4TU.NIRICT follow up of Community Day 22-11-2017

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Positioning ICT science: challenges & directions

This document describes the results of the discussion that took place at the 4TU.NIRICT community day that was held on 22-11-2017 in Utrecht on the topic “Position of ICT research community amidst policy developments”. The discussion started from the observation that society increasingly asks that research is performed within the context of concrete societal, technological or economic challenges. Examples are the requested contributions from industry in HTSM and FP9, and applications addressing society-wide challenges in NWA and VSNU Digital Society.

This trend gives rise to opportunities as well as challenges for ICT researchers:

- Too applied: As an engineering profession, the connection with concrete applications is inherent in what we do: whether our research is use-inspired or more fundamental, eventually it is targeted towards creating better Information and Communication Technology to serve society. On the other hand, it is often expected that we provide ready-made solutions to be used in research within a particular application context. Such solutions are not always available or can seem uninteresting from an ICT research perspective.
- Connecting with domain experts (vertical): digital technology becomes more and more pervasive in society. This puts ICT in an excellent position to play an important role in these developments. However, focusing only on our own position and the role of ICT has the risk of alienating domain experts as prospective future collaborators. How can we serve application contexts without losing our own identity?
- Crosscutting (horizontal): ICT is crosscutting through various application contexts. On the one hand techniques that we develop can often be used in various contexts, and at the same time for the purpose of research we often need to focus on a particular context. For this we need to acquire some domain knowledge, yet we cannot and do not want to become domain experts. How can we find the right balance in this, in particular when working in multiple domains?

The discussion centered around a the question how can we make use of opportunities provided by frameworks like the VSNU Digital Society while addressing its challenges. In particular, we focused on the following subquestions, each inspired by a proposition to stimulate discussion:

- Best practices: what do we do now that works well and why?
  Proposition: Application oriented research is key for identifying fundamental research questions
- Changes: what do we – as individuals and community – want to do differently and why?
  Proposition: Veni/Vidi/Vici is not suited for ICT research, because we have to be fully aware of the context as ICT researcher
- Barriers: what are barriers for these changes and what can we do to remove them?
  Proposition: Fundamental research is considered of higher quality than application oriented research

In what follows we describe the results, further reflection and points of action that emerged from this discussion.

1. Introduction: use-inspired research

ICT is everywhere. Our society has become ICT dependent and maybe even ICT addicted. ICT has become a driving force behind fundamental and applied research and industrial innovations. For instance, big data and data science has changed the way drug research for curing diseases is done, invasive surgery has been boosted because of the improvements in image analysis, while software is a crucial factor in reaching nano-scale in lithography. These developments have stimulated ICT but also created challenges. ICT research has to dive more and more in an application area in order to be able to finance their (fundamental) research and to search for new fundamental questions and get inspired by problems.

ICT Science is an engineering science: our ultimate aim is to investigate how to create better ICT.[1] Creating better ICT requires that we study and advance four core aspects of our field: theory, methods, and tools for 1) computation, 2) engineering ICT, 3) understanding how end users interact with ICT, and 4) transforming society by means of ICT (move towards digitalisation) and studying the effects of this transformation.

On all four aspects research in ICT can be *design*, creating e.g., a new theory or method, or *empirical* - observing the workings of an algorithm, engineering process or ICT usage and analyzing this data, or a combination. This is in line with what is referred to as the "scientific paradigm" of computer science [1] in which the discipline is viewed as combining *a priori* knowledge through formal deduction with *a posteriori* knowledge through scientific experimentation. In the former sense, ICT can be compared to mathematics in the construction and formal analysis of mathematical objects, and to other engineering sciences such as civil engineering. In the latter sense, ICT can be compared to natural and social

[1] Interestingly, this is confirmed by Wikipedia which states that even theoretical CS is considered to derive its motivation from practical challenges: "*Theoretical Computer Science* is mathematical and abstract in spirit, but it derives its motivation from practical and everyday computation." https://en.wikipedia.org/wiki/Computer_science

sciences, in which an existing phenomenon is studied with the aim of better describing and understanding it. The difference is that the phenomenon under investigation is (in part) what is created through applying the results of ICT science. The outcome of empirical studies thus feeds back into creating better theories and models for ICT. That is, empirical studies in ICT are performed not only to better understand the phenomenon under investigation, but as a step towards engineering better ICT. ICT can be characterized as an engineering discipline that creates complex artefacts and studies the complexity of these created artefacts.

While ICT can thus be seen as an engineering science, it is important to distinguish research in ICT from engineering ICT. Moreover, we need to distinguish *fundamental research* - for example studying which factors influence programmer productivity, or formal specification of a new type of programming language, and *use-inspired research* in ICT - for example research in behaviour change support systems or crowdsensing. These differ with respect to their main outputs and applicability (see Figure 1).

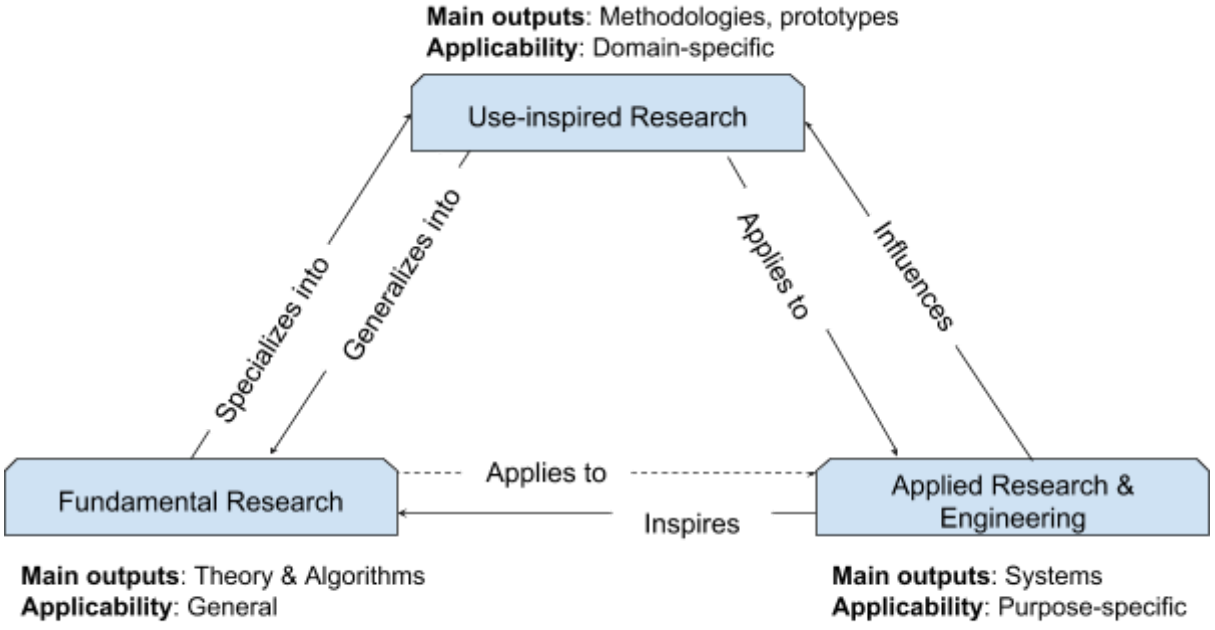

Figure 1: Visualisation of types of research and dependencies.

a. Current ICT research landscape

ICT research in the Netherlands is performed at (technical) universities, research institutes, such as CWI, TNO, eScience center, and (software) industry and society. There is a lot of interaction between these three bodies. On the scale of fundamental versus applied research a rough classification is that fundamental research is mainly done at the universities and CWI with higher risk and longer timespan and applied research mainly by TNO and the industry with lower risk and shorter timespan. Of course, there is cross-fertilization and interaction between these bodies and the border between fundamental and applied may be vague. The main goal is to increase the body of knowledge on ICT, to educate the next generation of ICT researchers (read PhD students) for both academia and industry, and to enable ICT innovations and create business opportunities in industry.

Companies have challenging concrete problems that lead to fundamental research questions, or challenges related to scalability of tools and techniques developed in academia.
The interaction with other disciplines, for instance medicine or physics, leads also to new research opportunities, ICT as enabler to do research, in these cases it is not only data but also the development of software to do fundamental research. Consider NL-RSE (Dutch branch of Research Software Engineering), this organisation promotes the use of software engineering results in the area of academic software development.

The role of the various actors is also different. This can be explained using the Technology Readiness Level[2], introduced by NASA to determine the maturity of a technology. Universities typically are interested in more high-risk, long-term technology research (TRL levels 1-3). Research organizations are more focused on technology development and validating technology in realistic conditions (TRL 4-6). Industrial partners are more interested on deploying technology in operational environments, in a competitive manner. While university, research organizations and industry perform use-driven research and have overlapping interests, they also have distinct roles to serve, as illustrated in the Figure below.

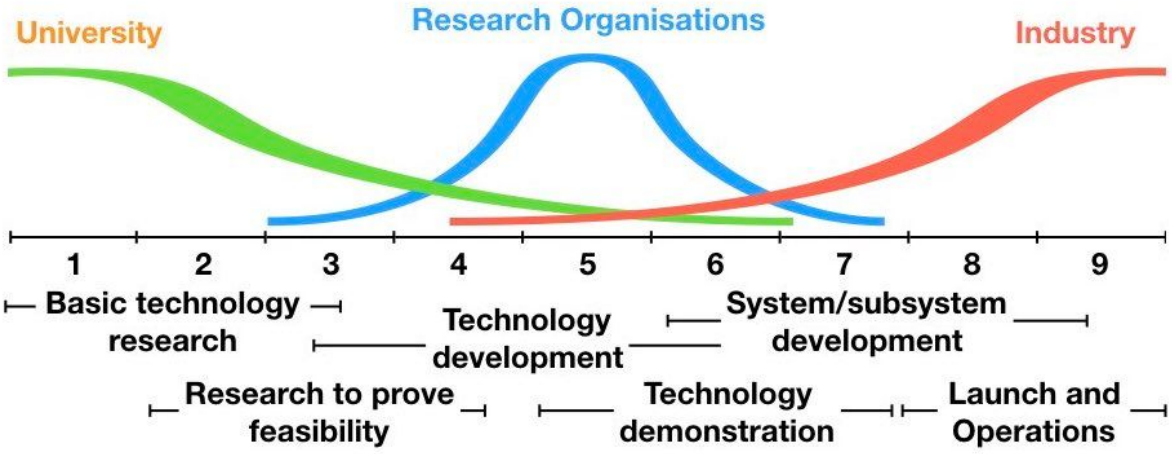

Figure 2: The different roles of university, research institutes and industry in use-driven research.

There are four major challenges. The first is the difference between the **time span** of research at the university and the solution needed by industry. Four years of research by a PhD student versus solving the problem of today. It is important to identify short term problems which have sufficient substance to allow a PhD student to investigate and write scientific papers. A similar challenge arises when doing research in joint projects with other disciplines: they need the outcome of the ICT research in order to do their research, but cannot wait for the ICT PhD student to finish. The second challenge is the **intellectual property**. There may be issues with publishing results which are directly related to the main activities of a company. This depends to a large extend on the size of the company, bigger companies have in general less of an issue. The third challenge is the **financing** of PhD research. PhD students are considered too expensive for a lot of companies, specially the

[2] See https://en.wikipedia.org/wiki/Technology_readiness_level

SME companies. As a result, the threshold for SMEs to benefit from our research is much higher than the one of larger companies. In order to maximize ICT's impact in our society, such issues need to be addressed. The fourth challenge is that some industrial partners are reluctant to use or **depend on academic prototypes**. If there is an (intermediate/startup) company involved these industrial partners are more eager to use products derived from academic research, this is mainly to ensure the continuity. These startups can bridge the "valley-of-death" when transfering research results to industry.

2. Where can the 4TU.NIRICT community go from here

In this section we outline the required changes that our community has to go thought in order to be more effective in positioning ICT research and to foster collaboration with other parties.

Required Changes

In order to be effective there should be a healthy ecosystem of universities, research institutes and industry, as well as open interactions between those. It takes a lot of time to build up a good relation between a research group and a specific company. A research institute, such as ESI/TNO, can be of great help to bridge the gap.

There are quite a number of funding opportunities to enable research between companies and academia, for instance HTSM (Top Sectoren) and TTW Perspectief on the National level, and ECSEL and H2020 on the European level. These programs are geared towards industry-inspired research and transfer of knowledge between the partners.

First and foremost, it is of utmost importance to make the role of ICT research understood by funding agencies, companies and the Dutch society that assist, support and benefit from our research outputs. ICT's research goal is not to perform mere engineering tasks with some research angle. Instead, it focuses on use-inspired or fundamental research and does not necessarily have immediate effects in the society or the industry. Research is characterized by its high-risk, high-return nature. Both the society, and funding agencies ought to embrace the high-risk that research entails; not all results will be positive, and the possibility to fail should be taken into account both when research proposals and research results are evaluated[3].

On the other end of the spectrum, applicable research results need to depart from research institutes and be monetized in a timely manner, without bureaucratic processes standing in the way. For this to happen research institutions have to alter their structure and practices, but most importantly, the mentality of researchers should be altered in a way that they understand and embrace entrepreneurship.

Industrial partners that directly fund and benefit from research outputs need to respect the openness of the scientific process, and allow the timely publishing of research results, instead of blocking them with strict non-disclosure agreements. Keeping scientific results behind closed doors is not a choice, especially since research institutes are mostly funded

[3] Some communities have solutions for such issues, https://jnrbm.biomedcentral.com/

by public, taxpayers money. Any attempt of the industry to fund research with the goal of influencing research results should be blocked at very early stages. Just like openness, integrity and objectivity are very foundational principles of research. Since the industry and research have conflicting interests, they have to meet in the middle: industry partners can take fund research and make profits, as soon as research is performed within the three foundational principles.

As an academic community we need to make steps into understanding societal and industrial needs and try to meet industry half-way, by stepping out of our comfort zone. We need to seek out for inspiration and funding from the industry but also create a better environment for collaboration between research and industry, and make sure that both benefit from their collaboration. Research institutes are often regarded by industry as too sterile and theoretical. On the other hand, industrial projects are often been regarded by researchers as mere engineering. Both sides should re-evaluate their views of each other.

It is our role as ICT research community to pass over all these messages to the respective stakeholders and demand changes in our future collaborations. Research partners should take hard decisions and reject funding when that has the wrong strings attached to it. Through dialog we need to create avenues for industrial and research partners to collaborate more and achieve higher impact.

Barriers preventing changes

The barriers preventing us from changing our practices are both intrinsic and extrinsic. First, any *change in our research culture* cannot take place before our community realises the problems and proposes solutions. Moreover, the *institutional and organizational structures* that perform allocation of funding are slow and difficult to change their practices. Funding agencies but research institutes themselves find it very hard to evaluate and most importantly justify negative results to taxpayers and governments. Finally, industry partners use their funds to sometimes dictate their research agenda and maintain the intellectual property of the results. These conflicting goals are very hard to accommodate and require deep changes in the culture of our industrial partners.

3. Overcoming barriers

In this section we discuss how we can overcome the barriers to more effective positioning of ICT research and collaboration with other parties. We focus on *what we can do ourselves* as 4TU.NIRICT community i) within our community, ii) regarding our relation with possible collaborators, and iii) in relation to funding agencies.

3.1 Within 4TU.NIRICT community

Positioning ourselves and functioning effectively as a community means that we consistently *tell the same story* and have a common understanding of who we are when we represent the community in various contexts.

A major challenge in doing this is the diversity of the field concerning i) the *subject* of research ranging from theory, models and tools for computation to societal transformation through ICT, ii) the *type* of research ranging from design to empirical, and iii) the *applicability* from generic (fundamental) to domain-specific (use-inspired). Moreover, as an engineering *science* it is important that together we understand and can explain its relation with engineering (Fig. 1).

Overcoming these barriers requires that ICT community members make conscious and additional efforts to jointly shape and understand our story, respecting the breadth of ICT research.

In particular, in order to fulfil our (academic) role and strengthen interaction with industry and governments, the 4TU.NIRICT community should clarify what we mean by high quality fundamental research and high quality use-in*spired research*. Both can be of equally high quality, and we need to support this as a community. Research can have business value, societal value, and/or academic value. This means fleshing out more precisely what this means for ICT research such that both funding agencies and community members who take part in NWO committees can take this into account when evaluating proposals in which ICT plays a role.

Moreover, the 4TU.NIRICT community has a responsibility to *define a societal relevant ICT research agenda and key challenges*, in order to proactively take position as ICT researchers in the context of larger funding schemes. This can be achieved via a better “internal” organisation. The Cyber Security community is exemplar for their organisation and outreach to governmental and industrial stakeholders. Other communities within the ICT domain should strive for a similar organisation. ICT researchers should be more aligned in evaluation committees to increase the chances of success for getting funding. Given the restructuring of NWO this will even be more important.

3.2 Relation with other research domains, research institutes & industry

From this joint understanding of who we are as a community, we can relate more effectively to collaborators in other research domains, research institutes and industry by better *explaining* what is the value of both fundamental ICT research *and* use-inspired research in relation to engineering.

To overcome the barrier that research is slow while industry and other collaborators need concrete engineering solutions to make progress we need to *build lasting relations* with them so that this bootstrapping problem is addressed by being able to build concrete solutions based on previous results. The creation of colocation centers where researchers/engineers from industry work together with academics may facilitate this, and could lead to new ideas and allows a direct interaction with respect to ideas, prototypes and opportunities. Moreover, we need to step out of our comfort zone of “pure” and deep research and also pick low-hanging fruits by creating prototypes that can be built on by parties performing applied research and engineering.

Sharing best practices among community members in new ways of collaborating with these parties and building fruitful collaborations is important and could make us more effective as a whole.

To overcome the barrier that research is open while industry remains closed, we need to have an open discussion with the direct stakeholders in technology companies, startups, big corporations, and consultancy companies and do not involve the legal departments too early. The legal departments should be by the (industrial) stakeholders and not the other way round. In many cases researchers are not allowed to publish concrete results or company data, and it requires effort to generalize or abstract from these results and data in order to get a publication. Another way is to directly involve the company stakeholders as authors on the publications. This creates sometimes extra space.

In the design of the collaborative projects, we need to make sure that *high risk research is balanced with more straightforward steps* such that collaborators can safely build on the latter results.

3.3 Funding agencies

In order to address the issue that the organization structures that perform allocation of funding are slow and difficult to change their practices, we need to take the initiative to actively and constructively propose required measures to funding agencies.

In particular, to overcome the barrier of the difficulty of justifying negative results to taxpayers and governments which may lead to risk aversion in research, we need to *propose ways of evaluating also negative results* (and replication studies). We need to clearly express and convey the importance of such research, as well as ways in which negative results that are the result of high risk can be distinguished from negative results that are the result of poor science. Submitting for review already the design of a study and corresponding hypotheses before actually performing the study may be a way of addressing this issue in case of empirical research.

4. Action plan

To concretize these ideas, we foresee the following main actions as starting points towards reaching the goals outlined above. We distinguish actions that we can do within the 4TU.NIRICT community, and those that concern outreach to other parties.

Internal

- **Writing the story of (4TU) ICT research**: before we can tell the same story, we need to define and write that story. To this end, the 4TU.NIRICT board will organize a discussion during the coming community day to come to a shared understanding of how to characterize the (4TU) ICT research field, taking Section 1 of this document as a starting point. This discussion will bring together 4TU.NIRICT research from different parts of the field as highlighted in Section 1, to discuss, e.g., differences in research approach and ways of evaluating results. The 4TU.NIRICT board will take

the initiative for writing a follow-up document in collaboration with community members to capture the results of that discussion. This will serve both to explain our field to other parties, and to create mutual respect and understanding within the field.

- **Sharing best practices regarding collaboration with industry and non-ICT researchers**: the 4TU.NIRICT board will organize a discussion during the coming community day to facilitate this. In particular, this will include a discussion on how to evaluate negative results and how to organize projects such that they balance high-risk and more straightforward steps. We will aim for inclusion of people from industry and other research fields in this discussion.
- **Organizing the field along a societally relevant research agenda**: the 4TU.NIRICT board will organize a discussion at the coming community day to discuss how we can better organize the field and define a societally relevant research agenda, taking the Cyber Security community as an example.

External

- **Creating and distributing an action plan targeted towards industry, governmental organizations, and funding agencies.** This action plan will be distributed among the following organizations, to collect their feedback and gather support:
    - ICT Next Generation (ICTng)
    - ICT Research Platform Nederland (IPN)
    - ICT Top Team
    - NWO Informatica Tafel

References

[1] A.H. Eden. Three paradigms of Computer Science. *Minds and Machines*, special issue on the Philosophy of Computer Science, Vol. 17, No. 2 (Jul. 2007), pp. 135-167. Springer.