RAPPORT - ARBEIDSGRUPPE FOR UIBS AI SATSING

15. JUNI 2021

UNIVERSITY OF BERGEN

RAPPORT - ARBEIDSGRUPPE FOR UIBS AI SATSING

I februar utnevnte UiB ved rektor Margrethe Hagen og direktør Robert Rastad en arbeidsgruppe for UiBs AI satsing. Utnevnelsesbrevet sier blant annet:

> *Som del av Universitet i Bergens satsing på IKT og digitalisering, vil vi styrke det tverrfaglige samarbeidet om forskning og utdanning innen Artificial Intelligence, UiBAI, og etablerer en arbeidsgruppe som skal gi anbefalinger til de overordnede strategiske mulighetene for oppbygging av dette fagfeltet. Arbeidet skal blant annet baseres på planene som er skissert for AI-Bergen og medisinsk AI.*

Arbeidsgruppen har hatt følgende representanter:

- Inge Jonassen (MN) leder
- Koenraad De Smedt (HF)
- Helge Ræder (MED)
- Haris Tzoulis (MED)
- Christoph Trattner (SV)
- Marija Slavkovik (SV)
- Ana Ozaki (MN)

Arbeidsgruppens mandat:

- Arbeidsgruppen bes foreslå en implementeringsplan for hvordan budsjettet på kr 1 mill kan brukes til å initiere første års aktivitet (2021) for utvikling av AI gjennom tett samhandling mellom fakultetene ved UiB og i samhandling med relevante eksterne aktører (Norce, Helse Bergen, industri, mm)
- Arbeidsgruppen bes beskrive de overordnede strategiske mulighetene for den videre byggingen av AI i Bergen de påfølgende årene, og foreslå en prioriteringsrekkefølge for satsningsoppgaver. Beskrivelsen bør inneholde budsjett og med flere scenarier som funksjon av budsjettstørrelsen.
- Arbeidsgruppen skal ta utgangspunkt planene som er skissert for AI-Bergen og medisinsk AI.

Arbeidsgruppen beklager at vi ikke helt har klart å overholde fristen for levering, 1. juni 2021.

Da gruppen inkluderer flere medlemmer som bare i begrenset grad behersker norsk, har arbeidet foregått på engelsk og vi ber om forståelse for at hovedrapporten dermed er på engelsk. Denne innledningen samt oppsummeringen er på norsk.

Arbeidsgruppen har avholdt en rekke møter og også innhentet informasjon om relevant aktivitet og behov fra fakultet som ikke direkte var representert i gruppen. Rapporten er skrevet av gruppen i fellesskap og gruppen som helhet stiller seg bak rapporten.

SAMMENDRAG PÅ NORSK

Kunstig intelligens (AI) handler om å utvikle og bruke systemer som kan automatisere oppgaver som krever intelligens. Med vår tids digitalisering og tilgang til store datamengder, åpner AI for nye muligheter til å meningsfullt fortolke og anvende all denne informasjonen innen forskning, innovasjon og utdanning ved UiB, hos UiB sine samarbeidspartnere og i forvaltning og næringsliv.

Vi mener en satsing på AI ved UiB må bygge på de eksisterende kvalitetene ved breddeuniversitetet, fremme fremragende forskning og bidra til å bygge eller styrke AI-aktivitet ved alle fakultetene, for eksempel gjennom tverr-fakultære samarbeid. Vi beskriver ulike bærekraft-perspektiv som vi mener må ligge i bunnen for en satsing på AI ved UiB. Dette inkluderer sosial bærekraft som sikrer at bruk av AI gjøres på en måte som ikke bryter med viktige sosiale verdier som for eksempel tillit og global bærekraft som kan knyttes til FNs bærekraftmål. Vi mener også det er sentralt for bærekraften av selve AI-forskningen per se å vedlikeholde den eksisterende fremragende grunnleggende AI-forskningen.

UiB har allerede sterke og internasjonalt anerkjente miljøer innen både grunnleggende og anvendt AI-forskning knyttet til medisinske, samfunnsmessige og etiske aspekter. Vi mener at UiB og Bergen har de beste forutsetningene for å sikre en nasjonalt ledende rolle innen dette feltet I Norge.

Vi foreslår at UiB oppretter en satsing som vi kaller *AI Bergen* som gis ressurser til å koordinere og binde sammen eksisterende aktivitet, legge til rette for og stimulere utvikling av nye initiativ og samarbeid og systematisk synliggjøre og markedsføre aktiviteten. Det bør investeres i felles tilgjengelige e-infrastruktur-løsninger som muliggjør etablering av AI-dreven arbeidsflyt for dataanalyser på tvers av anvendelsesområdene. Dette vil gjøre det mulig å bygge på erfaringer og løsninger som allerede er bygget opp og gjøre det mindre krevende for nye initiativ å ta i bruk AI-tilnærminger. Midler allokert gjennom AI Bergen kan stimulere fakultetene til økt AI-satsning gjennom rekruttering og utvikling av nye tverrfaglige samarbeid om forskning, innovasjon og utdanning. Det vil være nødvendig for UiB å finne mer sømløse prosesser for tverr-fakultære ansettelsesforhold. Vi skisserer eksisterende og foreslår muligheter for nye utdanningsprogrammer innen AI. I tillegg foreslår vi et program med såkorn-midler som forskere ved UiB kan søke for å etablere nye forsknings- eller utdanningsinitiativ. Dette kan rettes inn mot tverrfaglige satsinger, men kan også brukes for å styrke AI-forskning som sådan.

Vi foreslår også et gjesteforsker-program som åpner for at internasjonalt ledende forskere etter søknad kan tilbringe noen måneder I Bergen, invitere samarbeidende forskere fra hele verden og ha seminarer og workshops rundt et bestemt tema knyttet til AI. Dette vil bringe bergenske forskere og studenter i kontakt med internasjonalt ledende forskere, stimulere lokal forsknings- og undervisningsvirksomhet og internasjonal nettverksbygging og øke satsingens synlighet.

AI Bergen vil gjøre UiB og Bergen til et nasjonalt ledende og internasjonalt anerkjent fyrtårn for AI. Dette kommer på et tidspunkt hvor AI er i ferd med å få et globalt fotfeste. AI Bergen vil løfte forskning- og innovasjonsaktivitet ved UiB og samarbeidspartnere og gjøre Bergen til det foretrukne stedet å studere AI. Dette vil bidra til økt tilgang til kompetanse og kvalifisert arbeidskraft både for UiB, Helse Bergen og øvrig forvaltning og næringsliv i Bergen og regionen og bidra til økt samarbeid mellom institusjonene i Bergen innenfor dette viktige feltet.

I rapporten foreslår vi hvordan bevilgningen på 1 million kroner kan disponeres for å få i gang aktivitet det første året. Vi foreslår også å opprette en styringsgruppe som kan ha en koordinerende funksjon I det videre arbeidet. Vi skisserer tre ulike scenarier for oppbygging av AI Bergen med ulike ambisjonsnivå.

INTRODUCTION

Artificial Intelligence (AI) is concerned with the problem of automating tasks that require intelligence. AI is today actively being developed at all levels of the technology readiness scale: from foundational research through innovation to applied technology. Because AI technology and AI innovation by design change human activities, with the potential to disrupt societal processes, AI is also a political issue. The purpose of AI remains to be the improvement and extension of human capacities.

Our country, as our entire globe, is undergoing a major transition through digitalization. AI takes an increasingly vital role in digitalization. Its capability to analyze Big Data faster and deeper than humanly possible, supports problem analysis and decision making to name a few. AI also gives rise to possibilities that were hard to even imagine a few years ago and will continue to do so in the future. Other countries, and especially China, are making enormous investments in AI technologies and can even be considered leaders in promoting AI education.

The importance of AI for Norway is underscored by the fact that Norway launched a national strategy for AI recently. Our government has ambitions on the nation's behalf when it comes to delivering excellent research in AI and taking the lead in this field with respect to applications and innovation. Unfortunately, the University of Bergen (UiB) is today not perceived as the national leader in AI. This is particularly unfortunate given that we are uniquely positioned to take on that role as detailed in the following sections.

AI Excellence of UiB. UiB has strong, internationally recognized, research groups in fundamental AI research fields and other core components of AI research, at the Departments of informatics (MN), information science and media studies (SV), linguistic, literary and aesthetic studies (HF), and mathematics (MN). It can be directly seen by our publications that we are delivering internationally leading fundamental research in the core methodologies of AI, but also in AI related ethics associated with handling Big Data, autonomous machines, surveillance and privacy. No other university in Norway has this comprehensive competence in the fundaments of AI.

We offer the first bachelor program in AI in Norway, and the largest portfolio of AI bachelor and masters courses. Our researchers are regularly selected or invited to contribute to doctoral level education in AI via international doctoral schools and conference affiliated tutorials.

In addition, Bergen is strong also when it comes to applied AI research. UiB hosts a center of excellence (SFF) and two centers of research-based innovation (SFI) with a strong focus on AI: CCBIO (MED), MediaFutures (SV) and Smart Ocean (MN), and participates in several others in areas like medicine, climate, energy, media, ocean, environment, transport and finance. Recently, the application Centre for Social Algorithms was invited to submit a full application in the fifth SFF round. A coordination of the fundamental AI research has been initiated through the establishment of Centre for Data Science (CEDAS). MED and Helse Bergen are leading the way with applied research in medical AI through the medical AI-based research Centre Mohn Medical Imaging and Visualization (MMIV), NeuroSysMed - Norways's first research center for clinical treatment, and Intromat - an SFI on mental health. Companies and public administration in Bergen are immensely interested and highly motivated to integrate AI methods and tools in their business and technological solutions. They are in close contact with UiB and with technology and knowledge clusters, like NCE Media, NCE Finance Technology, Norwegian Health Tech and Alrek Health Cluster, and they are partners in several SFIs focusing on AI.

In the view of the working group, one important reason why **UiB lacks national visibility for its AI excellence** is in the fragmented nature of our activities and very limited efforts towards promoting the results we achieve. AI

researchers and researchers interested in applying AI are dispersed on the campus, only to a limited extent know about each other and do not have venues through which they can come in contact with each other. The university is also strongly invested in promoting global sustainability. AI is being seen as critical to addressing the global challenges we face[1], however, at UiB AI is not positioned as such a resource. The work of this committee has also found that researchers outside of the core AI research departments have extremely hard time to identify and connect with their colleagues to pursue AI related activities and cooperation.

> *We propose to establish **AI Bergen**, a center that will implement our strategy for the University of Bergen to consolidate, coordinate and facilitate excellence in AI and interdisciplinary AI research, innovation, education and technology with a focus on sustainability.*

UiB has already demonstrated excellence in AI; however, great power must be matched with great responsibility, and caution must be taken to not go so fast as to break things that matter. That is why the AI excellence must be supported with considerations for sustainability.

Sustainable AI excellence has five pillars which are to be promoted by AI Bergen:

1. AI excellence,
2. socially sustainable AI,
3. AI for global sustainability,
4. AI in the disciplines, and
5. sustainability of AI research.

AI Excellence. A prerequisite for taking the lead in the field of AI with respect to applications and innovation is a strong foundational, theoretical research that is underpinning the future AI applications. The two largest components of methodological AI research are identified by the national AI strategy as machine learning and machine reasoning. The UiB already has strong research groups in these fields and other core components of AI research including AI Ethics. At the same time, the UiB has many innovation and application partners from the private and public sector who are immensely interested and highly motivated to integrate AI methods and tools in their business and technological solutions. We offer strong AI education programs and courses, but also have an untapped potential to educate future AI entrepreneurs.

Socially sustainable AI. Unprecedented digitalization has also brought a new reality in which, for example, activities that have been private now are meticulously datafied. Also, undesirable activities that were expensive to undertake, such as the proliferation of misinformation, are now easy. AI has an immense potential to improve accessibility to social goods and services for the disempowered. At the same time AI can deteriorate the condition of such people and entrench biases by allowing them to exist in our data representations. Today, AI is used predominantly in partial automation. Namely, a task that was done by human specialists is now partly done by people and partly by an AI system. This state of distributed agency can obfuscate the understanding and regulation of responsibility. Use of AI changes society dynamically. That dynamic change must be matched with dynamic vigilance of AI use consequences to ensure the sustainability of the social values we have all worked very hard to ensure in our society. Tackling the issues of responsible use of AI is only

[1] AI is considered an existential threat along the side of inequality and climate change, see for example Meeting the Challenges of Existential Threats through Educational Innovation
A Proposal for an Expanded Curriculum *Edited By Herner Saeverot*
https://www.routledge.com/Meeting-the-Challenges-of-Existential-Threats-through-Educational-Innovation/Saeverot/p/book/9780367894856

possible by a coordinated research effort from disciplines that are focused on humanity, society and technology because use of AI affects humanity, society and technology at the same time.

AI for global sustainability. The world faces many challenges including moving to renewable energy forms, ensuring sustainable use of resources, performing producing smarter to be competitive on the global market. AI can be a powerful resource in addressing the UN sustainability goals (see also Appendix A). At the same time AI devices and AI computing do pull on the same resources whose sustainable use we would like to ensure. This is particularly an issue of AI applications to Big Data. Global sustainability first requires social awareness which is not possible without awareness of costs involved. To make the right choice of AI use we need to understand the cost of each available option. Understanding the cost of an AI solution is a task that requires understanding of cost in terms of computational resources, cost in terms of human resources and cost in terms of environmental resources. At present each of those costs are analyzed in separation by different academic disciplines. At the same time, we all share the one planet.

AI in the disciplines. A number of disciplines are already engaged in AI research – including methodology research developing methods applicable to AI – and research into consequences of AI for example in terms of societal consequences or necessary adaption of legal regulations. However, we believe there is a need for increased effort both in breadth – including new disciplines – and in depth – extending and linking current efforts. This applies to research, innovation and education. For example, AI is shifting the geopolitical balance giving rise to new research topics in political sciences; practice in for example medicine and law is going to change as AI technologies are increasingly utilized for diagnosis, treatment and data processing. Our research, innovation and education need to include these and other aspects, and AI Bergen will work to facilitate and foster a development in this direction across all the faculties of UiB.

Sustainability of AI research. One of the primary goals of a public university is to champion foundational research. The spotlight that AI technologies attract makes it easy to forget the basic research in AI that has made that technology possible. This research has been done decades prior to the technological breakthrough, typically without funding from the private sector and it has always been an interdisciplinary effort[2]. If we want continuous growth in AI innovation and technology, we must ensure the sustainability of foundational research. AI has yet to face numerous foundational research challenges such as: learning from a small number of examples, identifying causal relationships in data (machine learning can only identify correlation patterns), automation of common-sense reasoning, to name a few. New generation of scientists need to be encouraged to undertake research in foundational AI research, which is difficult under the temptations of private sector jobs.

In this report, we set out goals and strategic opportunities for the University of Bergen in AI. We build on two documents: (1) A pre-application to the Trond Mohn Foundation (TMS) to strengthen AI at UiB submitted to TMS October 2020, (2) the report “Center for Medical AI” from August 2020. We first describe the strategic opportunities for UiB in AI, then we summarize existing relevant assets across the university and the bottlenecks, and finally we propose concrete ways forward for UiB in this area.

[2] To illustrate this point in Appendix D we give the history of Deep Learning through papers and the affiliations of its authors.

POSITIONING ON A NATIONAL AND INTERNATIONAL LEVEL

Bergen is well connected to AI research in Norway and in the world. UiB and NORCE are members of Norwegian Artificial Intelligence Research Consortium (NORA), as well as members of Confederation of Laboratories for Artificial Intelligence Research in Europe (CLAIRE). In this report we show that Bergen has an excellent basis - arguably the best in Norway - to become the national AI capitol. What is needed is a mechanism to coordinate all these initiatives:

- to provide an environment for excellent interdisciplinary fundamental and translational AI research, and
- to enable the new groundbreaking AI research results to come to play in applications, businesses and public management, leading to radical innovations.

Such an initiative is timely in light of Norway's national AI strategy, the recently launched strategy of NORA, and ongoing strategy planning throughout the European research and innovation community. The next figure shows how we envision the proposed center.

UiB researchers already involved in AI have established international profiles and broad international collaboration networks. Our research network covers the top research institutes, including MIT, Stanford, UC Berkeley, Harvard, Oxford, Microsoft Research, and Google Research. Renown leaders of their respective subfields of AI, Computer Science, and Machine Learning will contribute to the center's work as international partners.

These can be used to promote the UiB AI excellence internationally. There exist numerous opportunities to host international events in Norway but also to organize multi-disciplinary events abroad. For example, hosting a major AI conference requires the involvement of more people that any individual department in UiB can spare at present. On the other hand, given additional resources we can organize an event such as a AAAI Spring Symposium at Stanford. We have in the past successfully organized numerous Dagstuhl seminars with international participants.

GOALS AND STRATEGIC OPPORTUNITIES

The underlying goal of our proposal is to the development of AI which is both sustainable in its practice and contributes to a sustainable society and environment.

We define sustainable AI as advanced data-driven algorithms that are responsible and trustworthy, and thereby play a secure, long term role in the advancement of priority areas such as the ones defined by UiB. There is much concern about AI which is biased, violates privacy or confidentiality, or lacks transparency, thus leading to distorted conclusions or broken trust relations. Sustainable AI tackles ethical and legal challenges and promotes AI methodologies and infrastructures that are responsible and equitable in the sense that data and algorithms should be fair, accurate, confidential and transparent (FACT). Trust and social welfare are prime markers of the Norwegian brand.

Sustainable AI is dependent on new, broad competencies that build on elements from several disciplines. Enabling future careers requires lowering the barriers between faculties and establishing attractive cross-disciplinary educational programs and communication arenas where students and experts from different faculties, as well as stakeholders from outside the university, can meet. This will promote a multiplication effect of our assets which are currently locked in silos and enable us to develop high quality, sustainable AI research and development that contributes to a sustainable society and environment. Moreover, this will prepare for future careers in AI requiring new cross-disciplinary competencies.

We can attain the proposed goals by pursuing strategic opportunities. Our assets are in research, education, innovation, communication and cooperation, as will be described below. We can build on our internationally leading research into the foundations, application areas, and consequences of AI, utilizing the broad perspective of a general university including humanities, social sciences, psychology, arts, law, mathematics and natural sciences, and medical research. We can also build on data available through, or generated through use of, our research infrastructures as well as publicly available data. We can expand our opportunities by working with strategic collaboration partners towards important application areas including health (Helse Bergen), the marine sector (IMR, Norce and others), as well as media, consulting, banking, and insurance. There is further opportunity in the creation of business models that attract partners and reduce UiB costs.

In the committee's opinion, it is imperative that UiB forms a university level strategy and action plan in this area aimed at mobilization of relevant expertise. Strategic investments and resources for coordination across all faculties will strengthen and coordinate the diverse aspects together enabling UiB to take a leading position in this field. A well-coordinated action plan should provide the fundament for outstanding research and education and attract students, faculty, and external funding. This will enable UiB to contribute to the development of sustainable AI, aligning with UiB's chosen strategic areas and advancing the UN's sustainability goals.

ASSETS ACROSS THE UNIVERSITY

We highlight existing innovation, research, education and communication assets at UiB. They are distributed in the faculties and would benefit from more synergy cutting across domains and disciplines. These are either activities in AI or activities that have clear potential to adopt AI approaches through bridges, training and seed funding. A complete list of relevant educational AI-related courses is given in Appendix B.

Faculty of Medicine

The Medical Faculty (MED) and Helse Bergen (HB) is co-hosting several large and internationally renowned medical Centers where AI has a central or relevant role, and where there is already substantial external funding from several sources, including the Norwegian Research Council.

The medical AI-based Mohn Medical Imaging and Visualization Center (MMIV, strategically funded by Trond Mohn Foundation in 2017 with 25 MNOK, currently headed by Prof Ingfrid Haldorsen, Dept of Clinical Medicine) has attracted in total 150 MNOK in external funding (RCN Digital Life, RCN Toppforsk, Cancer Society) and is localized as a physical Center at the Haraldsplass hospital, with 50 employees from UiB and MED and MN-CBU (for MN please see below). The research focus is on Machine learning and Cancer and Brain visualization, including method development and application in diagnostic imaging.

The Neuro-SysMed Center is Norway's first national research center for clinical treatment, funded by RCN in 2019 (160 MNOK over 8 years, plus a matching institutional contribution), hosted by HB and MED, and directed by Prof Kjell-Morten Myhr (Head for multiple sclerosis/neuroinflammation) and Prof. Charalampos Tzoulis (Head for neurodegeneration). Neuro-SysMed has already attracted additional 80 MNOK of external funding. Neuro-SysMed integrates clinical studies and had vast amounts of multimodal data (e.g., clinical, imaging, genomic) and application of supervised and unsupervised stratification approaches to identify disease subtypes.

The RCN-funded project Intromat (a Center for Research-based Innovation scheme = SFI, funded in 2020 shared between HB and MED and headed by Prof Tine Nordgreen at Department of Department of Global Public Health and Primary Care) has attracted 180 MNOK in external funding. The goal of the center is to promote mental health with focus on online treatment in mental health and using AI methods.There are also two chatbot initiatives in gynecology (Dr Agnethe Lund) and genetic counseling (Dr Cathrine Bjorvatn).

MED and HB host or are associated with several clinical registries including several national registries, the Medical Birth Registry of Norway, the Norwegian Prescription Database (NorPD), Norwegian Cause of Death Registry and Norwegian Cardiovascular Disease Registry. These unique huge population-based data sources on health and demographics have for years given Norwegian researchers an advantage when exploring various health conditions throughout the human lifespan. There are several efforts at MED and PSYK to analyze data across registries or combine with biological data and/or wearable health technology data from individual patients (precision medicine) using AI methods. For these efforts, please see Appendix C.

The recently established Trond Mohn Foundation-funded Center for Regenerative Medicine (25 MNOK funded in 2021, headed by Prof Einar Kristoffersen, Department of Clinical Science) will provide precision medicine cell models to validate findings from Registry studies using AI methods, but will also require AI methods for automating the process of analyzing and visualizing the data to identify molecular pathways that can be targeted by stem cell therapies and tissue engineering approaches.

The RCN-funded Center of Excellence Center for Cancer Biomarkers (CCBIO, headed by Prof Lars Akslen, Dept of Clinical Medicine) is providing a framework for digital pathology and AI analysis based on traditional pathological sections (Dr Sabine Leh, Dr Elisabeth Wik) or tissue microarray (Prof. Nils Halberg, Dept of Biomedicine).

SEFAS (Center for Elderly and Nursing Home Medicine, funded partially by GC Rieber Funds) is focusing on Nursing Home patients and elderly living at home, on local, national and international levels, and use assisted living technologies (digital phenotyping) to collect clinical information subjected to AI analysis.

A Center for Early Drug Discovery shared between MED, MN (Dept of Chemistry) and HB will generate huge amounts of data that require extensive computational analysis and AI methods. MED and HB currently have partnerships with companies and run drug trials (Phase I-IV) in existing clinical trial units. Current projects include the development of scoring functions to predict affinity off small molecules and the development of novel probes for diagnostic biomarker discovery, simultaneous diagnostic imaging and therapy.On behalf of UiB, MED will host the Medical Innovation Center ("EITRI medical incubator), inaugurated Nov 1, 2021) which will be a testbed for innovation related to medical AI-applications as well as host physical centers with focus on AI applications. Although there are several active health startups and companies in Bergen, there is currently no Health Cluster of companies (Helsenæringsklynge) led from Bergen.

In Alrek Helseklynge, MED is planning to host an education test arena for innovative, AI-powered tools and an innovation test lab that can be constructed to test future healthcare solutions allowing near-hospital-level care of patients in the context of their homes.

The faculty offers an elective course in Artificial Intelligence and Computational Medicine (ELMED219) and plans a Master program in medical AI.

Faculty of Mathematics and Natural Sciences

Research in AI:
Several groups at the Department of Informatics work on development of theory and methods which are central to AI. These include the machine learning group, the algorithms group, the visualization group, the optimization group, and the bioinformatics group (placed within the Computational Biology Unit – CBU). They have been successful in attracting external funding from prestigious funding agencies. Fomin, Saurabh, Lokshtanov, and Helwig at the department appear in the list of most influential AI researchers in the world, as the only researchers from Norway (https://www.aminer.org/ai2000). The research includes groundbreaking theoretical research in algorithms, based on parameterized complexity (Fomin, Saurabh, et al.); widely respected, large-scale assets regarding varied approaches in computational biology/biomedicine (CBU, Inge Jonassen et al.); visual data science, based on long-term, internationally respected research on interactive visual data exploration and analysis (Hauser et al.); optimization, based on gradient methods and convex analysis (Flåm) and on combinatorial optimization (Hemmati, Haugland, et al.), in particular, HyperHeuristic algorithms and stability; applied machine learning with industry experience (Drange); and fundamental research in machine learning, based on topological data analysis (Blaser), machine learning theory (Ozaki), and Bayesian networks (Parviainen). CBU is also playing a central role in the inter-disciplinary national center Digital Life Norway that includes efforts towards applying modelling and AI methods towards biotechnological research and innovation.

Several researchers have explored topics beyond the main topic of their research group. Fomin, Golovach, and Saurabh have explored the algorithmic foundations of machine learning and studied robustness in unsupervised machine learning. Langedal and Manne have investigated graph neural networks and Telle studied machine teaching. Ozaki studies learning and reasoning processes within ontologies and knowledge graphs. Drange has studied probabilistic methods in programming and algorithm design. Researchers within the CBU utilize machine learning and AI applied on molecular life science data for example towards precision medicine (Jonassen, Michoel, Valen). At the faculty level, machine learning has also been applied for meteorology and climate research.

The Department of mathematics has extensive research activities related to methods development relevant for AI including Bayesian inference using large-scale biomedical data learning algorithms for evolutionary trees (Johnston), sparse Bayesian methods (Li), clustering and topological data analysis (Brun), machine learning in computational fluid dynamics (Alendal), local correlation measures (Støve), image analysis (several research groups), and high dimensional Bayesian computation using automatic differentiation (Skaug). Recently started research activities include uncertainty quantification in machine learning (several research groups), gradient tree boosting (Lunde), application of machine learning in insurance (Gundersen).

The Department of Chemistry applies machine learning techniques to find optimal, functional chemical compounds, and to achieve optimal conditions to produce them (Børve). We also highlight research on algorithms and software for *de novo* design of functional molecules (Foscato); on automated chemical synthesis and instruments and software for analysis of products; and on chemometrics analysis of complex multi-dimensional data sets.

At the Department of Informatics, several groups are involved in centers and activities spanning multiple departments at our university and beyond. For example, the department is involved in developing AI-based clinical & pre-clinical solutions for the Western Norway Health Region, with partners from Haukeland Univ. Hospital & HVL at the Mohn Medical Imaging and Visualization Center (MMIV, Bartsch et al.) and also with CCBIO and Neuro-SysMed. To a significant extent, the relevant research is linked with the **Center for Data Science** (CEDAS), and it also includes groups from other departments at the University of Bergen. The department is actively pursuing further opportunities, for example it leads an SFF application on developing better algorithms for society involving other departments of the university of Bergen (recently invited to submit a full SFF application).

Towards research infrastructure provision, notably the CBU leads the Norwegian Node of the pan-European research infrastructure ELIXIR for biological data and has extensive expertise and practical experience with research data management, FAIR data sharing, secure data handling, including controlled access data sharing (respecting GDPR related privacy regulations) and within use of cloud solutions, dockerised workflows, sustainable software development. This is also supported through national center Digital Life Norway, specifically through testing out approaches on a set of digital biotechnology projects linked with the center. The visualization group also has extensive experience with research data collection, data sharing and harmonization for international research studies (GEMRIC, ABCD, PING).

Education
The Department of Informatics has a master program in machine learning with advanced courses in deep learning, reinforcement learning, and selected topics in artificial intelligence and machine learning. It also features courses in Meta Heuristics and Data Science. The Department of Mathematics offers a number of relevant courses including STAT260 Statistical learning. Strømme and Telle at Department of Informatics are UiB's annual organizers of NIO - Norsk Informatikk Olympiade. A list of relevant courses is given in Appendix B.

Faculty of Social Sciences

Research in AI:
At the faculty of social science basic and applied AI research is conducted at InfoMedia (Department of Information Science & Media Studies). This includes the study of information, communication and media technologies leveraging AI, as well as foundational AI research in multi-agent systems,

knowledge representation and AI ethics. The department has successfully executed numerous NFR projects in both ICT and media, and hosts several NFR funded innovation and research projects, including IKTPLUSS, KULMEDIA, SAMANSVAR and BIA projects with an application to or in the context of AI.

The department's/faculty's current AI lighthouse initiative is the SFI MediaFutures, Norway's first Research Center for Responsible Media Technology & Innovation - worth around 260MNOK, led by Prof. Christoph Trattner. The main objective of the centre is the development the next generation of AI in the form of responsible media technology for the media sector. The center is a consortium of the most important media players in Norway. User partners include NRK and TV 2, the two main TV broadcasters in Norway, Schibsted, including Bergens Tidende (BT), and Amedia, the two largest news media houses in Scandinavia/Norway, as well as the world-renowned Norwegian media tech companies Vizrt, Vimond, Highsoft, Fonn and the global tech and media player IBM. Other current larger AI projects include the IKPLUSS project RE-AIMED (15MNOK) - Readjusted responses by use of AI in medical calls lead by NORCE and Prof. Trattner and DELIGHT - Deontic Logic for Epistemic Rights led by Prof. Slavkovik at UiB.

Research groups with a focus on AI: The faculty of social science hosts four research groups with focus on AI at InfoMedia.

The AI & Logic research group led by Prof. Thomas Ågotnes and Prof Marija Slavkovik does foundational research in the AI areas of: Multi-agent Systems, Knowledge Representation, Reasoning, and AI Ethics. Prof. Ågotnes is also a Changjiang Chair Professor at the Centre for the study of Logic and Intelligence at Southwest University, China. Prof Slavkovik is a member of the informal advisory group on Ethics, Legal, Social Issues (ELS) of CLAIRE and one of the two Norway representatives in the European Association for Artificial Intelligence. The group has a longstanding international cooperation with many Universities in Europe among which Oxford University and the University of Amsterdam.

The DARS research group is led by Prof. Christoph Trattner and co-lead by Assoc. Prof. Mehdi Elahi http://dars.uib.no/ The DARS research group performs cutting-edge research in methods (e.g., AI methods to predict user behavior) and applications (e.g., intelligent user interfaces) in the context of behavioral data analytics and recommender systems. Current main research application areas of DARS includes: media, finance, energy, and health. The research group is a spin-out of the Intelligent Information Systems (I2S) group at the at UiB. DARS closely collaborates with the Center for Data Science (CEDAS) at the University of Bergen, the Norwegian Artificial Intelligence Research Consortium (NORA). The DARS group is the main driver of the SFI MediaFutures.

I2S is a Research Group for Intelligent Information Systems led by Prof. Andreas Opdahl which studies information systems (IS) that employ artificial intelligence (AI) and related techniques such as: data analytics, data and process mining, image analysis, knowledge graphs, machine learning, natural-language understanding, predictive modelling, and semantic technologies. The group is or has been involved in a long range of national and international research projects and networks, both as lead and as partner. Its members publish widely and is centrally involved in esteemed international conferences, journals, and organisations within its research areas. Central application areas are: digital multimedia forensics, decision making in finance and insurance, health IS, media archiving and production, personal data analysis, and predictive modelling.

Finally, there is the HCI research group led by Prof. Morten Fjeld and Frode Guribye. The group conducts research in the design and evaluation of AI empowered user interfaces is currently running several AI research projects with industry participation at the department, such as, TOMOCON (Marie Sklodowska-Curie grant), The Wallenberg AI, Autonomous Systems and Software Program –

Humanities and Society (WASP-HS) or innovation project videoworkflows with Vizrt focusing on how we can use AI to automate video workflows.

Education in AI:
The InfoMedia department offers AI courses (see list of courses) to its bachelor students and masters' students in Information Science, as well as to the bachelor students in the Cognitive Science program. Starting from the autumn of 2021 the department hosts the first bachelor's program in AI, executed in cooperation with the Department of Informatics. In addition, the department will offer a PhD course in AI ethics (INFO901) in cooperation with the University of Oslo. Slavkovik, Pedersen and Ågotnes have contributed tutorials and courses in international graduate level AI summer schools and conferences.

Faculty of Law

The Faculty's Research group on Information and Innovation Law gathers employees with competence in AI/IPR, AI/Legal Technology and AI/Data Protection/Privacy Legislation, national and international sanction regimes for risk of damage caused by the use of AI (Tande and Kielland - https://www.uib.no/fg/innovasjonsrett). The Research group collaborates extensively with the student group INNORETT on several research activities. INNORETT is one of the largest student groups at UiB with 170 members. The student group is a part of the Association of Law Students (Jurisforeningen) that gathers law students interested in the interplay between law and technology, especially AI, and have already developed a large network of external partners (http://juristforeningen.com/innorett/).

Privacy law, Data protection and GDPR: Ass Prof Malgorzata Cyndecka participates in one of four projects approved for the Norwegian Data Protection Authority's (Datatilsynet) Sandbox for responsible AI. As potential PI she participates in an application for an SFF to be financed by the Norwegian Research Council and led by The Department of Medicine. The Faculty of Law intends to establish a wider cooperation with MED, in particular with respect to health-related projects in Alrek Helseklynge.

The leadership at The Department of Informatics and The Faculty of Law have also initiated discussions on to help initiate collaborations between the two units.

Education: The faculty is also a partner with the UiO-based Center on Experiential Legal Learning (CELL) as partner in CELL Norway. Through this collaboration the Faculty offers JUS295-2-A Legal Technology: Artificial Intelligence and Law (course coordinator: Knut Martin Tande). The faculty also offers the course JUS294-2-A Privacy and Data Protection – GDPR (course coordinator: Malgorzata Cyndecka) Both courses are project based and have developed a very successful model for interdisciplinary collaboration[3].

The course Privacy and Data Protection is based on projects provided by Media City Bergen where students for instance develop mobile applications helping users in daily life situations. Such apps process large amounts of personal data and thus raise several data protection issues. In addition to lectures, students work in groups with projects. Their task is to identify, analyze and solve existing and potential privacy and data protection issues raised by the project, cooperating with its author(s) and a

[3] See https://www.uib.no/emne/JUS295-2 and https://www.uib.no/emne/JUS294-2-A.

supervisor. The students present their findings in a report and give legal advice during an oral exam to student projects from Media City Bergen.

Faculty of Humanities

AI modeling of natural language has opened possibilities for language technologies such as information extraction from documents, topic modeling, inclusive communication, and many more. Natural language processing is in many ways a *horizontal asset* that cuts across many application domains, such as medicine, media, and law. In the National Strategy for AI, technology, data and resources for Norwegian and Sami are important areas that need strengthening.

The research group on Language Models and Resources (LaMoRe) has research experience in AI-based neural machine translation (Bamba Dione), AI for certainty factors in business news (Seong Cho), AI processing of sign language (Vadim Kimmelman, Carl Börstell) and writing processes (Christer Johansson). The group is experienced in AI and participates in relevant international projects, but it must be expanded with academic staff and technical support staff to reach critical mass to become a true *Hub for AI-based language processing with cross-disciplinary applications*.

Since 2012 LaMoRe leads the national CLARINO research infrastructure (Koenraad De Smedt) for language data and technologies, in cooperation with the Digital Humanities Lab at the Bergen University Library and a national consortium. The group co-leads a work package in the SFI MediaFutures.

The Digital Culture research group studies the impact of AI technologies such as machine vision on the human mind, ethics, culture and everyday life (Jill Walker) and studies AI in electronic literature (Scott Rettberg). This group is strong and broad in its external communication.

AI is integrated in linguistics courses that treat machine learning of natural language with neural and statistical models, and applications such as sentiment analysis, document classification, topic modeling, stylometry, etc.

Faculty of Arts, Music and Design

The focus of KMD on AI is through two strands, the technical and a thematic approach. Central questions include the role of the human experience (Erkennung) and AI. There are no courses offered related to AI applications, but there are AI projects. Prof. Dániel Péter Biró from the Grieg Academy has ongoing projects with AI including “Sounding Philosophy,” which deals with AI in music composition and is funded by the Norwegian Artistic Research Program (2021-2024) as well as “Computational Ethnomusicology,” an ongoing international research project, which focuses on music analysis and transcription using machine learning. PhD candidate Thorolf Thuestad works with emotional machines composing for unstable media and algorithmic composition. PhD candidate Juan Vassallo is working on a project involving automated composition, machine learning, neuroscience and AI technology. At Department of Design, there was recently a project combining sensor technology and creative computing related to human biometrics and Surveillance Capitalism lead by

Associate Prof. Albert Cheng-Syun Tang. The department has visual communication and VR as fields of study and research.

The faculty needs a space for acoustic experimentation and analysis, possibly shared with the Department of Biological and Medical Psychology. This would also involve funding for purchasing and installation of necessary hardware and software. A relevant digital research infrastructure and repository (ARIIS) is also desirable. Hardware and software systems are also necessary for Design. Recently an RNC Infrastructure application was submitted as a collaboration with Faculty of Psychology and the Media City Bergen (SV faculty).

The faculty would benefit from PhD students (see above) and professors (Design + Music) and technical staff (overingeniør). A cross-listed professor appointment between the Grieg Academy, Department of Music and the Department of Informatics would allow for the development of a music technology program, centered on AI, at UiB.

Faculty of Psychology

SLATE is an interdisciplinary research center designed for the advancement of the Learning Sciences. Learning analytics, the focus of SLATE, uses AI methods and technology. One of the focus areas for the next 5 years is Intelligent Learning Environments. Current AI research includes open learner models and learning analytics to support adaptive learning systems and machine learning for profiling and clustering in big data sets (several projects). Artificial Intelligence in Nordic schools (aiLife) is a Nordforsk funded project that explores the nature of AI application in the unique context of Nordic education; currently 2 EU applications in the area of AI are being developed.

Relevant research expertise (Wasson) includes AI in education, intelligent tutoring systems, open learner models, competence modelling teacher inquiry, learning analytics, and pedagogical agents, and others (Khalil, Samuelsen & Miesjuk) includes machine learning. SLATE is currently developing 3 EVU courses related to artificial intelligence; data and algorithmic literacy, and has plans to announce a PhD, a Postdoc, and a Professor in artificial intelligence in education, within the next 3 months.

Wasson leads an UiB committee that wrote a report on developing courses for UiB students (and potentially staff) on the use of data and algorithmic literacy, where AI technologies are central. Finally, SLATE participates in Datatilsynets (Norwegian Data Protection Authority) AI Sandbox with its Activity Data for Assessment and Adaptation (AVT) project. The AI Sandbox takes a Privacy by Design perspective where privacy (personal data) is to be considered throughout the design and development of ai-based technologies. Datatilsynet writes (on their English site) "The goal is to promote the development of innovative artificial intelligence solutions that, from a data protection perspective, are both ethical and responsible."

The *BridgeAR* project explores ways to use artificial reality (AR) interfaces to facilitate maritime communication. The PhD student in the project is supervised by Bjørn Sætrevik collaboration with Morten Fjeld (Information Science). The project will be expanded with a post doc position within the next two years.

Koelsch plans to use deep learning in an SFF-application on molecular profiles of resilience to identify molecular resilience patterns in big data including endocrine, metabolic, genetic, epi-genetic, and immune parameters.

Lundervold uses AI methods (machine learning) to predict cognitive ageing and neurodegeneration and plans to study the Brain-Gut-axis in patients with Irritable Bowel Syndrome and to study registry data on self-harm in adolescents and adults with ADHD. Beresniewicz intends to apply machine learning to reveal hidden sub-

groups of schizophrenia patients based on their clinical evaluation.Specht develops, together with colleagues from the Mohn Medical Imaging and Visualization Center (MMIV), AI-based methods for analyzing functional brain imaging data and combining them with other physiological and biological measures, such as sleep quality and duration, and parameters extracted from blood samples.

WAY FORWARD: ESTABLISHING THE AI BERGEN CENTER

A common institutional strategy for AI will fully exploit our strategic opportunities and will leverage our combined expertise. The implementation of the AI Bergen strategy will galvanize collaborations between research groups and educational and innovation environments by creating common meeting places for existing environments.

We propose to establish a center, the AI Bergen Center, that will meet the core needs, as detailed below, by performing coordinated research and education in AI, with the faculties as pillars and means to facilitate cross-disciplinary collaboration. The added value of the Center, as further detailed in the Value Proposition section below, will require the following fresh assets to consolidate and complement our existing assets.

- **Coordination and communication**. Given the many different faculties, departments, people, projects, students and external stakeholders involved in AI at Bergen, some personnel must be fully dedicated to coordination, communication (both internal and external), event organization and user involvement.
- **Personnel.** New personnel with state-of-the-art competencies, especially at senior levels (professor and postdoc), must be attracted especially in faculties where AI activities have not yet reached a critical mass. Existing personnel must be given time to not only strengthen their own expertise, but also to build strong transversal relations with AI researchers in other departments and faculties, as well as external stakeholders.
- **Education and researcher training.** State-of-the-art expertise must permeate masters and PhD-level courses. Academic staff must also be given opportunities to attend tutorials, workshops and conferences. Highly competent guest lecturers will be recruited.
- **Computational systems and support.** Transparent access to HPC systems including very large numbers of GPU/TPU units, as well as data collection pipelines, data management and FAIR (Findable, Accessible, Interoperable, Reusable) data sharing, must be provided. Technical support for data handling and programming platforms, both general and tailored to specific fields, is essential. Data management efforts – enabling FAIR sharing of project data – is key for sustainability of AI research and importantly is also central to making project data interoperable with external reference data and ready for application of AI approaches.

- **Arenas.** All people involved in AI Bergen should be able to meet and work together in suitable common spaces to be allocated in new or existing buildings (Medical Innovation Center, Technology building, etc.).

VALUE PROPOSITION OF THE AI BERGEN CENTER

In this section we highlight the unique benefits of an AI Bergen Center for UiB, the university hospital and the private and public sector, respectively.

For UiB

- The Center will **enable research excellence** by providing a framework, establishing methods and technology in order to accelerate the transformation of ongoing research into applications in various areas within the university. The Center will create a common methods and data management infrastructure and toolbox for AI applications including and extending the repertoire of AI methods. The Center will also assist in procurement of AI equipment. The Center will provide UiB students and employees with computing infrastructure with sufficient power for complex analyses (e.g., more computational power and adaptable server infrastructure).
- By providing scientists with a cutting-edge platform, the Center will increase the competitiveness of UiB fundamental and applied AI research in the national and international scientific arena, thereby increasing the success rate of UiB researchers at obtaining national and international **external funding**. Thus, from the financial perspective, the Center will be an excellent investment, which will generate “revenue” quickly exceeding its cost.
- The Center will also provide UiB students and employees with infrastructure (including sensor technology – IoT and digital interfaces) that is suited to **collect and combine data from different sources** (e.g., integration between AI tools and routine clinical reading systems) and for curating these data. In some areas only unstructured data are available and there is poor harmonization of variables as well as of data management.
- The center could help projects share data internally to enable different groups to contribute with their expertise analyzing shared project data – and help projects share data and analyses in a FAIR and as open as possible fashion to support open science and **promote trust** in AI analyses. Project-generated data should be usable together with data available from other resources.
- The Center will stimulate and aid new departments engage in research, innovation and education activities linked with AI – including AI methodology development, use of AI approaches, and societal, ethical, legal, economic aspects linked with use of AI.
- The Center will increase cross-faculty collaboration by linking different AI methodologies to **use cases in research and education** (e.g., media texts or medical texts can be use

cases for linguistic AI approaches at HF; medical problems from the Medical Faculty or music problems from the KMD faculty can be use cases for new AI approaches at MN).

- The Center will provide UiB students and employees with increased **access to qualified personnel** both with AI domain expertise as well as cross-disciplinary research expertise across different disciplines (e.g., expertise in both computer science and medicine or music, or expertise in both computational linguistics and law, sociology or politics).
- The Center will create arenas also for **professional exchange and UiB internal collaboration**. Cross-disciplinary collaboration on current issues in AI, such as consequences for regulation (Law Faculty), ethics and society (SV Faculty), and mind and culture (HF) will promote integrative innovation. Both groups and individual researchers will benefit from collaborating on interdisciplinary projects on AI topics.
- The Center will provide **educational resources** to UiB students and employees as well as continued education increasing cross-disciplinary competence, i.e., integrated ECTS courses for the training of UiB students and employees.
- The Center can provide **seed funding opportunities** and information about funding possibilities for early phase innovation directed towards AI solutions, and benefiting UiB students and employees.
- The Center will maintain and improve excellence in **fundamental research** in AI by funding projects, academic events, and facilitating the attraction of guest researchers at UiB.
- The Center will provide **regulatory and ethical support** and guidance to applied AI and fundamental projects.

For the private and public sector:

- The Center will provide private and public sector stakeholders efficient access to expertise on AI spanning from methods development to applied AI (medicine, media, finance, climate, etc.). This will be accomplished through continued education opportunities, outreach initiatives and consulting.
- The Center will catalyze interactions with UiB environments searching for collaborative industry partners in the context of smaller or larger grants (i.e. SFI) and in focused industry clusters.
- The Center will provide educational courses open for industry related to topics leading to AI domain expertise.
- The Center will provide a base of students looking for internships or work possibilities in AI-driven industry.
- Joint ventures between academia and industry will lower innovation costs by sharing R&D costs.
- The Center will educate future City and County employees with a range of domain specific AI competencies, and can address direct competency needs directly to the Center.
- The Center will provide a base of students looking for internships or employment opportunities related to AI competency in City and County municipalities.
- The Center can catalyze collaborative projects between UiB and City and County municipalities by serving as a common interface between these institutions. NFR has an increased focus on such collaboration, and the Center will enable more efficient synergies.

For the University Hospital:

- The Center will seamlessly integrate clinical research and make use of all data across time and and space: within the hospital but also pre- / post-hospital follow-up. This will enable personalized medicine and contribute to understanding disease mechanisms, helping clinical follow-up, developing models for the effects of pharmacological interventions and permit a lifespan perspective on health and disease from cradle to grave.
- The hospital is establishing digitalized solutions for treatment occurring inside of the hospital (Structured Electronic health records) as well as outside the hospital (telemedicine solutions). The hospital also has an interest in solutions for the management of hospital logistics (flow of medical equipment, patient beds, patient movements before/under/after hospitalization, dedication of health care professionals, patient risk due to viral or bacterial outbreaks and more). All these digital solutions will create data streams that are well suitable for AI analysis, and a Center will provide state-of-the-art integration solutions for the analyses.
- The continuous self-reporting and sensor-based registration (IoT-based data acquisition) of clinical data from the patients will need the development of digital solutions as well as a regulatory framework (compliant with Norwegian Law) and repository solutions being integration with AI analysis. The Center can offer state-of-the-art regulatory and AI expertise, test beds and expertise to the hospital.
- The hospital has currently established partnerships with industry companies and run drug trials (Phase I-IV) in existing clinical trial units. The hospital is also aiming to establish a dedicated clinical trial hospital ("Utprøversykehuset") for experimental interventions and surgical procedures. These efforts will generate data streams suitable for AI analysis, and a Center will provide state-of-the-art integration solutions for the analyses that are yet to be developed.
- The Center can also provide testbeds for novel software and hardware, i.e. in the Medical Innovation Center.
- The Center will make an essential contribution in developing new disease biomarkers for diagnosis, prognosis, treatment monitoring, and treatment selection (precision medicine).

IMPLEMENTATION AND SCENARIOS

Here we describe how we envisage AI Bergen to be built – that is which building blocks it will consist of. The three scenarios describe different dimensioning of the center both in terms of which building blocks are included and in terms of the scale of individual blocks.

Leadership and communication: We propose to hire a director to act as the daily manager and champion for the Center's operation. The director will be recruited through a broad announcement with highly selective criteria. The director is to ensure interaction between the different participants at UiB, as well as interaction with external partners. Innovation and contact with businesses, public sector and all academic and research partners will be the responsibility of the director. Here, we want a visionary person who is able

engage, excite, generate collaboration, and ensure excellence in research and innovation. In addition, there will be an administrative coordinator, a PR officer, and a coordinator for education and training. The center will have a steering board, to which the director will report, and a Scientific Advisory Board (SAB) providing advice and guidance to the steering board and the director. The director will be appointed by the steering board with advice from the SAB. In addition to a budget for the salary of the center leadership, there needs to be a budget for organizing meetings, establishing common arenas, outreach activities etc.

Seed funding: In order to stimulate inter-disciplinary collaborations and make progress towards the specific goals defined above, we propose that the center will have resources to fund research projects, ideally inter-disciplinary, through announcing appropriately formulated calls. A process for evaluating the proposals will be established through consultation with the steering board and the SAB of the center.

Events, meetings and seminars: To stimulate the collaboration between researchers from different faculties, there will be an annual meeting where researchers can present their work and establish new collaborations within the university and abroad. The meeting will have co-located events: (1) a research conference with international invited keynote speakers; (2) an inter-faculty research school tailored to master's students, PhD students, postdocs and other researchers motivated to deepen their knowledge in a particular topic; (3) a workshop where participants of the research school can deliver oral presentations and present posters; and seminars where internal and external researchers can present their work, guest researchers from the Guest Researcher Program (see below) will be invited to give seminars; and (4) an open lecture to the general public. In addition to the annual meeting, we propose seminar series featuring presentations from both international and local researchers and bringing together investigators and students from across the faculties.

Guest Researcher Program: AI Bergen will facilitate a guest program, where internationally leading AI researchers based abroad find an excellent environment to spend their sabbaticals. The center will invite guest research groups for a duration of up to one year. Each guest group will have a leader who will contact and invite researchers they would like to work with to Bergen. This way, the guest program will have an enforcing effect: internationally leading AI researchers coming to Bergen and collaborating in new constellations. The guest program will not pay salaries, but provide office space and seminar facilities, some travel funding, and opportunities for interaction with scientists, students, and professionals in Bergen.

Arenas: These include the areas within the New Technology building, Alrek Helseklynge, the Eitri Medical Incubator/Medical innovation Centre. Also, we can foresee satellite hubs at some of the faculties serving as physical contact points. For testbeds, it is important to have space allocation for trying out digital solutions deploying AI.

Scientific Positions – professors, postdocs and PhD students. The Center would open calls for temporary positions (postdocs and Ph.D. students), where excellence and cross-disciplinary research is stimulated. For permanent professor positions the Center could co-fund start packages for recruited professors potentially employed at two or more faculties. Such packages would not only stimulate cross-disciplinary competence but also stimulate stronger international recruitment. One mechanism to accomplish such an endeavor could be through the allocation of 1-3 UiB PhD and postdoctoral positions for a limited time and some funds towards basic running costs to permanent cross-faculty professor recruitments. In these endeavors, two or more faculties would be able to collaborate to create such AI-dedicated permanent positions, for example, by reallocating professor positions (due to retirement). UiB should also develop mechanisms for a more seamless employment process of cross-faculty positions.

Hardware/software solutions, data processing infrastructure: UiB needs an AI-empowered data science pipeline. This will make it easier for new "applied projects" to utilize AI approaches, it will

enable re-use of solutions between centres and allow capitalizing on experiences across projects and faculties. Finally, it will provide a framework enabling methodology-oriented groups to test out new approaches by plugging into an existing e-infrastructure. We believe the e-infrastructure enabling the AI-empowered data science pipeline can be set up and coordinated by the IT division in collaboration with the Department of Informatics. The e-infrastructure needs to include data management solutions that integrate data from multiple sources enabling use of project-generated data together with data from other sources including reference data. This implies a need for data management support that should also include support for FAIR and as open as possible sharing of data and results. The solutions should ensure GDPR compliant and safe handling of data and handling of copyright. While some of these efforts need to be field specific since each field has their own standards and repositories, much is to be gained by coordination across fields. For example, solutions are relatively well developed for molecular life science data where ELIXIR is playing a central role (e.g., https://rdmkit.elixir-europe.org/). Experiences, and to some extent solutions, can be carried over to other fields given additional resources. Importantly, solutions enabling running of computationally demanding analyses needs to be put in place. This will likely involve use of generic e-infrastructure resources as provided by Sigma2 likely complemented by local compute or commercial compute resources. The eX3-2 application under evaluation in the Infrastructure program of the Research Council of Norway includes funding of an AI-oriented supercomputer that would give researchers in Bergen a competitive edge. There is experience with use of both academic and commercial cloud providers and the center can play an important role in coordinating these efforts avoiding duplication of efforts and improved basis for strategic decisions. These aspects need to be coordinated with the IT department at UiB and other relevant parties.

Teaching solutions: AI Bergen will play a key role in coordinating and marketing *educational activities* across the UiB and partners helping make Bergen the preferred choice, at least on a national level, for students interested in AI - through offering high-quality courses and programs spanning all relevant disciplines in a well-coordinated fashion. One example of how UiB can construct a cross-faculty and cross-institutional (UiB and HVL) 20 ECTS course is provided in Appendix E (based on the suggestion from the report on Medical AI from 2020). Educational activities may also include offerings in “continued learning” (EVU) - extending on what is already established for example at Department of Informatics. We propose that AI-Bergen opens calls for projects aimed to build or strengthen relevant courses, programs and training activities.

Guest Lecture Program: Courses can have higher quality if they can be taught by multiple experts in the topics of the course than by only one faculty member. We propose the development of a model that promotes co-teaching and co-supervision across departments and faculties. AI Bergen can be a good vehicle for developing such a model.

ACTION PLAN FOR YEAR 1

We describe the actions for the first year. The plan for the main activities is as follows.

Steering group: The first action is the establishment of a cross-faculty steering group with the responsibility of ensuring that the activities are in line with the strategies of the involved faculties. In addition, the steering group will have a responsibility for contacting candidate partner institutions and explore funding possibilities. During this first year, the steering group will also coordinate an effort to map out needs, existing e-infrastructure solutions and resources performing a gap analysis and working out a plan to address these as the center moves forward. This will form the basis for planning e-infrastructure investments going forward.

Administrative coordinator: A position for administrative coordinator with a 50% position initially for one year will be announced. The administrative coordinator will be responsible for the following tasks.

- Maintain the website and social media accounts to communicate results to the general audience.
- Produce short video clips/posts, newsletters, brochures, reports and roll-ups explaining the scope and key results of the center.
- Maintain media relations to promote the experts and the newest research results and innovations.
- Organize seminars, dedicated meetings, workshops, conferences and networking events for the partners and the general public, among other related tasks.
- Support the work of the steering group.

Communication materials: It is crucial to establish communication channels both internally across all faculties and to the public. Part of the funding will be used for acquiring services for the creation of a website, a template for a newsletter and a logo. We propose the URL www.aibergen.uib.no for the website. The website will have links to other related initiatives already in place at UiB, e.g., CEDAS, SFI MediaFutures, CBU, and NORA. There will be a Twitter/FB account @AIBergen, maintained by the administrative coordinator. We propose that the newsletter is issued every two weeks. It will contain information such as AI events at UiB, open positions, seminar announcements, announce research guests at the university, communicate the results of project proposals, etc.

Seminars/Talks: The internal communication will be supported by seminars organized by the administrative coordinator. The focus will be on having faculty members presenting outside of their department. During the first minutes of the presentation, the speaker could briefly talk about his/her career and teaching duties, with the purpose of identifying potentially interesting guest lectures. Then, the speaker would proceed with a presentation about his/her research, targeting a non-technical audience (since this ideally will not be in the same department the speaker works).

Kick-off Conference: There will be a kick-off conference in early June 2022 (tentative dates 02.06 and 03.06). This will be a two-days event with around 200 participants (physical, hybrid, or fully digital, depending on the COVID situation), and possibly co-located with other related conferences at UiB. This event will bring excellent international invited speakers. The main target audience will be researchers in AI working on fundamental and applied AI at UiB and in the region. We also propose talks to the public, announced in a local newspaper, and conducted in an accessible area (e.g., Grieghallen or Nygårdsparken).

The main purpose of this event will be to mark the first year of the Center and announce plans for the next five years. The first day of the conference will focus on fundamental research in AI and on horizontal research that cuts across domains, such as sustainability and robustness in AI, natural language processing, legal and ethical aspects, while the second day will focus on the applications of AI in selected domains, such as medical fairness and trust in AI-driven diagnostics and therapeutics; media liberty; an ocean sustainability. The organization of this event will be supported by the administrative coordinator, who will be responsible for the non-scientific organization tasks.

Externally Funded Related Events: The Center may further support the organization of externally funded events in AI. The logo of the Center would then be added as a sponsor to the website of the event and the organizers would present the Center and its organization (steering group and administrative coordinator for Year 1) in an opening session.

- In 2022, there will be a research school combined with a workshop from 06.06.2022 to 10.06.2022 (website under construction https://researchschool.w.uib.no/). These 5 days event will bring leading experts in AI (notably, international ERC grant winners). The topic for 2022 will be "Knowledge graphs & Machine Learning". It will have 50 selected participants (mostly master's and Ph.D. students) and it will be organized in 2022 by Ozaki, Guimarães and Cosimo in connection with the NFR project "Learning Description Logic Ontologies". There will be a peer-reviewed proceedings with lecture notes and participants will have the opportunity of presenting their work in oral and poster sessions.
- Other events may be considered/supported during Year 1.

Meeting: The appointed work group organized a one-day meeting to work on the report.

The budget plan for the 1 MNOK for Year 1 is presented in the following table.

Administrative Coordinator (50%)	Communication Material	Kick-off Conference	Externally Funded Events and Meeting
450 k	100 k	400 k	50 k

SCENARIOS FOR A FIVE-YEAR PERIOD

We suggest three different scenarios based on funding level. Each proposal is for funding an initial period of five years, followed by an evaluation and possible continuation. The distribution of the budget should aim at some level of equity and inclusion of all faculties.

Low- Total budget of 40 MNOK

Center management – director plus 1.5 full time equivalents (FTEs) for admin support, PR, and educational coordination (in total 2.8 MNOK per year) plus running costs (meetings etc) 1.2 MNOK per year – in total 20 MNOK

Seed funding: 15 MNOK over 5 years (500 KNOK/project/year).

Data management infrastructure: 5 MNOK over 5 years (severely underestimated).

In total 40MNOK.

Medium- Total budget of 100 MNOK

Center management – director plus 2.5 full time equivalents (FTEs) for admin support, PR, and educational coordination (in total 3.6 MNOK per year), offer of support, funding to set up task force for IT systems support, plus running costs (events and meetings etc) 2.4 MNOK per year – in total 30 MNOK

Seed funding: 15 MNOK over 5 years (500 KNOK/project/year).

Data management infrastructure: 15 MNOK over 5 years (slightly underestimated)

Funding 6-10 education-oriented activities (in total 8 MNOK).

Funding of a guest program with 3 visiting groups per year (in total 3 MNOK)

Funding of outreach activities: 9 MNOK

Funding to support the recruitment of cross-disciplinary professors and funding PhD students and Postdoctoral fellows: 20 MNOK.

In total 100 MNOK.

High- Total budget of 195 MNOK

Center management – director plus 4.0 full time equivalents (FTEs) for admin support, PR, and educational coordination (in total 4.7 MNOK per year), offer of support, funding to set up task force for IT systems support, plus running costs (events and meetings etc.) 3.3 MNOK per year – in total 40 MNOK.

Seed funding: 20 MNOK over 5 years (500 KNOK/project/year).

Data management infrastructure: 25 MNOK over 5 years

Funding of four large (ideally cross-disciplinary) research projects (in total 40 MNOK, potentially with TMS) and 10-14 education-oriented projects (in total 18 MNOK).

Funding of a guest program with five visiting groups per year (in total 5 MNOK)

Funding of outreach activities: 12 MNOK

Funding to support the recruitment of (ideally cross-disciplinary) professors and funding PhD students and Postdoctoral fellows: 30 MNOK.

International positioning– networking, participation in international projects, workshops: 5MNOK

In total 195 MNOK.

APPENDIX A

Possible AI impact on the UN sustainability goals

How AI impacts the UN sustainability goals (for ease of reference, all sustainable development goals – SDGs – are listed below):

Quality education is education that enables students with skills to take future jobs but also to create future jobs. AI competences are an asset to both employability and job creation. By strengthening Goal 4, we indirectly contribute towards Goal 1 and 2.

AI systems are increasingly involved in decision-aiding processes that involve allocation of resources and goods, such as access to loans, information, education and services. AI systems work with a model of the world, they follow rules that model aspects of the real world and/or they extract and follow patterns from data that describes aspects of the real world. The models of the world often reflect existing biases and injustices in allocation of resources and goods, but also in representation. At the same time, AI systems offer an opportunity to improve on the same: while it takes a person a lot of training to become aware and reject bias, and AI system can be directly corrected. It is these aspects of AI that contribute directly to advancing Goal 5 and Goal 10 and indirectly, goal 16.

AI systems involved in medical applications are increasingly enhancing the ability of physicians to... AI applications help people manage their disabilities. In this aspect AI contributes towards advancing Goal 3.

Recent technological advances have made it feasible to create and deploy cheap and efficient devices that directly monitor the usage of resources such as water and power, as well as the usage of the infrastructure that supplies them. Such devices create data that can be fed to an AI system. AI systems here are used to build a model of resource and infrastructure usage that helps devise plans to reduce waste and improve the environmental and societal sustainability of the water and power supply. This advances Goals 6 and 7, but also 12. Furthermore, precise data would help elucidate who does not have sufficient access to critical resources and infrastructure, thus contributing to information that can be used to advance Goal 10. At the same time, measuring and datadying behavior of people and communities creates its own vulnerabilities. It is important to consider the benefits of technology in the context of the society in which they are deployed and ensure goal 16 is not accidentally undermined.

Our activities are increasingly conducted online: studying, shopping, communication. The digital infrastructure that enables this is thus transformed into a commodity rather than luxury. We are inseparable from our mobile phones that are a cluster of sensors. In addition, we increasingly adopt many wearable devices, both leisure and medical. All these relatively new practices create new opportunities and new vulnerabilities. Any pursuit of Goals 8 and 9 necessarily involves computation, data analytics and AI that supports both. Again, as above, particularly the use of AI can lead to callous undermining of Goal 16.

AI has an unsurmountable potential to improve accessibility for a range of services. Natural language processing is currently used in text to speech and speech to text allowing people with hearing and speaking disabilities to access media content. Automated translation helps people overcome language barriers. Autonomous vehicles can be used by a vision impaired person as a personalized

independent means of transportation. Social robots have been used to help children to surpass with various cognitive challenges. All this contributes directly towards achieving Goal 10

Part of Goal 11 is to “provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons” AI already plays an active role in this in the world. In Norway we see a possibility for improvement.

Goal 12 includes “Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle” as well as " ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature”. This is part of AI and media [to be expanded]

Goal 13: managing spread of disinformation on climate requires monitoring of information in the news and social media, which dependent on natural language processing, which for the Norwegian language need strengthening.

Goal 14: fish projects & bioinformatics, use of data from sensors in the ocean – e.g., on pollutants, temperature, currents, but also biodiversity through image data or through molecular data. Ecology, monitoring of effects of oil drilling, sea windmill farms etc.

Goal 15: there are ai and farming initiatives in Norway we are not involved in https://nordictestbednetwork.se/participants/

Relevant paper: https://link.springer.com/article/10.1007/s43681-021-00043-6#:~:text=In%20this%20paper%20I%20propose,ecological%20integrity%20and%20social%20justice.

GOAL 1: No Poverty

GOAL 2: Zero Hunger

GOAL 3: Good Health and Well-being

GOAL 4: Quality Education

GOAL 5: Gender Equality

GOAL 6: Clean Water and Sanitation

GOAL 7: Affordable and Clean Energy

GOAL 8: Decent Work and Economic Growth

GOAL 9: Industry, Innovation and Infrastructure

GOAL 10: Reduced Inequality

GOAL 11: Sustainable Cities and Communities

GOAL 12: Responsible Consumption and Production

GOAL 13: Climate Action

GOAL 14: Life Below Water

GOAL 15: Life on Land

GOAL 16: Peace and Justice Strong Institutions

GOAL 17: Partnerships to achieve the Goal

APPENDIX B

Educational assets at MED and MN

ELMED219 Artificial Intelligence and Computational Medicine 6 https://github.com/MMIV-ML/ELMED219-2020

ELMED223 Innovation and Entrepreneurship 6 https://www.uib.no/en/course/ELMED223

BMED360 In Vivo Imaging and Physiological Modelling 10 https://www.uib.no/en/course/BMED360

BMED370 Computational Methods for Drug Design 5 https://www.uib.no/en/course/BMED370

HELIKT620 Health Care Informatics 20 https://github.com/MMIV-ML/HELIKT620-KI-2019

MAT260 Numerical Solution of Differential Equations 10 https://www.uib.no/en/course/MAT260

MAT261 Numerical Linear Algebra 10 https://www.uib.no/en/course/MAT261

MAT262 Image Processing 10 https://www.uib.no/en/course/MAT262

MAT264 Computational Science II 10 https://www.uib.no/en/course/MAT264

MAT265 Parameter Estimation and Inverse Problems 10 https://www.uib.no/en/course/MAT265

MAT625 Computational Thinking and Programming in Math. 15 https://www.uib.no/en/course/MAT625

MNF201 Science in Today's World 10 https://www.uib.no/en/course/MNF201

MNF262 Introduction to Image Processing and Visualization 10 https://www.uib.no/en/course/MNF262

MNF990 Theory of Science and Ethics 5 https://www.uib.no/en/course/MNF990

STAT100 Introduction to Data Science with R 10 https://www.uib.no/en/course/STAT100

STAT202 Biostatistics 10 https://www.uib.no/en/course/STAT202

STATLEARN Statistical Learning 10 https://www.uib.no/en/course/STATLEARN

BIO300B Biostatistics 5 https://www.uib.no/en/course/BIO300B

BIO302 Biological Data Analysis II 5 https://www.uib.no/en/course/BIO302

BINF305 Systems Biology 10 https://www.uib.no/en/course/BINF305

INF161 Introduction to Data Science 10 https://www.uib.no/en/course/INF161

INF170 Modelling and Optimization 10 https://www.uib.no/en/course/INF170

INF253 Visual Data Science 10 https://www.uib.no/en/course/INF253

INF264 Introduction to Machine Learning 10 https://www.uib.no/en/course/INF264

INF265 Deep Learning 10 https://www.uib.no/en/course/INF265

INF367 Selected Topics in Artificial Intelligence 10 https://www.uib.no/en/course/INF367

INF368 Selected topics in Machine Learning 10 https://www.uib.no/en/course/INF368

KJEM326 Selected Topics in Chemometrics 10 https://www.uib.no/en/course/KJEM326

MTEK100 Medical Technology in Practice 10 https://www.uib.no/en/course/MTEK100

PHYS212 Physics of Medical Imaging 10 https://www.uib.no/en/course/PHYS212

Educational assets at HUM, PSYK, SV, LAW and HVL

LING310 Computer modeling of language and applications 15 https://www.uib.no/emne/LING310

LING123 Language and computers 15 https://www.uib.no/emne/LING123

CDP919 Causal Modeling: Statistical Analysis of Mediation and Moderation 2 https://www.uib.no/en/course/CDP919

CDP991 Linear Mixed Modeling of Treatment/Intervention Studies 2 https://www.uib.no/en/course/CDP991

GHIG923-B Quantitative Methods: Experimental Design and Analysis 1 https://www.uib.no/en/course/GHIG923-B

IGSIN911 Functional Neuroimaging 3 https://www.uib.no/en/course/IGSIN911

IGSIN913 Integrated Neuroscience 6 https://www.uib.no/en/course/IGSIN913

IGSIN918 Course in the Software Package R 1 https://www.uib.no/en/course/IGSIN918

MAPSYK301 Perspectives in Psychological Science 15 https://www.uib.no/en/course/MAPSYK301

MAPSYK319A Behavioral Neuroscience 1: Biological Psychology 15 https://www.uib.no/en/course/MAPSYK319A

MAPSYK319B Cognitive Neuroscience 15 https://www.uib.no/en/course/MAPSYK319B

MNPED660 Collegial Teaching and Learning in STEM Education 5 https://www.uib.no/en/course/MNPED660

PSYCH301A Quantitative Methods as the Basis for Psychological Sci. 5 https://www.uib.no/en/course/PSYCH301A

PSYCH305A Cognitive Psychology 9 https://www.uib.no/en/course/PSYCH305A

AIKI100 Introduction to Artificial Intelligence 10 https://www.uib.no/en/course/AIKI100

AIKI110 Artificial Agents 10 https://www.uib.no/en/course/AIKI110

AIKI210 Artificial Intelligence and Ethics 10 https://www.uib.no/en/course/AIKI210

AIKI200 Bachelor thesis in Artificial Intelligence 10 https://www.uib.no/en/course/AIKI200

INFO100 Introduction to Information Science 10 https://www.uib.no/en/course/INFO100

INFO132 Introduction to Programming (Python) 10 https://www.uib.no/en/course/INFO132

INFO162 Introduction to Human-Computer Interaction 10 https://www.uib.no/en/course/INFO162

INFO180 Methods in Artificial Intelligence 10 https://www.uib.no/en/course/INFO180

INFO216 Knowledge Graphs 10 https://www.uib.no/en/course/INFO216

INFO282 Knowledge Representation and Reasoning 10 https://www.uib.no/en/course/INFO282

INFO284 Machine Learning 10 https://www.uib.no/en/course/INFO284

INFO318 Research Topics in Cognitive Computing 15 https://www.uib.no/en/course/INFO318

INFO319 Research Topics in Big Data 15 https://www.uib.no/en/course/INFO319

INFO371 Research Topics in Networks and Text Analysis 15 https://www.uib.no/en/course/INFO371

INFO381 Research Topics in Artificial Intelligence 15 https://www.uib.no/en/course/INFO381

INFO382 Logic for Multiagent Systems 15 https://www.uib.no/en/course/INFO382

NFO383 Research Topics in Artificial Intelligence Ethics 15 https://www.uib.no/en/course/INFO383

INFO345 Research Topics in Recommender Systems 15 https://www.uib.no/en/course/INFO345

INFO901 Introduction to AI Ethics 10 (for doctoral students) https://www.uib.no/en/course/INFO901

ECON121 Health Economics 10 https://www.uib.no/en/course/ECON121

ECON342 Cost-Benet Analysis 10 https://www.uib.no/en/course/ECON342

FIL228 Moral Philosophy 10 https://www.uib.no/en/course/FIL228

FIL235 The Philosophy of Mind 10 https://www.uib.no/en/course/FIL235

JUS250-2-C Health and Human Rights in the Welfare State 10 https://www.uib.no/en/course/JUS250-2-C

JUS260-2-A Design and Patent Law 10 https://www.uib.no/en/course/JUS260-2-A

JUS295-2-A Legal Technology: Artificial Intelligence and Law https://www.uib.no/emne/JUS295-2-A

JUS294-2-A Privacy and Data Protection

DAT158 Machine learning and advanced algorithms 10 https://github.com/alu042/DAT158ML

DAT255 Practical deep learning 10 https://www.hvl.no/en/studies-at-hvl/study-programmes/course/dat255

DAT254 Health Informatics 10 https://www.hvl.no/en/studies-at-hvl/study-programmes/course/dat254

RAD820 Pasientforløp i klinisk radiografi 5 https://www.hvl.no/studier/studieprogram/emne/rad820

RAD840 Biomedisin, bildebehandling og bildeanalyse 15 https://www.hvl.no/studier/studieprogram/emne/rad840

RAD850 Biomedisin tema innan mammografi 5 https://www.hvl.no/studier/studieprogram/emne/rad850

APPENDIX C

Supplementary information for the assets at the UiB Faculties

Faculty of Medicine

There are several efforts at MED and PSYK to analyze data across registries or combine with biological data and/or wearable health technology data from individual patients (precision medicine) using AI methods. These efforts are found within Precision endocrinology (Prof Eystein Husebye and Helge Ræder, Dept of Clinical Science), hematological cancer (Prof. Bjørn Tore Gjertsen, Dep. Dept of Clinical Science), ortopedics (Dr. Håvard Visnes), hypertensive nephropathy (Prof. Hans-Peter Marti, Dept. Of Clinical Medicine), ultrasound in cardiac disease (Ass prof Stig Urheim, Dept of Clinical Science), laryngeal obstruction (Dr Hege Clemm, Dept of Clinical Science), and decision-support systems in neonatal sepsis (Dr. Jobin Varughese) and emergency calls (Dr Jesper Blinkenberg, Norce). There are also efforts underway to learn causal mechanisms that are not easily tested using conventional randomized trials, which will ultimately lead to new targets for intervention for disease prevention as well as treatment (three pending grants to RCN Center for Clinical Trials, 2021). There are also deployments of AI methods for Disease risk prediction and Genomic data analysis and integration (Prof Anagha Joshi, Department of Clinical Science, Prof Jan Haavik, Dept of Biomedicine) and analysis of clinical mass spectrometry data (Dr Ralf Kellmann, Dept of Clinical Science).

On behalf of UiB, MED will host the **Medical Innovation Center** (“EITRI medical incubator), inaugurated Nov 1, 2021) which will be a testbed for innovation related to medical AI-applications as well as host physical centers with focus on AI applications. Although there are several active health startups and companies in Bergen, there is currently no Health Cluster of companies (Helsenæringsklynge) led from Bergen. Industry partners engaged in areas relevant to medical AI and identied by us include member companies of the Norwegian Smart Care Cluster (the Cluster leadership is based in Stavanger with a node in Bergen) and of Norwegian Health Tech (leadership based in Oslo but a node is planned in Bergen), mainly promoting solutions to facilitate smart living and digital phenotyping. There are also potential companies associated with VIS and with the StartUp Lab Bergen, and companies associated with research centers (NeuroSysMed and the Bergen Center for Brain Plasticity) and with Intromat and SEFAS. Notably, Intromat and SEFAS collaborators exemplify the corporate portion of a medical AI-relevant accademia-industry ecoystem with small and medium-sized enterprises: Sensor providers (e.g. Atea; Attensi, Tidewave); Platform providers (e.g. Atea, Tidewave; Youwell); AT and sensor providers (e.g. Motitech; Friskus; Attensi; NyBy; Jodacare, Brain+; Visdoc; Lifekey); Housing providers (Snøhetta & Medvita; BOB; Husbanken, GC Rieber Foundation) and dissemination providers (Hold Fast! and KLP).

APPENDIX D

History of Deep Learning

1943 McCulloch & Pitts proposed the first neural model, the Binary-Threshold Neuron. University of Illinois, University of Chicago.

1959 Hebb proposes a theory of the adaptation of brain neurons during the learning process. McGill University.

1957 Rosenblatt proposes a new model of neuron able to learn from examples, the Perceptron. Cornell Aeronautical Laboratory Inc.

1969 Minsky & Papert: showed strong limitations of the perceptron: the interest on neural networks disappeared for many years. MIT.

1982 Hopfield: developed a neural network capable of behaving as an associative memory. California Institute of Technology.

1982 Kohonen: developed a competitive learning model to create Self-Organizing Maps. Helsinki University of Technology.

1983 Barto, Sutton & Anderson: proposed a neural network capable of learning without supervision (Reinforcement Learning). University of Massachusetts.

1986 Rumelhart, Hinton & Williams: formalized the process of learning by examples, defining the so called Backpropagation algorithm. University of California, Carnegie-Mellon University.

1989 LeCun, Boser, Denker, Henderson, Howard, Hubbard, and Jackel : Applying back propagation to a neural network for a vision classification task. AT&T Bell Laboratories.

1998 LeCun,Bottou, Bengio, Haffner: Multilayer neural networks trained with the back-propagation algorithm constitute the best example of a successful gradient based learning technique. AT and T Research Laboratories, Université de Montreal.

2017 Researchers from Google introduce the Transformer architecture.

APPENDIX E:

Example of how UiB can construct a cross-disciplinary 20 ECTS AI course

This Appendix gives a sketch description a modular 20 ECTS course on Clinical Data Science and AI. The idea is to establish a course that gives a comprehensive introduction to the field if followed in its entirety, while being sufficiently modular to be used with existing courses and study programs across UiB and HVL by picking and choosing modules. It can also be a source for continuing education offerings and for short workshops targeting specific professionals. There are multiple elements of the course that are kept open, as the exact profile of the course depends on the prole of the final Centre.

Objectives and content

With massive amounts of data flowing from advanced imaging and sequencing to consumer-level sensors, there is a clear need for solutions able to extract meaningful, actionable insights that are practically useful for the present and future healthcare system. Artificial intelligence (AI) offers the potential to create such insights. Machine learning (ML), a sub-field of artificial intelligence (AI) dealing with methods that enable computers to learn from data, is particularly relevant. Successful introduction of techniques from machine learning and AI into healthcare can open the door for more predictive, preventative, personalized and participatory medicine, and to new innovations in healthcare at large. However, there are many obstacles for machine learning in healthcare, and machine learning alone cannot solve any real problems. What is needed is a broader understanding of clinical data science and AI. This course provides an introduction to this field, giving practical know-how and deep appreciation of the hurdles faced when attempting to bring machine learning and AI into healthcare.

The course is modular in nature. In its entirety it includes components covering the nature of clinical data and the use of machine learning for electronic health records, precision medicine, diagnosis, improving clinical workflows and drug discovery. Topics of general interest to a broad audience will be covered, including ethical considerations, interpretability, algorithmic fairness, regulations, and more. The course also covers more technical topics, including sensor data analysis, feature engineering, time-series analysis, deep learning, and more. Guest lectures by clinicians from the Bergen area and course projects that deal with real clinical data show the many subtleties faced when working with clinical data, and the arduous road to be traveled to translate AI into clinical practice.

One cannot become an expert on a topic based on a single course alone, but as part of existing curricula and study tracks, the course will be a very useful addition for anyone dealing with topics related to clinical data science and AI. In particular, it can form the basis for delving into related topics in MSc or PhD thesis work.

Learning outcomes

Knowledge-based learning outcomes

-Is able to explain what makes healthcare different from other fields, and how that impacts the construction, evaluation and use of AI-based tools.

-Has knowledge of how AI and ML fits with the broader field of healthcare informatics and analytics

-Can describe possible futures for healthcare

-Is able to explain basic operational principles of selected sensors and measuring devices in medical research and clinical practice

-Is knowledgeable about core concepts from machine learning and can provide examples of their use for personalized and predictive medicine.

-Is knowledgeable about the concepts and importance of “open science", “data sharing", an “reproducible research".

...

Skill-based learning outcomes

-Can analyze the role played by current AI-based techniques in healthcare

-Can make active use of methods and techniques from AI and ML as applied to problems in healthcare

-Can initialize, plan, execute, monitor and close medical AI-related projects

...

General competence

-Understand the importance of mathematical models and computations in the analysis and understanding of complex physiological systems and disease processes, and the need of cross-disciplinary collaborations in future medicine.

-Able to reflect on the possibilities and limitations for AI applied in healthcare

Content and teaching methods

The course consists of X independent modules:

1. What makes healthcare unique? Topics include:

-The future of medicine: predictive, preventative, personalized and participatory

-The goals and needs of healthcare.

-What kind of expertise is needed for the future of medicine?

-How medical AI relates to healthcare informatics.

2. Electronic health records

-Clinical data. Standardization.

-Current limitations of EHR and related systems

-Predictive modeling using EHR data

3. Sensors and physiological time-series. Topics include:

-Wearables

-Smart hospitals

-Hospital@Home

4. Medical imaging and imaging diagnostics. Topics include:

-The principles and main modalities of medical imaging

-Medical image analysis, focusing on methods from computer vision

-The future of computer-aided image diagnostics

5. Drug discovery

6. Integrating heterogeneous information sources; Digital biobanking

7. Translating technology into clinical practice: regulations, ethics, infrastructure and the diagnostics Process

Each module has three parts: (i) a general introduction to the topic, including locally sourced examples; (ii) a hands-on session where students get to work with real-life problems and data, writing essays and/or computer programs; (iii) a survey of the state-of-the-art in the field.

Parts (i) and (iii) can be used as components in courses for students without programming experience, while part (ii) can exist in different versions, adapted to both technical and non-technical students. For example, a clinician can complete the first and last module in the course, as well as parts (i) and (iii) of the most relevant remaining modules. As in the existing elective course ELMED219 at MED offered to medical students and software engineering students at UiB and HVL, clinicians can be expected to complete some versions of the hands-on parts.

We envision four main tracks through the course, adapted for different types of backgrounds and interests: 1) AI specialization: possess previous knowledge of ML and software engineering. Get to attack real-life problems in healthcare 2) Medicine specialization: medical students interested in AI. Some hands-on exposure, obtain strong conceptual knowledge 3) AI engineering specialization: previous knowledge of ML engineering, interested in deployment of AI-based solutions in healthcare 4) Other: interest in both medicine and AI, i.e., from law, philosophy etc. Conceptual understanding of medical AI, opportunities, challenges and current limitations, as well as the broader field of computational medicine.

The students are expected to complete problem sets associated to each module. There will also be a large course project where students work in teams solving a real-world challenge.

Course projects.

Groups of students team up to propose a problem they want to investigate. As far as possible, they are encouraged to form groups that span multiple disciplines, e.g., medical students + software engineers, software engineers + health informaticians, and so on. The projects will be addressed as real research projects, including hypotheses / questions, expositions of related work, experiments or arguments meant to test the hypotheses, and analyses of results. These will be written up in a report and also presented as posters, following one of the fixed, scientific formats provided by the course organizers. Throughout the course period there will be multiple deliverables, designed to make sure the students stay on track and that they are given timely feedback from lecturers and teaching assistants.


UNIVERSITAS
BERGENSIS