participate in workshops and other interactive programs, experience Informatics, and learn in a playful way.

### 6.6 Library (Informatics and Mathematics)

The branch library for the two departments is located in the department building and offers work space, printed literature (books, journals, etc.) and online services for all students and members of the Departments of Mathematics and Informatics. In addition to desk space for reading and working for 192 students, 38 workstations are provided to students for online literature research and e-publications on the three floors of the library. Five meeting rooms, equipped with whiteboards (some with touch screens) can be reserved by students for group work. The library is open seven days a week, until midnight on weekdays.

TUM University Library offers more than 40,000 textbooks and monographs in Informatics. In addition, TUM’s central textbook collection in Garching offers more than 10,000 copies (more than 1,000 titles) to be borrowed by students and researchers. In the last years, the range of e-books offered has been systematically extended, and now includes among others the Safari Tech Books Online (35,000 e-books) and the relevant German-language Springer series. Lecturers can request a term collection of reference copies, to ensure that literature for their course is available to students at least for inspection. To train students and researchers in research strategies, how to manage literature and references, and similar skills, the library staff offers an extensive series of courses and seminars on these topics.

The department receives an annual budget of currently approx. 75,000 € from TUM for scientific journals and proceedings. In the last years, the department usually managed not to increase expenses beyond this budget. The access numbers to subscribed journals and individually purchased articles are closely monitored, in order to identify contracts that should be discontinued, but also to spot demand for new journals. Subscriptions are typically shared with other departments for more cost-efficient bundled subscriptions, and the department also profits from Germany-wide initiatives for subscription of key journals.
7 Support of Young Scientists

A prime mission of IN.TUM is to support young scientists so that they become mature researchers in a competing international environment. Students, doctoral candidates as well as postdoctoral scholars are integrated directly into ongoing research activities. In fact, much of the department’s excellent research is carried out by young scientists.

Bachelor’s and master’s students, in addition to opportunities at the chairs, have the chance to attend the Ferienakademie (Summer Academy). This annual two-week summer school has been held in South Tyrol since 1984. It is organized jointly by TUM, the Friedrich-Alexander University Erlangen-Nürnberg, and the University of Stuttgart; IN.TUM takes the lead in the organization. Participants can choose from a broad spectrum of research-oriented courses and work intensively with the lecturers (cf. Section 2.9). Moreover, for outstanding students, IN.TUM maintains a program best.in.tum that promotes the best two percent of the students. The program includes, for instance, the following support: (1) assignment to a chair of the student’s choice so (s)he can get early insight into current and open issues in informatics research; (2) nomination for the central TUM promotion program TUM: Junge Akademie (Young Academy) with its focus on interdisciplinarity, soft skills, and personality development; (3) special courses such as Gems of Informatics; (4) special support in planning external studies or internships in Germany and abroad.

A privilege of universities is to grant doctoral degrees. Over the past years, the doctoral education in Germany and Europe has undergone some changes. The classical training, focusing exclusively on thesis research, has been criticized for not providing all the skills and qualifications necessary to succeed in a future work environment. In response, IN.TUM has established and maintains CeDoSIA (Center for Doctoral Studies in Informatics and its Applications), that provides its doctoral candidates with a structured and interdisciplinary training program; details are given in Section 2.7.1.

CeDoSIA is one of the 25 Graduate Centers at TUM and, as such, part of TUM Graduate School (cf. Section 2.1).

Last but not least, IN.TUM is proud to host postdoctoral researchers and junior research group leaders. These colleagues have already achieved a certain independence so that less general guidance is necessary. An individual, specifically-tailored mentoring is provided by the chairs hosting the scholars.

7.1 Doctoral researchers

We describe CeDoSIA and report on the population of doctoral students and conferred degrees.

CeDoSIA trains doctoral candidates in Informatics and its applications to achieve excellent research results within the international research community. To this end CeDoSIA provides a structured, yet flexible interdisciplinary education addressing research methodology, philosophy of science, research project management, and soft skills. The training program complements the individual research work of a doctoral candidate and prepares him/her to succeed in a wider employment market in academia or industry. It is worth noting that CeDoSIA was founded prior to the establishment of the TUM-GS.

All doctoral candidates in Informatics, independent of their financial funding scheme, become a member of CeDoSIA. The only exception are candidates who choose to join a Thematic Graduate Center such as the International School of Science and Engineering (IGSSE) or the Graduate School of Bioengineering (GSB). An enrollment in CeDoSIA is strongly recommended right at the beginning of the doctoral studies. Every CeDoSIA member is a member of the TUM-GS. Master’s students can
also become preliminary members of CeDoSIA; a professor has to recommend the respective admission.

Once enrolled in CeDoSIA a doctoral candidate — beside his/her dissertation work — passes a structured training, consisting of three or four years. The general structure is depicted in the figure above. The first year is devoted to research foundations, where a doctoral candidate gains an interdisciplinary view of the scientific foundations of Informatics. Furthermore, the candidate and his/her advisor sign a supervision agreement. He/she attends a kickoff seminar and courses on research methods. The second year provides candidates with the skills to manage their research projects. A doctoral candidate must pass an interim evaluation, typically consisting of a presentation and an in-depth feedback session with the advisor. He/she receives an individual coaching regarding the publication of achieved research results. During the second year of training the candidate is also expected to attend two interdisciplinary courses. The following two years foster individual excellence. A doctoral candidate focuses on research work. This may include an international research phase that is also financially supported by CeDoSIA. The candidate attends three further interdisciplinary courses. Towards the end of the doctoral work, he/she participates in a final seminar. In total, six term hours of subject-related courses must be completed. As a minimum requirement, each graduate must publish at least one paper in an international conference or journal. A detailed description of the CeDoSIA elements is presented in the next section.

CeDoSIA is widely accepted among the doctoral candidates who enjoy the training program. The enrollment has grown steadily over the past years. Figure 37 shows the statistics as of December 2016. At that time, CeDoSIA had 384 members. They represent 9% of the members of the entire TUM-GS. The number is comparable to that of the Department of Electrical and Computer Engineering, the Department of Physics, the Department of Chemistry, and the TUM School of Medicine. Only the Department of Mechanical Engineering and TUM School of Life Sciences have significantly more doctoral candidates registered through their Graduate Centers. In IN.TUM about 17% of the doctoral candidates are women. The average over all departments at TUM is 33%. Furthermore 40% of the CeDoSIA members come from abroad. Over all TUM departments the average is 28%. This confirms that IN.TUM attracts a considerable number of international doctoral candidates.

<table>
<thead>
<tr>
<th>Research Foundations</th>
<th>Research Management</th>
<th>Individual Excellence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervision Agreement</td>
<td>Interim Evaluation</td>
<td>International Research Phase</td>
</tr>
<tr>
<td>Kickoff Seminar</td>
<td>Publication Coaching</td>
<td>3 Interdisciplinary Courses</td>
</tr>
<tr>
<td>Research Methods</td>
<td>2 Interdisciplinary Courses</td>
<td>Final Seminar</td>
</tr>
</tbody>
</table>

The CeDoSIA training.

| Year 1 | Year 2 | Years 3 and 4 |

Figure 37: Doctoral candidates in Informatics in 2016. (Source: IN.TUM)
Curriculum of CeDoSIA

CeDoSIA comprises a broad spectrum of elements. First of all, a large variety of courses and seminars is offered in the following three areas.

Foundations. This area addresses the methodological and theoretical fundamentals, with emphasis on informatics and related disciplines such as information systems. The following seminars have been offered on a regular basis:

- Modern aspects of philosophy of science in informatics and its applications (K. Mainzer, e.g. winter 2017),
- Research methods in informatics and its applications (H. Krcmar, e.g., fall 2016).

Multidisciplinary and Future Theme Studies. This area offers many seminars on current, multidisciplinary topics and future challenges in the field of Informatics. The doctoral candidates can broaden their scope beyond disciplinary confines. Due to space constraints, only some selected events are listed here:

- Economics and computation (F. Brandt, 2017),
- 2013 Nobel Prizes in chemistry for computational work (B. Rost, 2016),
- Internet multimedia (J. Ott, 2016),
- Do-it-yourself (DIY) networking (J. Ott, 2016),
- Interactive theorem proving: The Isabelle perspective (T. Nipkow, 2016),
- In-memory data(base) processing (A. Kemper, 2016).

Research and Training. This area provides the necessary fundamentals for scholarly work and training. It focuses on both the communication of research ideas and possible existing deficiencies in the candidates’ competencies. The workshops and seminars integrate research and teaching aspects in scientific work:

- Fit for graduation: Success strategies for earning a doctoral degree (Dr. Jürgens, 2017),
- Fit for scientific publishing (Dr. Weinl and Ms. Bäcker, 2017),
- Fit for advising: supervising excellent bachelor’s and master’s theses (Dr. Jürgens, 2017),
- Fit for presenting at international scientific conferences (Prof. Wagner, 2016),
- Fit for visibility and impact in research (Dr. Weinl and Ms. Bäcker, 2017),
- Designing and writing a grant proposal (Prof. Seidl, 2015).

In addition to the listed courses and seminars, CeDoSIA also includes more individual elements.

Proofreading Support. Before submitting a paper to a conference or journal, a doctoral candidate may send it to a native English speaker who is familiar with scientific publishing. The service is free of charge.

Internationalization Support. Doctoral students are encouraged to spend a research stay abroad as part of their dissertation work. CeDoSIA provides financial support for such international visits.

Last but not least, CeDoSIA offers two highlight elements.

Top Speakers Series. This series was initiated in 2014 and features extremely distinguished lecturers from science, industry, and politics. CeDoSIA is proud that the following speakers have given presentations so far:

- Bill McDermott, CEO SAP, September 2016,
- Prof. Dr. Siegfried Russwurm, CTO Siemens AG, May 2016,
- Prof. Dr. Dr. h.c. mult. Kurt Mehlhorn, Director MPI for Informatics, January 2016,
- Prof. Dr. Dr. h.c. mult. August Wilhelm Scheer, Scheer Group, July 2015,
- Prof. Dr. Dr. h.c. Monika Henzinger, University of Vienna, January 2015,
- Prof. Dr. h.c. Hasso Plattner, SAP, July 2014.
Visit the Lab. CeDoSIA organizes excursions to important scientific locations. So far, visits to Google Lab Zurich (2016), CeBIT (2015), and CERN (2014) have taken place.

The CeDoSIA training program is supervised by two directors, currently H. Krcmar (director) and S. Albers (vice director). W. Wörndl acts as managing director. Until September 2015, E. Mayr was director of CeDoSIA. M. Sayih served as managing director until April 2017. Moreover, CeDoSIA has a scientific advisory board consisting of four further faculty members (currently A. Bode, A. Kemper, G. Klinker, and A. Pretschner).

Completed Doctoral Degrees

For several years, IN.TUM has been conferring an increasing number of doctoral degrees, with a current peak of 94 in 2016. Figure 38 gives a survey of the completed degrees in the years 2012 to 2016. The conclusions are similar to those made for the doctoral candidates. The number of graduations in IN.TUM represents about 8% of the total number of graduations at TUM. The number is comparable to that in the Department of Electrical and Computer Engineering, the Department of Physics, and the Department of Chemistry. Only the TUM School of Medicine, the TUM School of Life Sciences, and the Department of Mechanical Engineering confer more degrees annually. In IN.TUM about 10% of the doctoral degrees are earned by female scientists. The percentage has increased over the last two years. About 25% of the degrees are conferred to international doctoral candidates. The average over all departments at TUM is 18-20%.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Male</th>
<th>Female</th>
<th>National</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>60</td>
<td>53</td>
<td>7</td>
<td>44</td>
<td>16</td>
</tr>
<tr>
<td>2013</td>
<td>82</td>
<td>77</td>
<td>5</td>
<td>65</td>
<td>17</td>
</tr>
<tr>
<td>2014</td>
<td>66</td>
<td>61</td>
<td>5</td>
<td>48</td>
<td>18</td>
</tr>
<tr>
<td>2015</td>
<td>83</td>
<td>69</td>
<td>14</td>
<td>56</td>
<td>27</td>
</tr>
<tr>
<td>2016</td>
<td>94</td>
<td>83</td>
<td>11</td>
<td>73</td>
<td>21</td>
</tr>
</tbody>
</table>

Figure 38: Conferred doctoral degrees in Informatics 2012-2016. (Source: IN.TUM)

7.2 Postdoctoral researchers

Habilitations. The career paths for postdoctoral scholars seeking a permanent position in academia have changed over the past years. The colleagues gain independence at an earlier stage in their career by heading a junior research group and/or by holding a Tenure Track Professorship. Nonetheless, IN.TUM still confers a number of habilitation degrees, as depicted in Figure 39 for the years 2012
to 2016. Not surprisingly, most of the habilitations are earned by male, German scientists. Again, IN.TUM confers about 8% of the habilitations awarded at TUM.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Male</th>
<th>Female</th>
<th>National</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2013</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2014</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2015</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2016</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 39: Habilitations in Informatics 2012-2016. (Source: IN.TUM)

**Independent Junior Research Groups**

IN.TUM always hosts a number of junior research groups. In recent years, they were headed by the following colleagues:

- C. Grothoff was junior research group leader, funded by the Emmy Noether Program of the German Research Foundation, from 2009 to 2014. He led the *Free Secure Network Systems Group*, affiliated with Chair I8 (Network Architectures and Services). Since 2014 Christian Grothoff has been Team Leader at INRIA DÉCENTRALISÉ, Rennes, France.

- S. Günnemann was junior research group leader, funded by the Emmy Noether Program of the German Research Foundation, from July 2015 to September 2016. The project, entitled *Robust Data Mining of Large-Scale Attributed Graphs*, was affiliated with Chair I3 (Database Systems). Since October 2016, Stephan Günne mann has been Rudolf Mößbauer Tenure Track Professor for *Data Mining and Analytics*.

- M. Heinig has been junior research group leader for *Genetic and Epigenetic Gene Regulation* at the Institute of Computational Biology, Helmholtz Zentrum München, since 2015. The group was affiliated with Chair I12 (Bioinformatics).

- C. Plant has led the junior research group *iKDD (Integrative Knowledge Discovery in Database)* in the Scientific Computing Research Unit, Helmholtz Zentrum München, from April 2013 to December 2015. The group was affiliated with Chair I3 (Database Systems). Since January 2016, she has been Professor for Data Mining at the University of Vienna.

- A. Simon was junior research group leader, funded by the Emmy Noether Program of the German Research Foundation, from 2009 to 2014. The group was affiliated with Chair I2 (Formal Languages, Compiler Construction and Software Construction). Since 2014, Alex Simon has been Senior Researcher at Google.

Other examples from former years are T. Fuhrmann, R. Jakob, M. Sachenbacher, A. Stamatakis, and C. Urban.

Graduates (PhD and habilitation) at IN.TUM in December 2016.
8 Diversity, Equality, and Internationalization

IN.TUM is committed to equality and equal opportunity across all diversity dimensions as a vital strategy that leverages our innovative qualities and our status of excellence in research and teaching. We address diversity dimensions such as gender, disability and special needs, social-economic and educational background, family and care responsibilities, and international status, but also non-traditional dimensions such as previous knowledge of incoming students.

Our goal across all diversity dimensions is an inclusive climate that is carried by mutual respect and appreciation among all groups in the department and that brings out the best in each individual member. We build engagement for and commitment to change throughout the department through processes that ensure consensus and cooperation. We guard against cultural mechanisms that may cause feelings of not belonging (imposter syndrome, stereotype threat).

A target agreement on diversity (linked from http://www.in.tum.de/en/current-students/equal-opportunities.html) and guidelines on internationalization (linked from http://www.in.tum.de/en/international-affairs.htm) codify our commitment. A large number of innovative and effective programs and initiatives that further awareness, inter-cultural competence, interaction, and integration fill it with life.

There are a number of indicators for successful inclusion across diversity parameters, both quantitative and qualitative ones. We trust that hard quantitative indicators of equal participation and inclusion, that cannot be influenced directly, will automatically evolve in a positive direction through our culture-sensitive strategy.

The remainder of this section describes general initiatives for a vivid and inclusive campus life. In each section, we explain, where appropriate, how its topic ties into the departmental structure and what specific principles and strategies apply; we also list prominent initiatives and activities.

8.1 Gender

The stated IN.TUM diversity strategy ties equal opportunity into departmental mission and vision statements. The strategy to address un-equal participation of women and men is built on the premise that differences between women and men in areas that are relevant in academia (choice of study program, academic performance and advancement in a study program or in scientific research) are most convincingly explained not by inherent differences between women and men but by cultural or social mechanisms. Keywords are gender expectations and gender bias, stereotypes, token syndrome, glass ceiling, and glass cliff. This evidence-based model that is backed by research in social psychology and related fields generalizes to explain and to provide a handle for any kind of under-representation, not just for that of women in technical fields.

Institutional commitment

Members of IN.TUM have been Gender Equality Officers at TUM level (main officers and deputies) for many years. Under their leadership, the cultural or sociological perspective on phenomena of inequality has been introduced and continuously strengthened; on the practical side, the Agentur Mädchen in Wissenschaft und Technik, which is now integrated into the central Student Services Unit of TUM, SSZ, has been founded. IN.TUM has been the first department at TUM to elect Gender Equality Officers at the departmental level and has always had strong and active teams.
The “Informatik-Forum Frauen” (IFF), also called Women in CS at TUM, https://www.facebook.com/IFFTUM/, was created in 2010 as a platform to bring together members of IN.TUM who are engaged for advancement of women and other under-represented groups. The group received a substantial donation from Google to support its work. IFF holds a monthly open Jour fixe with increasingly broad participation, also from outside the department.

The IN.TUM Gender Equality Officer is a member of the Panel of Study Affairs, the Department Council (with regular agenda item), and faculty recruitment committees. Her reports are regularly heard and discussed on Faculty Retreats. There is excellent cooperation with public relations.

IN.TUM finances a student assistant to support the Gender Equality Officer. It has financed nine person months to consolidate inclusion of gender in statistical reporting. Processes have been established to regularly update recurring statistics and to make them available in the department’s intranet. A number of individual statistics were collected, some of which can be starting points for further activities (for example, raising the proportion of female applicants that actually register for a course of study after admission).

The topics of gender and diversity are regularly and successfully considered on many levels in the department: press, search committees for faculty positions (Leuchtturmbereufungen), or honorary doctorates, to name some examples.

We include three statistics that demonstrate the following points: The percentage of female student admissions and other indicators have been slightly up; we observe that women are higher represented among international than among national students – another demonstration of culture influencing female participation. Our pipeline across academic levels is narrow, but only slightly leaky, as it is

Figure 40: Participatory profile of women in IN.TUM from 2007 to 2016. (Source: IN.TUM)
typical for an engineering discipline. Student admissions versus immatriculations (male/female) show a gender gap that bears looking into.

In 2010, the Departments of Informatics and Mathematics held a joint workshop TUM-Familie... Familien-TUM on reconciling requirements of work, study, and family with seven discussion forums. The goal was to connect activities around the topic and to elicit requirements and ideas of members of the two departments regarding further initiatives. This workshop led to the flexible childcare service that the two departments offer in their “Kinderzimmern”.

Announcing the opening ceremony for the Kinderzimmern at MA/IN.TUM.
One of the two Kinderzimmern at MA/IN.TUM.

Information about the childcare services is available at www.in.tum.de/kinderzimmer. For the fifth anniversary of the services, the IN.TUM press office published a report that is available at http://www.in.tum.de/fuer-studierende/services-einrichtungen-it/kinderzimmer/happy-birthday.html and that was prominently placed on the IN.TUM homepage www.in.tum.de for a number of months. IN.TUM cooperates with other departments on Campus Garching to extend flexible childcare. The IN.TUM Kinderzimmer has been a model for the Kinderzimmer at EDU. The service is provided in cooperation with TUM.Family and is a prominent highlight in the service portfolio of the Departments of Mathematics and Informatics. There is a wide spectrum of use cases (accommodating guest researchers with children, coverage of intense study periods, conferences, or project meetings, bridging holiday periods or strikes in regular childcare institutions, providing initial childcare for parents that are new in our departments). The service is used by parents and caregivers of any status or gender.

Community building around gender

IFF is working hard to build community around gender. We are proud of and grateful for the increasing active participation of women in the department. Here is a list of past and ongoing activities:

- **IFF Lunch Meeting**: Two years of monthly women-only events for advanced students and young faculty with guest speakers.

- **Liesel Beckmann Symposium Puzzling out Informatics** organized by IN.TUM. Workshop with nation-wide participation on the image of Informatics in the public and the internal view and its implications for the participation of women.

- **IFF Travel Grants to Grace Hopper Celebration of Women in Computing**, since 2014, including kick-off workshops; thirteen awardees in the years 2014 to 2017. Experience reports are available on our web site.

- **IFF@SET**, introducing IFF at the Studieneinführungstage SET of the Departmental Student Council since 2015, presentations available on our web site.

- Events, most recently the 2016 **IFF Fall Event**, as a welcome event for new students, with speakers from Google and Microsoft, and the 2017 **IFF Spring Event**, featuring a TUM alumna and founder. We are currently setting up a rhythm of two IFF Signature Events per year, the IFF Spring Event with an external female speaker, who acts as a role model in presenting her work combined with insights into her career path in a male-dominated field, and the IFF Welcome Event in the fall, where we present IFF and the possibilities of getting involved to new students.
Gender awareness and gender competence

One goal is to increase gender awareness and gender competence in faculty recruitment and to establish gender competence as a topic in faculty recruitment. We are working towards professionalizing faculty recruitment with respect to gender and diversity on the basis of current insights in social sciences. We want to be able to delegate responsibility for gender-fair recruitment practices to regular members of recruitment committees.

We have established a practice to prepare candidates for the fact that they are expected to report on their gender and diversity practices.

A larger three-part workshop for IN.TUM faculty that results in precise and practical guidelines for addressing gender and diversity in recruitment processes has been planned but had to be deferred due to illness of external experts.

IFF members have created a one-hour interactive workshop on gender awareness and unconscious bias that has been piloted in the fall of 2016 and that is intended to be used in tutor trainings. In 2017, the workshop has been offered in MW and as part of a seminar on unconscious bias in Informatics, to great acclaim.

As an example of gender activities initiated by research projects, the DFG Priority Program SPPEXA offers gender workshops regularly, in conformance to DFG guidelines.

8.2 Internationalization

Internationalization is of great significance to IN.TUM. We already have a very international environment; see Figure 43.

<table>
<thead>
<tr>
<th>Students (Bachelor, Master)</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctoral candidates, PostDocs</td>
<td>33%</td>
</tr>
<tr>
<td>Professors</td>
<td>14%</td>
</tr>
<tr>
<td>Administrative Staff</td>
<td>9%</td>
</tr>
</tbody>
</table>

Figure 43: Internationalization at IN.TUM in 2016. (Source: IN.TUM)

As the situation evolved over the last ten years, we worked hard to cope with the challenges imposed by this internationalization. We have built structures and programs that secured us our leading position among German-speaking departments of Informatics in exercising rigorous internationalization.

This has two facets: First Internationalization at Home, which means that everybody in IN.TUM shares an international experience during his/her stay at TUM, and second Internationalization by Experience Abroad, which means that everybody should have the opportunity to experience a stay abroad. In order to accompany this process and to integrate and support all involved groups, we have many projects; the most important and successful ones will be explained below.

We hired an Admission Officer, esp. to ensure quality assurance for the aptitude testing (Eignungsverfahren) and to give administrative advice for international degree students; this includes a close contact to the SSZ and to the Liaison Officers of TUM. These Liaison Officers are representatives of TUM in strategically important places who provide interested students, graduates and researchers with information and help attract the best talents to TUM. We also hired an International Student Exchange Coordinator, responsible for both incoming and outgoing students, fostering and further developing exchange programs; this includes close contact to the International Center of TUM w.r.t. exchange programs, delegations (students and universities), special programs (e.g. internship programs), and scholarships (e.g. PROMOS). These two persons
work together very closely and initiate and supervise activities to accompany the internationalization process. The connection to and interaction with the academic program’s office and the academic advisors is close and intense.

Here are some examples of our activities.

**Intercultural competence at home**

To enhance the intercultural competence, we offer workshops at the beginning of every term, which are attended by national and international students. We plan to introduce an intercultural certificate for 2017, see Section 3.1.

We added language courses to the catalogue of support electives in all study programs to enhance the international language competence; the majority of classes in the master’s programs is taught in English.

We foster the interaction and integration of national and international students by our **MINGA Mentoring Program** (www.in.tum.de/en/minga), our **International Day** (www.internationalday.tum.de), and our **Talk TUM[i:] Language Café** (www.in.tum.de/en/current-students/student-life/talktumi-language-cafe.html).

**MINGA Mentoring** matches international students coming to TUM with current TUM students, providing the chance to connect with a peer even before arrival in Germany; in winter term 2016/2017, we matched more than 220 pairs. During the term, we organize an event program with, e.g., visits to the opera or trips to Bavarian castles.

**Our International Day** takes place once a year; There, students present their home countries or the countries during stays abroad; in 2016 we had more than 40 booths.

At the **Language Café** students (at bachelor’s, master’s, and PhD level) meet weekly at the tables in the Magistrale for up to 16 languages. During the last years, we had tables for Chinese, Czech, Danish, English, Farsi, French, German as a Foreign Language, Hebrew, Hindi, Italian, Japanese, Norwegian, Portuguese, Russian, Swedish, and Spanish. Around 70-100 students joined the tables every week.
Study abroad: Outgoings and Incomings

We provide places for studying abroad within our programs ERASMUS, TUMexchange, and departmental partnerships for all interested and suitable students at all levels (bachelor’s, master’s, PhD. Sending abroad, requires extensive advising, careful preparation as well as reliable expectation to transfer credits. For a small number of highly motivated students we also offer double degree master’s programs in Informatics.

Impressions from the Language Café.

Figure 44: Incoming exchange numbers in IN.TUM. (Source: IN.TUM)
We also welcome an increasing number of incoming exchange students; in the study year 2016/2017 the number was around 130. We strive for a decent preparation of their stays at TUM in order to maximize the study success despite the limited time frame (1-2 terms). The incoming exchange students also benefit from the broad experience of the department with international students and from the activities listed in this section.

IN.TUM is by far the most active department in terms of student exchange of all German Informatics departments (cf. Figures 46 and 47).

Figure 45: Outgoing exchange numbers in IN.TUM. (Source: IN.TUM)
Figure 46: Comparison of German universities: numbers of ERASMUS incomings in Informatics. (Source: DAAD 2016)
Figure 47: Comparison of German universities: numbers of ERASMUS outgoings in Informatics. (Source; DAAD 2016)
Support for international students

Concerning our international degree students, we have various activities to make their stay as successful as that of our national students, and the statistics show that it works.

The students are well prepared for their studies before the lectures start. We maintain an informative web page, an extensive email support, freshmen chats via Skype, the MINGA Mentoring Program, a welcome service at the airport, freshmen cafes with the advisors, the Study Introduction Days of the Departmental Student Council in English, intercultural workshops, a MOOC for preparation in math and programming esp. for students in the master’s program Biomedical Computing.

Besides these activities, the series Let’s talk allows them, besides their studies, to accommodate to the German academic culture, the program German Matters (www.sprachenzentrum.tum.de/en/languages/german-as-a-foreign-language/german-matters/) allows them to acquire advanced German language skills, and we have a tight integration into the Departmental Student Council and the ASTA via dedicated referees for internationalization.

A major challenge is to provide an internal environment as well as interfaces to the outside which are compatible with the internationalization process. All forms, the web pages, all announcements, the signs in the buildings, etc. have to be provided in English, too. We are continuously working on an internationalization check at all levels within and outside TUM (e.g., ZHS, KVR, Studentenwerk) aiming at a culture of warm welcome.

Intercultural competence for the whole department

Our goal is to include all groups of our department into the internationalization process, not only those who are learning or teaching. Therefore, we offer intercultural trainings also for the administrative staff, as well as English language coaching for lecturers. Furthermore, we encourage them to participate in ERASMUS staff mobility.

In terms of language, we demand all members of the Departments to be fluent in German or English and learn the other language during their stay at TUM.

Research in international context

Doctoral candidates and PostDocs perform their research at IN.TUM in an international environment. They collaborate in international projects and present their scientific results at international conferences. Currently, more than 30 European collaboration projects are, for example, worked on at IN.TUM. Doctoral candidates are also supported by international mobility phases during their education, through mobility grants by the TUM Graduate School, and through ERASMUS teaching mobility; vice versa, we invite international doctoral students, PostDocs, and guest professors to research and teach at IN.TUM.

8.3 Chronic illness and disability

IN.TUM strives to ensure that students with disabilities and chronic illnesses have equal and independent access to a barrier-free education and student life. Disabilities and chronic illnesses are as varied as people themselves. There are physical disabilities, walking impediments, organic disorders that are not necessarily visible, mental illnesses, hearing or sight impairments, and specific learning disabilities such as dyslexia. Regardless of the specific challenges posed to this set of students, whose lives at university are affected to a greater or lesser extent, their individual requirements must be taken into consideration to establish suitable conditions of study. IN.TUM appointed a Departmental Contact for Students with Disabilities and Chronic Illnesses who offers individual support and confidential advice on a wide range of matters, such as examination procedures, disability
accommodations, applying for electronic learning aids financial support, mentoring programs, part-time studies, and much more, www.in.tum.de/en/barrier-free.

Support for students in Informatics

In close contact to the Student Service Center–Office for Disabled and Chronically Ill Students and the affected student the Departmental Contact for Students with Disabilities and Chronic Illnesses aspires to ensure an entirely barrier-free education. Since every illness has individual impact on the student’s studies and challenges are as varied as the disabilities there are few universal solutions but mostly concepts on an individual basis for each student. Therefore, in all cases confidential and intensive talks with the student are necessary to find out how to accommodate his/her special needs. With a disability accommodation (Nachteilsausgleich) our goal is to ensure that affected students are well-supported to overcome the barriers they face on the way to obtaining a degree. Our emphasis is on supporting inclusion rather than on offering potentially easier solutions which could lead to an outsider position. The main disability accommodation is an extension for time limited exams. Since it is not possible, due to the sensitive nature of the topic and the confidentiality requirements, to collect statistics we will only mention some examples:

- Students with mobility impairments have unlimited access to all lecture halls, working spaces, and toilets in IN.TUM.
- Autistic students need a lot of individual support since there are different shapes of autism, e.g. one affected student needs exams on an individual basis.
- Blind students do not only need a disability accommodation for exams but as well for the studies in general, e.g. lecture materials and exercises have to be put in a for blind accessible way. Here the inclusion part is very important to ensure that blind students can cooperate with fellow students with normal vision.

Support for academic staff

Not just the students are in our focus but also the academic and non-academic staff at IN.TUM. To sensitize the lecturers and teaching assistants and especially to turn their attention to non-visible disabilities we organize training courses and information events with experts as needed. In special cases the departmental contact also gives individual assistance to lecturers to ensure a smooth course of action.

8.4 Refugees

The main goal of the Auditor Program for refugees organized between October 2015 and September 2018 is to give prospective students with refugee status the opportunity to sit in (audit) course modules at TUM for one term or more to familiarize themselves with the German higher education system and to have access to the university’s information and advising services. Ideally, after a few terms in the Auditor Program the refugee realizes if studying at TUM is the right choice. The Auditor Program with all support and advice was free of charge for the refugees enrolled in it. Every refugee within the program was assigned to a buddy preferably with the same study background. A lot of people affiliated with IN.TUM were committed to the buddy program so that refugees in Informatics could be mostly matched to Informatics students, doctoral candidates or staff. The enrollment and general advice for refugees interested in the program was organized by the TUM Coordinators for the Auditor Program for Refugees, https://www.tum.de/en/studies/international-students/refugees/. The buddy program and its matching was initiated and organized by the Executive Director of the Junge Akademie, https://www.jungeakademie.tum.de/en/buddies-for-refugees. The academic advisors at IN.TUM are attuned to ensure that refugees once enrolled in Informatics were closely supported and accompanied during their registration, www.in.tum.de/gefluechtete. We offered regular group meetings with refugees and their buddies, individual advising
on our courses and study programs, e.g., planning of individual study plans, access to computers, expectations, application process for our study programs. We kept close contact with refugees and buddies to exchange experiences and learn from each other. All coordinators worked hand in hand to ensure a smooth integration.

Advising for refugees in Informatics

In the following, we focus on refugees within the Auditor Program who are enrolled at IN.TUM. Most refugees are male and in their mid to end 20s.

The main group by far comes from Syria; another part is from Afghanistan. Almost all refugees at IN.TUM have been studying in their home country or have a very strong academic background. From the beginning of the auditor program, the numbers increased steadily. In summer semester 2018 around 25% of all refugees within the Auditor Program were enrolled in Informatics which made IN.TUM the department with the highest demand at TUM. The numbers show the high appreciation of the Auditor Program at IN.TUM. Around 20 refugee students (two of them female) from the Auditor Program have been enrolled in one of our Bachelor’s programs at IN.TUM.

In the beginning most students in the program were still in a phase of orientation, especially learning German, such that their participation in the lectures and tutorials was not stable yet, and it was also difficult to reach them and measure their progress. After three years we are very pleased that our auditors overcame their challenges and committed themselves to study Informatics (most of them), a few started studying Information Systems and Informatics: Games Engineering.

Other activities within IN.TUM

Besides the Auditor Program, IN.TUM had further activities that we wish to mention here: We offered an Orientation Day for underage refugees. Moreover, several apps have been developed to provide information to refugees, project coordinators, and volunteers (e.g. INTEGREAT). In particular, the app HalloDeutsch facilitates the learning of German as a second language.

8.5 Campus life

Due to the lack of student accommodations in its vicinity, Campus Garching is sparsely populated with social events when compared to other university campuses. Nonetheless, the Departmental Student Council has established a variety of events to improve the life on campus more towards a traditional campus life. We installed a fixed set of events to make the campus itself more attractive to students and employees as well as international members of IN.TUM. A notable fact is that all the events mentioned below are oriented towards all students and employees of the Department of Informatics, as well as those of the Departments of Mathematics and Physics, since the Departmental Student Councils of the aforementioned departments have congregated into the Fachschaft Mathematik/Physik/Informatik (MPI) which represents students of all three departments.

One of our biggest events is the Game Night, which is held weekly during the term. Starting off in 2013 as a small and almost private event, the Game Night now has about 200 visitors every week. We offer a broad variety of board games as well as group games for more than ten people. The weekly Game
Night is organized by the members of our event unit, who are also responsible for the organization of a variety of other events to reach a selection of possibilities for a vivid campus life. Our goal is to provide the students with alternatives for their free time to encourage community building and social activities. These events include a LAN Party which is held every term. This year the LAN Party took place at the Business Campus in Garching Hochbrück and had shortly under 200 guests who played cooperative and competitive computer games and also centrally organized tournaments.

Another large event organized by our event unit is the Real Life Scotland Yard which takes place in irregular intervals, about once or twice a term. In this event, the participants play a city scale version of the popular board game Scotland Yard, but in this case, multiple parties hunt down a fugitive Mister X who is only allowed to travel by public transport, disclosing his location every fifteen minutes. The game is spread out over the entire city of Munich, boosting the participants’ knowledge of the city.

Besides recurring events during the term, the Departmental Student Council also holds bigger events that only take place every year. The biggest event organized solely by the Departmental Student Council MPI is the Unity. This party takes place every summer term, mostly in May, and hosts over 2000 guests in the FMI building. Planning for the party already starts about six months earlier and involves around forty voluntary organizing staff, as well as just under 300 helpers on the party night. Established in 2011, the Unity has become a recurring and well-renowned event recognized amongst the members of IN.TUM.

Another student event that has become an institution in recent history is the Winter Ball that takes place at the end of November. First established in 2014, the third Winter Ball has been carried out in the past year, inviting 400 people to a night of dancing, including dancing lessons in the weeks before the event. The Winter Ball has also been a success and is set to become a regular event next to the Unity in the summer term.

An important part of the Departmental Student Council’s work evolves around facilitating the new students’ entry into their course of study. For this, we organize the Study Introduction Days ("Studieneinführungstage“ SET) every term, with a bigger focus on the winter term due to the larger
number of students starting their studies. We help
the students to find their way around campus and
introduce them to the life on campus. We also
encourage them to participate in joint activities on
campus and help them to get to know each other
at the beginning of their studies. Many students
come from outside the immediate vicinity of the
TUM, and we believe that building a healthy social
environment is an important part of a successful
study. In the last two years, we have hosted a
special Real Life Scotland Yard event during the
study introduction days which was attended by
nearly 300 first-year students, and we plan on
introducing more social events, such as a special
Game Night, this year. The team behind the Study
Introduction Days consists of about 30 staff
members who are supported by over 100 tutors.

Every summer, towards the end of the term,
IN.TUM hosts the IN.TUM Summer Party, inviting
all members of IN.TUM to an evening in a relaxed
atmosphere, that includes free food and drinks for
more than 1,500 visitors. The event is also attended
and supported by several well-known companies
connected to the IT industry, providing students
with a possibility to get in touch with potential
future employers, the main focus still being fun and
achieving a deeper connection of students to the
department and its employees. The organizational
staff is supported by student helpers from the
Departmental Student Council as well as other
students, preferably international students.
9 Impact Beyond the Typical

Today, Informatics is an established engineering discipline and the core enabler for science, economy, and society. For IN.TUM, as an Informatics department at a leading technical university, this means opportunities and a responsibility beyond research, education, and classical technology transfer, and the department has always taken that part actively. The following pages shall depict that role in a bit more detail.

Academic leadership

**TUM-internal.** IN.TUM contributed and contributes to TUM leadership. In recent years, the following members served on that behalf: A. Bode (Senior Vice President and CIO), H. Pongratz (Senior Vice President and CIO), A. Bode and H. Krcmar (Senate, Board of Trustees), H.-J. Bungartz and H. Seidl (spokesperson of all Deans of Studies), M. Gottlieb and P. Zarnitz (student member of the Senate and the Board of Trustees), F. Dietrich and H. Schäfer (spokesperson of the Graduate Council of TUM Graduate School and member of the Senate), H.-J. Bungartz (TUM Graduate Dean and Director of TUM Graduate School), S. Albers and C. Eckert (TUM Appointment and Tenure Board), H.-J. Bungartz (Board of the International Graduate School of Science and Engineering – IGSSE, Advisory Council of the Institute for Advanced Study – IAS).

**External.** Members of IN.TUM serve on various boards, in various functions. Among many others, we want to mention A. Bode (Board of Trustees, TU Graz), H.-J. Bungartz (Steering Committee, European University Association, Council for Doctoral Education; Advisory Board, Fraunhofer SCAI; BAR, Max Planck Society; Chair of Advisory Board of the Program Supercomputing and Big Data, KIT), G. Carle (Board, Fakultätenrat Informatik), C. Eckert (Board of Trustees, KIT and University of Applied Sciences Ingolstadt), H. Krcmar (Advisory Board, several Fraunhofer Institutes and Fraunhofer IuK Verbund), and J. Schlichter (TUM’s representative for vhb – Virtuelle Hochschule Bayern). Furthermore, several IN.TUM members are active for foundations such as “Studienstiftung des Deutschen Volkes”, “Max-Weber Program”, “Bayerische Elite-Akademie”, or “Stiftung der Deutschen Wirtschaft“ (sdw) (S. Albers, B. Brügge, H.-J. Bungartz, A. Knoll, H. Krcmar, H. Seidl). C. Eckert is director of the Fraunhofer Institute AISEC, A. Albu-Schäffer heads DLR’s Institute of Robotics and Mechatronics, H. Seidl coordinates the DFG Research Training Group PUMA, H.-J. Bungartz coordinates the DFG Priority Program SPPEXA, A. Kemper co-coordinates the DFG Priority Program 2037, A. Bode is involved in leadership of the European Project PRACE, and A. Knoll is centrally involved in leadership of the EU Flagship Project Human Brain Project.

Shaping IT infrastructure nation-wide and beyond

The German National Research and Education Network (DFN – Deutsches Forschungsnetz) is the institution that provides the communications network, in particular the X-WIN (Wissenschaftsnetz), and a variety of related cutting-edge services for research and education in Germany. DFN has become an integral part of the European (GÉANT) and global communities of research and education networks. In 1984, based on a sequence of projects funded by the federal government, the German science landscape did a pioneering step and decided to operate that network backbone in the future in an independent, self-organized way, as a German “Verein”. 33 years later, this organizational model is generally considered as an unrivaled success story, and today, DFN has about 340 member and 770 user institutions, employs about 80 FTEs, and has an annual budget of above 40 Mio €. From the first ideas of establishing a research network in Germany until today, members of IN.TUM contributed significantly to DFN leadership (E. Jessen, H.-G. Hegering, H.-J. Bungartz).
The **Commission for IT Infrastructure (KfR)** of the **German Research Foundation (DFG)** is the main strategy, planning, consulting, and evaluation body of DFG with respect to IT infrastructure at universities. KfR shaped programs such as CIP and WAP that should become a cornerstone for IT equipment of German universities; KfR initiated DFG funding of selected measures of information infrastructure and, thus, fostered the transition of universities to the digital era; and KfR organized the evaluation of HPC procurement for the **German Science Council (Wissenschaftsrat)**, and, thus, helped to build the HPC pyramid structure in Germany. Since the first days of the WAP program, members of IN.TUM have been members (H.-J. Siegert, E. Jessen, H.-G. Hegering, C. Zenger, A. Bode) or head (H.-J. Bungartz) of KfR.

The **Leibniz Supercomputing Center (LRZ)**, an institution of the **Bavarian Academy of Sciences and Humanities**, is one of the largest and leading scientific IT service centers also at an international scale. LRZ has a local (computing center of the Munich universities), a Bavarian (state supercomputing center plus several other Bavaria-wide services), a German (one of three sites of the Gauss Center for Supercomputing (GCS)), and a European (a PRACE tier-0 site) mandate. Since the early years after its foundation more than 50 years ago, members of IN.TUM have been involved in LRZ leadership, as board members (C. Zenger, H.-J. Bungartz) or chairman of the board (H.-G. Hegering, A. Bode). Through GCS and PRACE, there have been and are important contributions to the European HPC infrastructure.

**Education beyond classrooms**

**Ferienakademie** (www.ferienakademie.de) is a unique format for our best students. Founded by F.L. Bauer in 1984, following the example of the **Summer Academies of Studienstiftung des deutschen Volkes, Ferienakademie** is organized today by TUM and the universities of Erlangen (since 1985) and Stuttgart (2002), with university and industry funding. Every autumn, up to 200 selected students and 25-35 professors from the three universities spend two weeks in Sarntal, South Tyrol, in seminar- or project-based courses. The intensity of collaboration and exchange, but also the many careers to leadership positions in academia or industry that got a crucial input in Sarntal underline the success of this format (just as one example among many, the former board member and CTO of Siemens S. Russwurm got his inspiration to go for a doctorate at Ferienakademie). Although Ferienakademie is cross-disciplinary and typically comprises courses from basically all fields represented at all three universities, it was a child of IN.TUM, and IN.TUM has provided the organization as well as all directors (F.L. Bauer till 1995, C. Zenger till 2005, H.-J. Bungartz since then) so far.

Even older is the NATO-funded **Summer School Marktoberdorf**. Its early editions saw the birth and rise of the term “Software Engineering”, and ever
since then, the annual Marktoberdorf event has been a pivotal place for software engineering and theoretical computer science, the list of lecturers reading like a who-is-who of the respective fields. Since the beginning, the Summer School has been organized and directed by IN.TUM members (F.L. Bauer, M. Broy, J. Esparza, H. Seidl, T. Nipkow, A. Pretschner). This year, as part of the celebrations of “50 Years of Informatics in Munich”, the several-time Marktoberdorf co-organizer Orna Grumberg from Technion received an honorary doctorate from IN.TUM.

Furthermore, IN.TUM is probably the department with the highest involvement in programs in the framework of the Elite Network Bavaria (ENB), so-called elite programs. It currently participates in five elite programs (Center for Digital Technology and Management – CDTM; Finance and Information Management – FIM; Software Engineering; TopMath; Data Science (at LMU)) and coordinates a sixth one (Bavarian Graduate School of Computational Engineering – BGCE). All six belong to a small set of Bavaria-funded special programs that address excellent and highly motivated students. Finally, IN.TUM participates in the Executive Master offers of the TUM School of Management.

Relations to industry

IN.TUM’s relations to industry are manifold and base upon a large number of industry-funded projects or consortia with industry. This has been a strength of the department from its beginning, and it carried over to today. Of a special quality is the SAP University Competence Center (SAP UCC, H. Krcmar). SAP UCC Munich is one of six UCCs worldwide and provides web-based access to SAP systems for universities and other higher educational institutions. Also beyond these direct links, a lot of initiatives were initiated or headed by IN.TUM members. Prominent examples are BICC-NET, the Bavarian Information and Communication Technology Cluster (M. Broy), or ZD.B, the Zentrum Digitalisierung Bayern (M. Broy). Moreover, there is a significant number of spin-off companies of the department (4Soft, Validas, itestra, etc.), and there is fortiss – launched as an “An-Institut” of IN.TUM by M. Broy, A. Knoll, and H. Krcmar, and today also an Institute of the State of Bavaria, organized as a gGmbH. Links to industry are completed by IN.TUM members with leadership functions in companies, such as C. Eckert (supervisory board of EADS).

Political and societal impact

There are a lot of channels through which IN.TUM members provide advice to and produce impact on politics. A prominent example is the study on Big Data delivered by H. Krcmar and others to the German Federal Ministry of Economics. TUM’s School of Governance will offer additional opportunities our department will take. Societal impact was visible early through activities such as the informatics exposition in “Deutsches Museum”. More recent examples are the Munich Center for Internet Research (MCIR, headed by A. Pretschner) or the Integreat App designed by a team around H. Krcmar to foster the integration of fugitives and which has already won a couple of awards, cf. www.integreat-de.de.
10 Performance and Benchmarking

This section provides an overview of numbers and statistics describing the performance of IN.TUM as well as its positioning in the national and international academic landscape.

10.1 Education

The following figures present the numbers of enrolled students at IN.TUM as well as at selected departments at a national scale. Due to a lack of official statistical data, a similar comparison with international competitors is not possible, unfortunately. The figures show the overall numbers, the numbers at bachelor’s level, and the numbers at master’s level – and all of them for five successive years, 2015/2016 being the most recent one for reasons of availability of statistical data. In this section, we restrict ourselves to the mere numbers and comparisons. A detailed discussion of the IN.TUM situation can be found in Section 2.4.

The official statistics over the last five years on students enrolled in any program offered by an Informatics department in Germany confirms the impression given by the first figure: IN.TUM has taken the lead, with a quite stable positive gradient. As it can also be seen, technical universities show higher numbers and steeper ascents than comprehensive universities. Looking at the IN.TUM numbers for 2016/17 (about 4,800) and the prognosis for 2017/18 (based on the bachelor’s applications: + 10%), there is no significant change of trend in sight.

Concerning the bachelor’s numbers, IN.TUM is in the top group, currently at place 4. This has to be considered against the background of our eligibility and aptitude testing – which means a pre-selection of candidates and moderate drop-out rates of clearly below 30%.

The master’s numbers show the lead of IN.TUM. Actually, we had a few years with almost a tie between bachelor’s beginners and master’s beginners. We see the main reasons in the research strength of IN.TUM, but also in our internationalization strategy.

![Figure 52: Overall student numbers in the field of Informatics. (Source: TUM Controlling, Organization and Management)](image-url)
Finally, the last figure in this section shows the development of the doctoral graduates. There is, again, a clear positive gradient, with absolute numbers that put us also in a top position within Germany.

Habilitation still takes place at IN.TUM, however – mainly due to other career paths such as junior or tenure track professorships – at a reduced pace. On average, we had three habilitations per academic year over the past five years.
10.2 Rankings

The TUM has been very successful in national and international university rankings throughout the last years. The latest Reuters Europe’s Most

Innovative Universities ranking, for instance, ranks the TUM 5th in Europe and 1st in Germany. And the Global University Employability Ranking, which evaluates the quality of graduates from an employer’s perspective, places TUM 8th worldwide.

Figure 55: Number of doctoral graduates at IN.TUM. (Source: IN.TUM)

Figure 56: IN.TUM or Computer Science in international rankings 2015-2017.
In the last few years, the number of academic rankings has increased, and more and more often not only universities as a whole, but also individual departments or disciplines are evaluated at a national or international scale. Usually, such rankings evaluate the whole field of Computer Science or Informatics, but in some rankings, Information Systems is treated separately. In the following, we always write “IN.TUM”. However, if a field such as Informatics is evaluated, this also includes respective research in other departments, in particular EI or MA.

In many such international rankings, IN.TUM (i.e., Informatics / Computer Science at TUM) has been rated the best Informatics department at a German university multiple times in a row. As a special highlight, in the current **THE World University Rankings 2016-2017 by Subject**, IN.TUM stands at the forefront in global comparison as well: Ranked 9th globally, it belongs to the most renowned Informatics departments. The international rankings generally put a strong focus on research performance in their analyses.

### IN.TUM or Computer Science in *international* subject rankings

At 9th place in the **THE World University Rankings 2016-2017 by Subject**, IN.TUM also stands for the best rated Informatics / Computer Science in Germany. Times Higher Education (THE) asks scientists worldwide about the reputation of universities in terms of research and teaching. Additionally, the evaluation takes into account data such as the number of publications per scientist, citations per publication, the teacher-student ratio, third party funding received from industry, and the degree of internationalization.

In the subject ranking of the **QS World University Rankings by Subject 2016 – Computer Science & Information Systems**, IN.TUM holds 36th place and thereby counts as the top German university in the field of Informatics. IN.TUM has held this leading position in Germany for several years now. No other German department of Informatics has made it into the top 50. The **QS subject ranking** is based on surveys of academics and employers collected over the last five years as well as on the number of citations per scientific publication in the respective subject.

In the **Subject Ranking Computer Science of the Academic Ranking of World Universities 2015 – ARWU Ranking (“Shanghai Ranking”),** IN.TUM, just as in past years, appears as the top Informatics department in Germany. It is ranked 28th, whereas no other German Informatics department makes it into the top 150. The **Shanghai Ranking** evaluates the research achievements of universities worldwide. Taken into account are publications in important journals, scientist citation rates, and the number of scientists and alumni who have won Nobel Prizes or Fields Medals.

IN.TUM is also #1 in Germany according to the **National Taiwan University Ranking 2016, Computer Science**. No other German university made it into the top 100. Worldwide, the department is ranked 82rd globally and 15th in Europe. This ranking puts its emphasis on research as well, especially on the number of publications and citations. In many international rankings, IN.TUM has either been rising in the rankings or defended an already high position over the years. This can be seen, for example, in the Computer Science lists of the Shanghai Ranking from 2009 to 2015.

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Figure 57: International placement of IN.TUM / Computer Science in the Shanghai Ranking from 2009 to 2015.
Moreover, in a number of important international rankings, IN.TUM has consistently appeared as the best German Informatics department since 2012.

This is the case in the **Shanghai Ranking**, in the **QS World University Rankings**, and in the **National Taiwan University Ranking**.

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Figure 58: National lead of IN.TUM / Computer Science at TUM in international rankings.

**IN.TUM** in national comparison

While international rankings often place their focus exclusively on research, national rankings often take different perspectives.

The **DFG Funding Ranking 2015 / DFG-Förderatlas 2015**, compares the acquisition of third party funding for research and development. More concretely, it measures research funding by the German Research Foundation (DFG), here for the funding period 2011–2013. With 16.6 Mio €, IN.TUM ranks #1 in Germany in the field of Computer Science, meaning it has obtained the highest amount of DFG funding. IN.TUM is followed by the RWTH Aachen University and the University of Stuttgart.

The magazine **Wirtschaftswoche** emphasizes the quality of both research and teaching, and above all the practical relevance of higher education in its **Wirtschaftswoche-Hochschulranking 2016** (university ranking 2016). For that ranking, HR managers were asked which universities provide the best education for the needs of their companies. HR managers of German companies responded accordingly that the TUM produces outstanding graduates in Informatics and Information Systems. In 2016, IN.TUM ranked 3rd and TUM Information Systems ranked 2nd. In 2015, both disciplines held the first place.

The **CHE Ranking** operates within the German-speaking world and primarily serves as a guide for prospective students. The **Center for Higher Education Development (CHE)** surveys students and professors and uses various indicators in teaching and research. The results of this ranking are discussed in detail in Section 2.4.8 CHE Rankings.
Informatics has arrived at the heart of science, economy, and society. Way after the technological breakthrough of digitization, that buzzword of digitization currently characterizes a major re-thinking and re-shaping of almost everything, and it places Informatics in a leadership position for future progress in a very broad sense. The breathtaking development of Informatics also implies that it is not limited to Informatics in neither a disciplinary nor a departmental sense, but actually comprises almost all disciplines, departments, cross-departmental structures, and core facilities, as well as all aspects of research, education, and administration. Nevertheless, it is Informatics that provides the underlying technologies and realizes their transfer to other scientific domains, industry, and society. For IN.TUM, this means a lot of opportunities, responsibilities, and challenges at the same time.

Definitely, one of the biggest assets of IN.TUM has always been and is the excellent climate of mutual respect and esteem, of a highly collaborative spirit comprising faculty, staff, and students, and of an always constructive way of directing possibly diverging interests towards consent. While this gets more challenging to preserve against the background of an increasing variety of topics, contexts, and agendas present, as well as of growing numbers, we consider this as our probably most important guideline for all future planning and strategy development.

Finally, we are convinced that, in a dynamic field such as informatics, a modern strategy for the future cannot consist of rigid numbers, KPIs, processes, or goals; cannot be any “either this way or that”. Rather, our way is flexibility, an openness to emerging developments and opportunities, and being prepared for all kinds of possible developments, grounded in tradition and the principles that led IN.TUM where it is today. And it is our clear goal to close the gap to the best European Informatics departments and to establish IN.TUM in that club.
Appendix
## Informatics Faculty Members

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<thead>
<tr>
<th>Name</th>
<th>Rank</th>
<th>Denomination</th>
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<tbody>
<tr>
<td>Albers Susanne</td>
<td>Full Professor</td>
<td>Algorithms and Complexity</td>
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<tr>
<td>Albu-Schäffer Alin</td>
<td>Full Professor</td>
<td>Sensor-based Robot Systems and Intelligent Assistance Systems</td>
</tr>
<tr>
<td>Althoff Matthias</td>
<td>Assistant Professor</td>
<td>Cyber-Physical Systems</td>
</tr>
<tr>
<td>Bader Michael</td>
<td>Associate Professor</td>
<td>Hardware-aware Algorithms and Software for HPC</td>
</tr>
<tr>
<td>Baumgarten Uwe</td>
<td>Associate Professor</td>
<td>Integrated Computing Systems</td>
</tr>
<tr>
<td>Bichler Martin</td>
<td>Full Professor</td>
<td>Decision Sciences &amp; Systems</td>
</tr>
<tr>
<td>Brandt Felix</td>
<td>Associate Professor</td>
<td>Algorithmic Game Theory</td>
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<tr>
<td>Brügge Bernd</td>
<td>Full Professor</td>
<td>Applied Software Engineering</td>
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<tr>
<td>Brüggemann-Klein Anne</td>
<td>Associate Professor</td>
<td>Applied Informatics – Cooperative Systems</td>
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<tr>
<td>Bungartz Hans-Joachim</td>
<td>Full Professor</td>
<td>Scientific Computing</td>
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<tr>
<td>Burschka Darius</td>
<td>Associate Professor</td>
<td>Machine Vision and Perception</td>
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<tr>
<td>Carle Georg</td>
<td>Full Professor</td>
<td>Network Architectures and Services</td>
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<tr>
<td>Cremers Daniel</td>
<td>Full Professor</td>
<td>Computer Vision and Artificial Intelligence</td>
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<td>Eckert Claudia</td>
<td>Full Professor</td>
<td>IT Security</td>
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<td>Esparza Javier</td>
<td>Full Professor</td>
<td>Theoretical Computer Science</td>
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<td>Gagneur Julien</td>
<td>Assistant Professor</td>
<td>Computational Biology</td>
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<td>Gerndt Michael</td>
<td>Associate Professor</td>
<td>Architecture of Parallel and Distributed Systems</td>
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<td>Großklags Jens</td>
<td>Associate Professor</td>
<td>Cyber Trust</td>
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<td>Günnemann Stephan</td>
<td>Assistant Professor</td>
<td>Data Mining and Analytics</td>
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<tr>
<td>Haddadin Sami</td>
<td>Full Professor</td>
<td>Robotics Science and System Intelligence</td>
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<tr>
<td>Heinig Matthias</td>
<td>TUM Junior Fellow</td>
<td>Genetic and Epigenetic Gene Regulation</td>
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<td>Huckle Thomas</td>
<td>Associate Professor</td>
<td>Scientific Computing</td>
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<tr>
<td>Jacobsen Arno</td>
<td>Full Professor</td>
<td>Application and Middleware Systems</td>
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<tr>
<td>Kemper Alfons</td>
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<td>Database Systems</td>
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<td>Klinker Gudrun</td>
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<td>Augmented Reality</td>
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<td>Knoll Alois</td>
<td>Full Professor</td>
<td>Robotics, Artificial Intelligence and Real-time Systems</td>
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<td>Krcmar Helmut</td>
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<td>Information Systems</td>
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<td>Křetínský Jan</td>
<td>Assistant Professor</td>
<td>Formal Methods for Software Reliability</td>
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<td>Leal-Taixé Laura</td>
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<td>Dynamic Vision and Learning</td>
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<td>Matthes Florian</td>
<td>Full Professor</td>
<td>Software Engineering for Business Information Systems</td>
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<td>Menze Björn</td>
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<td>Image-based Biomedical Modeling</td>
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<td>Navab Nassir</td>
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<td>Computer-aided Medical Procedures</td>
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<td>Neumann Thomas</td>
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<td>Data Science and Engineering</td>
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<tr>
<td>Nießner Matthias</td>
<td>Assistant Professor</td>
<td>Visual Computing</td>
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# Honorary Professors and TUM Distinguished Affiliated Professors

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<tr>
<th>Name</th>
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<tr>
<td>Denert</td>
<td>Ernst</td>
<td>Honorary Professor</td>
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<tr>
<td>Hirzinger</td>
<td>Gerd</td>
<td>Honorary Professor</td>
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<td>Jenko</td>
<td>Frank</td>
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<tr>
<td>Moll</td>
<td>Karl-Rudolf</td>
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<td>Paulson</td>
<td>Lawrence C.</td>
<td>Distinguished Professor</td>
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<td>Runkler</td>
<td>Thomas</td>
<td>Honorary Professor</td>
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<td>Scheer</td>
<td>August-Wilhelm</td>
<td>Distinguished Professor</td>
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<td>Schwärtzel</td>
<td>Heinz G.</td>
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<td>Steger</td>
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## Adjunct Professors and Lecturers

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<tr>
<td>Groh Georg</td>
<td>Adjunct Teaching Professor</td>
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<td>Illic Slobodan</td>
<td>Adjunct Teaching Professor</td>
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<td>Kowarschik Markus</td>
<td>Adjunct Teaching Professor</td>
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<td>Lasser Tobias</td>
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<td>Mundani Ralf-Peter</td>
<td>Adjunct Teaching Professor</td>
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<td>Prehofer Christian</td>
<td>Adjunct Teaching Professor</td>
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<td>Schätz Bernhard</td>
<td>Adjunct Teaching Professor</td>
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<td>Struss Peter</td>
<td>Adjunct Professor for Model-Based Systems &amp; Qualitative Reasoning</td>
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<td>Täubig Hanjo</td>
<td>Adjunct Teaching Professor</td>
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<td>Triebel Rudolph</td>
<td>Adjunct Teaching Professor</td>
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<td>Weidendorfer Josef</td>
<td>Adjunct Teaching Professor</td>
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**Timeline of professorships at IN.TUM since 1967**

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**Note:** The table entries represent various academic positions and research areas within the field of computer science and related disciplines.