Strategy of the DigiWorld PRA for the years 2020-2025

Current global trends in the field addressed by the DigiWorld research area, principal challenges and research problems

To say that digitalization is an ever accelerating phenomenon is, to all practical purposes, as good as saying nothing. What matters is its impact on various scientific disciplines: those in the area of engineering as well as life sciences, social sciences and humanities. The actions carried out in the DigiWorld PRA will address the 'convergence points' of technology and the scientific disciplines which exert the most powerful impact on the state of the art in research and on society and economy; they will also be concerned with searching for new, insufficiently explored grounds, and they will focus on the improvement of research quality through the use of the most recent technological achievements.

The advancement in general-purpose graphic processing units since 2007 has brought about not only the acceleration of computing thanks to parallelization, but also – combined with exponential surge in volumes of data – a methodological boom: over the last decade deep neural networks have revolutionized, among other things, the processing of image, sound and text, transcending (extraction and transfer of painting styles, simultaneous translation of conversations or lip reading; beating world champions in the most complex of strategic games; machines autonomously learning to move around and to manipulate objects in complex environments). They are employed by numerous technology giants such as Google, Microsoft, Facebook, IBM, Baidu, Apple, Adobe, Netflix or NVIDIA, but ready tools are used by a staggering number of companies and institutions (recommendation engines, advertisement targeting, automation), thus affecting society and economy on an enormous scale.

Deep learning of neural networks – but also classic methods of machine learning and other advanced computational methods – also make for a useful instrument when it comes to processing large sets of data in many scientific disciplines. For instance, the last six years have seen the advent of qualitatively new natural language processing tools (so-called word embedding), which may be used in the pursuit of language, literary, media, historical, legal and social communication studies, to name a few. Similarly, the progress in image processing has been instrumental in diagnostics using all kinds of medical imaging techniques, microscopy etc. Related methods are employed for designing drugs, anticipating qualities of new particles or searching new elementary particles, but also for tracking and predicting the behaviour of markets. In purely technological terms, FPGA circuits are being developed, which constitute material implementation of artificial neural networks. At the same time, theories and technologies related to quantum information have progressed, including cryptographic algorithms, which touch upon all things cyber safety.

Given the vast impact range of such methods, it comes as an important challenge to ensure that we develop systems open to human interpretation (known as explainable AI); research of note here include theoretical studies of knowledge representations as well as training and designing such systems. Adjusting them, in turn, to the analysis of small, very precise sets of data is significant from the point of view of digital humanities. Social sciences, on the other hand, must not compromise on investigating, continuously, the multi-faceted impact of the digital transformation on humans and society (ethics, law, politics, security, economy etc.).

JU strengths in the DigiWorld research area

Considerable diversity of the faculties participating and the ever closer collaboration between their individual research teams constitute a significant asset in terms of research interdisciplinarity.

Those faculties carry out high-quality research (categorized A/A+; they employ eminent scholars with h-index over 20, sitting on important editorial and reviewer bodies; their PRA category publication output is above the JU mean average in terms of the Scopus Q1 journal publication), which manifests in the increasing success rate of their staff's applications for grants, also international ones (in the years 2014-2018 they acted as principal investigators in 16 international projects; they received, among others, two FNP TEAM-Net grants in the area of AI and quantum computers).

In terms of research internationalization: the number of students from Eastern Europe and Asia is on the increase; there are more outbound and inbound students, doctoral students and academic teachers on and from longer visits at research centres abroad (over 3 months); more than half of the published papers are written as international collaborations. The staff participate in university partnership networks (UNA EUROPA, Coimbra Group, The Guild and others).

There is infrastructure available: computational (e.g. supercomputers at the Faculty of Physics, Astronomy and Applied Computer Science, FPAACS), experimental (fMRI, EEG, TMS at the Faculty of Management and Social Communication, Faculty of Philosophy and the FPAACS) and teaching (Third Campus and new structures at the Second Campus). An additional asset is the proximity of the Krakow Technology Park and the relations with hi-tech companies. The faculty staff also have experience in mass education and science communication.

JU weaknesses in the DigiWorld research area

We identify the main weaknesses as related to the existent obstacles in the development of researchers' human capital, including: the employment policy resulting in a low percentage of research groups with origin in external (global or domestic) research circles; excessive workload in terms of teaching and administrative duties; relatively low remuneration compared to the pays at the market; no young researcher mentoring programmes on offer. This reveals the age structure of the staff to comprise too few young and dynamic researchers.

The progress in the PRA will also be negatively affected by the lack of mechanisms for initiating interdisciplinary collaboration, the tendency, among some of the staff, to carry out individual research with a narrow thematic focus and negligible impact on the advancement of global science, and low incidence of applying for prestigious international grants.

In terms of international cooperation capacity the weaknesses include: modest appeal of the JU to foreign researchers and low recognisability of JU research groups related to the systemic inefficacy of international result communication outlets; no integrated mechanism for the initiation and development of collaborations (also domestic) at their initial stages; deficient skills in initiating international collaborations and low percentage of researchers in international teams.

As regards scientific advancement of students and doctoral students (and involving them in research plays an essential role in forming dynamic research groups) the deficiencies include: no scholarship offer and activity programmes that would attract the best candidates; no teaching quality improvement incentive mechanisms; at some faculties no student involvement in the research; negligible funding to research carried out as part of diplomas; indifference on part of the research staff to science communication efforts and no up-to-date open on-line courses capable of attracting promising students and promoting the university.

In addition to the above, we have observed fairly limited scope of cooperation with international corporations; no occupational advice in organisations outside academia.

Advancement objectives and strategic goals of DigiWorld

DigiWorld's paramount objective is to enhance the standing of the University (and the recognisability of the its research groups in particular) globally in terms of the development, use and research of digital technologies for as long as this domain is the foremost scene when it comes to the dynamics of transformation in science and economy. It is prerequisite for conducting world-class research in the area in question that there be research teams who have considerable experience in the development, analysis, exploration and modelling of large databases, funds for the development of the necessary infrastructure and involvement of experts in individual research domains. We want to accomplish the strategic goal by the following means:

- development and implementation of instruments fostering the academic advancement of the staff, students and doctoral students and boosting the appeal of employment,
- integration of research teams across the university,
- improved visibility of the research carried out at the JU, increased participation of JU researchers in international research teams,
- facilitated initiation of research collaborations, projects and modes of securing funding from external sources,
- development of novel education formats receptive of the recent trends in the domain (on-line courses, blended learning solutions etc.),

- extended cooperation with social and business ecosystem in the area of key social and economic changes caused by technological progress.

DigiWorld research area priority domains

1. Advanced computational methods and artificial intelligence (AI)

The domain covers the research, both basic and applied, which blaze the trail to the development and conception of new computational techniques adjusted to different types of data, including among other things: non-standard types of machine learning (ML; e.g. semi-supervised learning, multi-task learning, multi-modal learning); non-linear signal multiplexing; advanced ML optimization methods; ML on small datasets, explainable AI; designing biologically based neural networks, building neuromorphic systems; quantum algorithms and quantum cyber security; computational social choices; analyses of image, speech, data streams etc.

2. Digital transformation of society and economy

The domain addresses research problems of digital transformations as well as the human being and society in the digital world, including among other things: human-machine interfaces, brain-computer interfaces, affective computing; psychological effects of digitalization as well as the use of tools of artificial intelligence for the analysis of psychological experiments; ethics, law and politics in relation to the development, implementation and use of information and communication technologies (e.g. autonomous machines), but also machine-learning-assisted legal decision processes; cyber security problems (securitization of the cyberspace, dehumanization of the battlefield); digital economy and macroeconomic and financial risk in a digital world (including the use of neural networks in the analysis of data from financial markets, exchange markets etc.); the effect of the newest technologies on media and social communication (including quantitative analysis, e.g. in order to develop strategies of fighting fake news).

3. Digital humanities

This domain includes among other things: *digital studies of language, literature and art*: quantitative and qualitative analysis of text and multimedia data, use of computational methods (machine learning, information retrieval, text mining, natural language processing) in literary, linguistic and cultural studies (stylometry, computational linguistics, including corpus linguistics, machine translation studies etc.); cultural heritage digital archives (text, image, sound, film, maps and 3D models): generating and maintaining digital resources, including text and multimedia digitalization, architectural, archaeological and other scans: effect of digitalization on social and cultural life; communication/cultural texts in a digital world (e.g. computer games, new media, electronic literature), digital tools and methods in teaching and translation.

4. AI in exact and life sciences

This domain spans the application and adjustment of diverse methods of artificial intelligence to large datasets in specific research problems of exact and life sciences, among other things: processing and analysis of macro- and microscopic images from space missions, generating and interpreting digital terrain models (DTMs); processing social, economic, geographical and other spatial data (satellite, aerial, lidar etc.) in order to model complex systems human – environment; analyses of medical and biological images; modelling and prediction of the properties and reactivity of chemical compounds, bioactive substances etc., investigation of self-organization of complex systems at the micro scale; optimizing and detecting elementary particles in the LHC experiments.

Actions intended to support the research area will be available in all the above domains († – under open calls; * – with a guaranteed minimum share of each domain).

- **New blood* – hiring new outstanding scientists (assistant professors and professors) expected to build new research teams
- †**Incentives programme* – building a system of mini-grants, incentives and awards for academic staff endowed for publishing in high-scoring journals
- **R2R* – funding trips, workshops, preliminary studies and other actions intended to initiate new international collaboration, including university networks
- *Strategic Research Infrastructure #1* – purchase of missing computational infrastructure
- *Strategic Research Infrastructure #2* – purchase of access to databases, licences and software
- †*Open Access* – Open Access publication funding
- **Jagiellonian Fellowship Programme* – temporary employment of recognized international standing, including funding of visiting professorships
- **Conferences & seminars* – funding workshops and scientific conferences
- †**Outgoing Fund* – funding travels to conferences and research fellowships abroad
- *EduPrograms for the Future* – launching and operating summer schools
- *Skills#1* – funding modular courses and developing novel teaching formats based on courses published on MOOC platforms
- †*Talent management* – research mini-grants for doctoral students and fist- and second-cycle programme students; scholarships for foreigners
- †*R2B* – funding, among other things, patent procedures and collaborative implementation in the form of mini-grants, fellowships and laboratory accreditations
- *R2S* – funding education activities addressed to young people and communication activities
- *Labs* – establishing research centres with research teams representing the above listed domains