**Institution/department:** Information Technology

**Part I. About the research**

The department performs research of very high quality as demonstrated by the ÖB19 reports from our individual research programs. This research is strongly connected to our education, which is essential for the faculty, and below we present reasons for expecting our educational role to increase even further with the digitalization of science and society. The value of FoFu/GU for the whole of Tek-Nat is 1.88, while for IT it is only 1.08\(^1\). This means that our academic staff is hard pressed, and that our room for new initiatives is limited. Even so, the IT department has a track record of joining forces to enable strategic initiatives for renewal. In the text below we discuss three strategic areas where we see possibilities for Uppsala University to make important contributions to society.

This self-assessment is longer than 5 pages. The assessments from the department’s research programs are correspondingly shorter.

\( a) \ How\ does\ the\ department\ view\ the\ balance\ between\ its\ research\ programs?\ Are\ there\ research\ areas\ currently\ absent\ in\ the\ department/section\ (or\ Faculty)\ “research\ portfolio”? \)

Our research concerns computers and how to use computers. Many topics in this area are well covered, and included in our research programs. However, there are important areas that do not fit the current program structure. They all represent significant challenges with enormous potential impact and need more resources to develop at Uppsala University.

**Computer science education research** is an example of a significant area that does not fit into any of our research programs. In the Uppsala Computing Education Research Group (UpCERG) the aim is to understand computing education in a broad sense. This includes technically related areas such as understanding aspects of learning and teaching in different areas of computing and content issues related to whole degree programs where computing is included, but also aspects relevant from a wider social perspective. Examples of the latter are researching how people understand and engage in computing, inclusion and exclusion of certain groups of people, and the importance of different contexts for learning and teaching computing. Contexts addressed include pre-school, schools, universities, companies and informal learning. UpCERG started in the mid-90’s and fulfill today all the characteristics of a research program listed in VP. Some examples of achievements since 2010 are 4 PhDs awarded, 163 peer reviewed publications listed in DiVA, four PhD students are currently active, one senior elevated to docent and two to professors, and organising leading ACM and IEEE conferences in the field. The activities have mainly been funded by external grants (e.g. VR and EU), the researchers have an extensive international network and the group is recognised as a leading group in computing education research. At Uppsala University the group has actively been involved in the creation of MINT, where today Anna Eckerdal is leading the center.

Another example is **Machine Learning**. The area has seen a significant increase since Thomas Schön was recruited to the automatic control (“reglerteknik”) program in 2013, but it has been present in several of our programs also before that. We believe that the entire university would benefit from making this line of research visible and recognized. Machine learning gives computers the ability to learn without being explicitly programmed for the task.

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\(^1\) These value are computed as (Långsiktiga resurser + Resurser fördelade utifrån modeller) / (Fördelat enligt modell baserat på prognos HSTK och utfall HPRK) with numbers from VP2019 http://regler.uu.se/digitalAssets/753/c_753790-l_3-k_teknat-vp19-till-webb.pdf
at hand. Machine Learning constitutes the mathematical and algorithmic core of Artificial Intelligence (AI), and it is currently one of the fastest growing technical areas. Over the past five years the Machine Learning team has grown from 1 Professor to now also include 1 tenure track associate Professor (a strategic initiative of the department), 7 postdocs and 10 PhD students (1 PhD student has graduated so far). Almost all of this is funded using external grants from VR, SSF and Wallenberg. The research group is one of few within Sweden that conducts basic research of high international standard within Machine Learning. As one indicator we can mention the fact that Schön is the only individual researcher associated with the WASP project (Sweden’s largest individual research program ever) with the following motivation from the WASP board "Enskilda forskare kan anslutas om det bedöms avsevärt stärka och komplettera satsningen. Enda hittills är Thomas Schön". Via WASP we also have a unique opportunity to significantly leverage (financially) an Uppsala University investment over the coming decade.

Our third and final example is Cybersecurity. It is, and will increasingly be one of the grand challenges of IT systems, and of the critical physical infrastructure and equipment that they control. Penetrations of systems that are critical for, e.g., health care, control of industrial plants, power distribution, or data repositories, are reported regularly, and may cause untold harm. Cybersecurity is a wide concept with sub-concepts such as secrecy, integrity, and authenticity, cutting across IT system design at all levels. Cybersecurity is also a rich scientific field, where many challenging problems are still open, and some even poorly understood. It is one of the favourite topics among students and an important topic for collaboration with industry.

Most IT departments have programmes and research groups on security. Uppsala University does not, but several groups in our department have for many years conducted security research in their respective domains. As one example, there is a stable collaboration with FOI on threat detection, through the IT department’s Security Arena. We are now rapidly increasing our efforts. This is in response to increased interest from students, industry, and society, and partly due to a significant increase in obtained external funding, including several SSF-supported projects with a total volume of around 30 MSEK over the next 5 years. The Uppsalabased VINNOVA Strategic Innovation Program on Internet-of-Things has identified security as the most critical issue. Many funding agencies, including the EU in Horizon 2020, are funding research on security, and such support is likely to increase in the future.

b) Which resources are available within the department, in addition to the research programs, where research is conducted (centers, nodes, etc.)?

Uppsala Computing Education Research Group (UpCERG) is described above.

The Centre for Image Analysis (CBA) promotes development of theory in image analysis processing as such, but also development of better methods, algorithms and systems for various applications primarily in digital humanities, life sciences, and medicine. CBA was founded in 1988 as an independent research unit, has been hosted by the Dept. of Information Technology since 2011, and is currently the largest academic image analysis group in Sweden.

Uppsala programming for multicore architecture research center (UPMARC) was initiated 2008, and is one of only 4 Linnaeus centers at Uppsala University. The focus is tools and approaches to make parallel programming easier. Activities include infrastructure for collaboration, summer schools, postdocs and Ph.D. students. The UPMARC funding expires after 2018-

c) Are there other research collaborations at department level (in addition to what is reported
in the program self-assessments)?

The IT department uses the concept of a research arena as an informal platform for collaboration and networking of researchers across the divisions. The arenas enable collective efforts to launch new lines of research and help form constellations that can seek funding for major research projects. Examples are the arenas for Biomedical IT, Applied optimization, Machine learning, Smart City and Security. Departmental funding is used to enable continuous arena activities, such as seminars, workshops, research visits, as well as for more focused activities. Joint funding was used to support so-called SPARCs (Scientific Project to Accelerate Research and Collaboration) within the Biomed-IT arena. The aim was to catalyze new research collaborations between IT and medicine/life science. To boost new areas, significant departmental funding was also used to support the recruitments of an assistant professor (biträdande lektor) in Machine learning (2016) and a professor in optimization (2014).

d) Which departmental (or faculty) joint resources are available for research; staff, infrastructures etc.?

The department is heavily involved in eSSENCE, one of the two national strategic research area (SFO) efforts in e-Science. eSSENCE is led by UU, with its director at IT, and includes the Universities in Lund and Umeå. The mission of eSSENCE is to pursue collaborative research on new methods and tools for computational and data-driven research. The SFO is a central platform for connecting research within several of our programs with computational and data-driven research in other fields. It is especially important for the program Computational Science (Tillämpad beräkningsvetenskap).

The Center for Interdisciplinary Mathematics (CIM) facilitates joint research between the mathematical sciences, other disciplines, and industry. The center co-funds PhD students working on interdisciplinary projects, organizes seminar series, thematic semesters, and workshops. CIM is also an important platform for initiating new interdisciplinary collaborations.

Science for Life Laboratory, SciLifeLab, is a national center for molecular biosciences with focus on health and environment, which provides researchers from all of Sweden with technology and know-how through a number of facilities. The Dept. of IT houses the SciLifeLab BioImage Informatics Facility, which provides support and education in image analysis. Methods from computer vision, machine learning, statistics, and bioinformatics are combined to extract quantitative information from image data and answer biomedical and biological questions.

The strategic innovation program Internet-of-Things Sweden (SIP-IOT) has its program office at UU, and is an important support for industrial contacts for our strong activities in this area.

The department is involved in the center for medical technology, Medtech Science & Innovation, mainly through our research on medical image analysis and sensor technology. Our emerging areas cybersecurity, machine learning, and also the socio-technical aspects from computer science education research will clearly be very relevant, and we see possibilities for increased involvement in these areas.

UPPMAX provides computational and storage resources that are essential for the research and education at the IT department. The research and education on high performance computing (HPC) and computational science require large scale computational resources. Data-intensive applications involving for example machine learning on large image datasets, require storage capabilities and cloud computing resources.
Part II. The department’s role and significance for education at all levels

e) The department’s reflections on and aspects of first- and second-cycle courses and study programs (UGA) and postgraduate education/education at doctoral level, beyond what the programs have described?

Delivering high quality education is an important activity at the department. Since 2010, approximately 4000 students per year have taken part in the education and this number is likely to increase in the near future, as discussed below. Educational development, both regarding course and program offerings, and pedagogy, is prioritized and teaching staff are offered ample opportunities for pedagogical inspiration and discussion. A result of this is that 13 of the faculty’s 35 excellent teachers are from the IT Department.

With the digitalization of science and society the need for a broad range of computer related competences is increasing, and will continue to increase in the foreseeable future. There is a growing need for education both of future experts and researchers in information technology, but also for teachers, and professionals in many other fields. Also important is the fact that IT is a rapidly developing field, and the education needs to be continuously developed to be relevant. The department has identified the areas machine learning and cyber security as areas with high societal demand, and where we are also seeing a strong interest from students.

To be able to provide top education in these emerging topics, it is crucial that research and education are developed hand in hand. Strengthened research in these areas will also enhance quality in the planned new branches of education, data science, data analytics, image analysis and machine learning.

Corresponding to the increasing role of computers and IT in society, the use of computer based tools in the education in all subjects must increase. The department has an important role to support integration of scientific computing/computer science tools into the disciplinary science courses at the faculty. We expect the integration to begin with physics, mathematics, and chemistry, and then continue with biology and geology. These are educational directions that fit well into existing engineering programs, in master programs and in postgraduate education. In a slightly longer perspective we expect a significant increase of the IT aspects also in the educations in the caring sciences, social sciences, and humanities.

With the increased demand for IT education, there is an increased need to understand how topics in IT are learned and thus are best taught. The research on computer science education contributes to this understanding in the local as well as the global context, and is therefore important for quality in our education. This research is also crucial for providing high quality teacher education for teachers at all levels.

The research conducted at the Department is highly visible in the education, particularly at the advanced and postgraduate levels. Our project courses include research both content wise and in approaches, e.g., use of literature studies and peer reviewing, focus on professional competences such as group interaction, planning, design, communication, etc. Sometimes students’ coursework result in conference publications.

To best utilize the breadth of competence within the Department, the aim is to merge the divisional educational structures into one departmental structure. Cross-division educational collaboration opens for students to achieve competence profiles that span historical subjectboundaries within IT and hence develop the field in new directions.

Part III. About collaboration

f) If relevant - describe the departments contacts with industry, authorities, civil society, NGOs etc. as well as utilization (including commercialization) of research results, beyond
what the programs have described.

Researchers at the department have extensive collaborative contacts, which are to a large extent described by the research programs. Here we only list very few examples of department-wide ongoing projects and activities.

Examples of activities on department level aimed at initiating collaboration are the AimDays on Internet-of-Things (October 2015), Machine Learning in Life Science and Biomedicine (May 2018), and Math in Industry, (October 2017), and a Workshop for initiating new collaborations with GE Healthcare in connection with the Testa center (April 2018).

There are many collaborative efforts involving several research programs. Some examples that demonstrate our involvement in our emerging new areas are listed below:

- The **HASTE project** involves researchers from two different research programs, is funded by SSF, and takes a hierarchical approach to acquisition, analysis, and interpretation of image data in close collaboration with Astra Zeneca and Vironova AB.

- **ANIMATAS** is an EU H2020 project focused on developing computational social learning techniques for robots to learn behaviours that are ethically appropriate in an educational scenario where the robot plays the role of an educational agent, i.e., identifying the appropriate values and the decision mechanism for promoting those values in human-robot interaction. The project involves a number of academic partners as well as companies such as Furhat Robotics AB and SoftBank Robotics.

- The goal of **The GreenIoT - Smart City project** is to develop an integrated system based on internet-of-things for monitoring air pollution and smart city planning. Collaborating partners are Ericsson Research, IBM, KTH, SICS, SenseAir AB, Uppsala Kommun, Upwis AB and 4Dialog AB.

- The EU H2020 project **CoM’n’Play Science** aims at investigating the role and effect of non-formal “coding, making and playing” science activities and their relation to formal education in Europe. Sweden is represented by researchers from two different research programs and involves collaboration with many providers of such activities, e.g., Hello World and Komtek.

- **FOI (Swedish Defence Research Agency)** funds a long-term collaboration regarding detection of terrorist threats on internet.

**Part IV. About the future**

**g) Are strategic plans available also at the department (section) level? If so, summarize these.**

As computers are being used in increasingly many areas in society, there will be a strong need for our skills, and great possibilities for us to contribute to future advances in both new areas and old. The goal is to be at the forefront in a broad set of areas, both when it comes to scientific depth, and to relevance for society. This requires constant renewal of focus, and collaboration with others. On departmental level the current strategic efforts are focused around the three areas identified.

**h) Briefly describe a vision for how the department as a whole will be developed during the next five years, including at least three concrete goals.**

**Artificial Intelligence (AI) and Machine Learning (ML):** Progress in AI and ML will continue changing our way of life by transforming area such as health, science, transportation and finance. We are already seeing this happening in our society and we believe Uppsala University has a very important role to play here and that we should aim to be proactive in the way this new technology affects our university, Sweden and humanity in general. The
department (as a response to an invitation from the Vice Rector) currently leads a coordinated effort at Uppsala University in Artificial Intelligence and Machine Learning to develop a plan for how Uppsala University as a whole can work with these developments and take control of the development rather than being controlled by the development.

Over the coming five years we want to:

- Further reinforce Uppsala University as the obvious leader in both basic and applied Machine Learning (the mathematical and algorithmic core of AI) research in Sweden.
- Be well recognized at the international forefront of Machine Learning research.
- Establish a university-wide team that can work with these game changing developments in a proactive manner to aid the entire university and the surrounding society. An important part is to ensure that the technology spreads rapidly to renew research and educational programs throughout the entire university.
- Provide relevant and interesting education of the highest international standard within the area of Machine Learning.

The effort includes collaboration and coordination between many departments throughout the university, and with platforms such as Upptech, MedTech Science and Innovation, SciLifeLab, and the e-science SFO eSSENCE. The Dept. of Cell and Molecular Biology has already expressed a strong interest to collaborate on AI for life sciences. Success requires support for basic research in Machine Learning, as well as support for interdisciplinary activities. There are currently very few people at senior level with knowledge in this topic and we believe that Uppsala can take a leading role in this development and in a proactive manner help society.

**Computing education research:** UpCERG encompasses a broad spectrum of areas related to computing education and we envision that the group has grown to leverage the unique position it currently has and continues to be a leading actor in this relatively new research area. The group will continue to be involved in running international conferences through ACM and IEEE, as well as conducting regular seminars both nationally and internationally.

Focus areas will be

- Understanding computational aspects in the school system. The starting point is the research on competencies, identity and role models. In the new setting sustainability and diversity will also be important.
- Educational issues with an international perspective. The work will consider competencies needed in global projects, and understanding of cultural influences in computing education.
- Collaboration within the department on education will ensure that new results directly influence and improve the education at the department and the faculty.
- UpCERG leads through MINT a coordinated faculty level effort to establish education research in disciplines where it is emerging.

There is an expectation that UpCERG will continue to bring in external funding, but dedicated long term funding for computing education research is necessary for the vision presented to be possible. Furthermore, additional support is essential for spearheading emerging discipline based education research in other subjects at the faculty.

**Cybersecurity:** Our vision includes a targeted initiative to establish and support cybersecurity as a core competence in the IT department, which would be very important, very timely, and very fruitful. With increased long-term support, we can recruit faculty members
with strong expertise in cybersecurity, which can develop the area and position the university for the future. Such an initiative will also be a platform for contacts and collaboration projects, both externally, and across the department. It will reinforce existing and fledgling efforts, which currently exist in different areas, including

- software security: ensuring software is secure against intrusion, data leakage, etc.,
- network security: security of networks and communication protocols,
- security and safety: of systems that control vital physical equipments and infrastructure,
- information privacy: ensuring that private information is not leaked, and
- threat detection: identifying potentially malicious individuals and software agents.

Many of our groups that work in these areas have a strong track record of collaboration in previous larger research efforts, such as the UPMARC Linnaeus centre, the WISENET competence centre, or SSF-funded framework projects. A cybersecurity effort would naturally sustain these and new collaborations, e.g., with machine learning. Collaborations within Uppsala University with the faculties of medicine, law, and social science will also be a strong possibility.

**Recruitment** is the most important strategic instrument. We will ensure that retiring professors now at age 60 or above are replaced by either recruitment or promotion in strategic areas with respect to both research within the research programs, and to interdisciplinary efforts at departmental and/or faculty level.

**On the educational side** the IT content in many study programs must increase, and the way courses in other subjects are taught must change to reflect the shift towards IT based methodology. Our vision includes an increasing involvement of the IT department in education at all levels. Specifically, there will be strong developments of the curriculum in cybersecurity and AI. There is already strong demands for such courses from students, on basic, advanced and PhD level.

*i) Describe any plans within the department for changes to its research programs (notwithstanding ÖB19)?*

A research program in Computer Science Education research is desirable. Some existing program funding could be used, but significant additional long-term funding is essential.

We want to make our successful Machine Learning activities visible in the research program structure. To further support this area increased long term funding is needed, which would make it possible to create a new research program. As described in 1c) the department has created an informal platform (arena), and already uses significant joint resources to support the machine learning activities.

The important and growing research on Cyber Security needs support and visibility. The department already supports the area through a newly created arena (see 1c), but additional long term funding is needed.

*j) Which obstacles exist hindering better research in the broadest sense according to the department (in addition to lack of financial resources)?*

To promote research that makes a difference for the big challenges in society we believe there is a need for stronger incentives to look at important problems from the different points of view that our broad competence allows. Possibly could structural changes enhance a broader view. The system with research programs seems to be too rigid and too conservative to adequately support the joint efforts that are needed to take on the big challenges. We also
believe that an increased diversity on senior level would help.

We are recruiting top international students as interns and as Ph.D. students. This is often difficult due to the long and unpredictable visa process with the Swedish migration agency.

**k) Describe a few “silver bullets” that would significantly improve the department’s prerequisites to pursue even more successful research, including estimated costs for these?**

To enable the developments in our vision for the future, long term support is needed for the activities in Machine Learning, Computer Science Education and Cyber Security. We believe the support needed is at the level of at least 1 FFF for each of these areas. Especially Cyber security is strongly interdisciplinary, and needs a different structure than the traditional research program.

**l) Which initiatives could be implemented if the department received an increase in the basic funding with 2 or 5 million SEK/year? If a lump sum of 2 or 5 million SEK was allocated to the department, how could this be used in the best manner (within the department or coordinated with other departments/faculties or with external partners)?**

With 2 M SEK/Year we suggest long term support for Machine Learning and, Computer Science Education.

With 5 M SEK/Year we suggest long term support for Machine Learning, Computer Science Education, and Cyber Security.

A lump sum could be used to boost the new directions by a short-term guest researcher program, workshops, and strategic sparc projects. It could enable sabbaticals at strategically chosen institutions for a few members of our academic staff.