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Research Agenda of the Mohn Medical Imaging and Visualization Centre in Bergen, Norway

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Abstract

The Mohn Medical Imaging and Visualization Centre (MMIV) was recently established in collaboration between the University of Bergen, Norway, and the Haukeland University Hospital in Bergen with generous financial support from the Bergen Research Foundation (BFS) to conduct cross-disciplinary research related to state-of-the-art medical imaging, including preclinical and clinical high-field MRI, CT and hybrid PET/CT/MR. The overall goal of the Centre is to research new methods in quantitative imaging and interactive visualization to predict changes in health and disease across spatial and temporal scales. This encompasses research in feature detection, feature extraction, and feature prediction, as well as on methods and techniques for the interactive visualization of spatial and abstract data related to and derived from these features. With special emphasis on the natural and medical sciences, the long-term goal of the Centre is to consolidate excellence in the interplay between medical imaging (physics, chemistry, radiography, radiology), and visualization (computer science and mathematics) and develop novel and refined imaging methods that may ultimately improve patient care. In this poster, we describe the overall research agenda of MMIV and describe the four core projects in the centre.

CCS Concepts
• ***General and reference*** → ***Surveys and overviews;***

The Mohn Medical Imaging and Visualization Centre

Due to inherent complexity as well as advances in medical imaging, challenges arise that require the close interaction between scientists from many disciplines. Furthermore, involvement of clinicians and patient groups is essential to ensure that research agendas are relevant, and to minimize the distance between development and implementation in clinical routine. Facilitating a culture for this kind of interdisciplinary research is often underestimated in terms of time, resources and efforts required to gain the necessary reciprocal respect and in identifying opportunities and limitations of the collaboration, i.e., "speaking the same language".

The Mohn Medical Imaging and Visualization Centre was established to facilitate the best possibilities for interdisciplinary research in medical imaging and visualization. The newly established offices, equipped with high performance computing facilities, are located at the Haukeland University Hospital. Here, computer scientists, clinicians, radiologists, physicists, engineers work side-by-side at the heart of one of Norway's largest radiology departments providing access to state-of-the-art imaging equipment (MRI/PET/CT/US and hybrids). The scientific agenda is determined by the four core projects that were selected after an open call with a two-step international review process, which are described in the following.

Computational Medical Imaging and Machine Learning Over the past few years there has been a dramatic development in areas associated to machine learning and artificial intelligence. This is caused by breakthroughs in deep learning, a collection of techniques that enable computers to uncover complicated patterns and connections in large data sets. Increased access to data (big data) and increased computational power has made it possible to use deep neural networks effectively, and they have become the state-of-the-art approach to many key challenges in computer vision, language modeling and robotics. These developments have enormous potential also within medicine, where large data sets from health registers, images, biopsies and gene sequences are collected.

The project "Computational Medical Imaging and Machine Learning – methods, infrastructure and applications" develops, implements, disseminates and evaluates machine learning techniques in the analysis of medical images and image-related data. The project's objective is to contribute to an increased degree of personalized medicine and better decision support for diagnosis, prognosis and therapy in diseases and conditions where images are an important source of information.

To successfully incorporate machine learning in medicine, doctors and medical specialists have to take a leading role. The project, initiated from the Dept. of Biomedicine at the University of Bergen in Norway (UiB) and the Dept. of Computing, Mathematics and Physics at Western Norway University of Applied Sciences (HVL), is therefore tightly connected with Departments at the Bergen University Hospital (HUS) where data is collected and decisions are made. It involves many researchers in Bergen, both clinical and methodological, in addition to national and international collaborators from world-class research institutions.

Additionally, the project employs new researchers, offers new interdisciplinary courses for medical students, engineers and natural science students, and disseminates and discusses methods and results with a wider audience. There's also a substantial innovation potential for machine learning in medicine, and the project aims at identifying and potentially pursuing these opportunities.

Precision Imaging in Gynecologic Cancer Gynecologic cancers have characteristic structural and functional imaging features reflected in clinical phenotypes, and these imaging biomarkers highlight pathogenic mechanisms potentially targetable by novel treatments. The challenge is now to integrate these imaging biomarkers into clinically relevant treatment algorithms by identifying molecular targets for treatment based on imaging biomarker profiles. MMIV researchers will exploit their multidisciplinary competency in computer science, visualization, machine learning, diagnostic radiology, clinical gynecology, preclinical models, and molecular biology/genetics and join efforts to pursue these challenges.

Molecular and imaging biomarkers in gynecologic cancer are studied in patients and in preclinical gynecologic cancer models. Potential imaging biomarkers are to be identified using machine learning algorithms applied to multiparametric and functional magnetic resonance imaging (MRI) and positron emission tomography/computed tomography (PET/CT) from patients and in mouse models during therapy. Furthermore, the molecular and genetic alterations in the tumors as well as clinical phenotype and survival are studied in relation to the corresponding imaging biomarker profile using integrative analyses. This research initiative provides a unique platform for identifying promising molecular targets for treatment and their corresponding imaging biomarker profiles. Studying imaging biomarkers in mice during targeted therapy can facilitate the integration of imaging biomarker guided treatment algorithms and imaging guided monitoring of treatment response in gynecologic cancer. This MMIV-project aims to improve patient care by enabling individualized and targeted treatment in gynecologic cancer patients.

Visual Data Science for Imaging Biomarker Discovery Technology is revolutionizing medicine. New scanners enable doctors to look into the patient's body and study anatomy and physiology without the need of a scalpel. New scanning technologies emerge at an amazing pace, providing an ever growing and increasingly varied look into medical conditions. Today, we cannot only look at the bones within a body, but we can also examine soft tissue, blood flow, activation networks in the brain, and many more aspects of anatomy and physiology. The increased amount and complexity of the acquired medical imaging data leads to new challenges in knowledge extraction and decision making.

In order to optimally exploit this new wealth of information, it is crucial that imaging data is successfully linked to the medical condition of the patient. In many cases, this is challenging, for example, when diagnosing early-stage cancer or mental disorders. Analogous to biomarkers, which are molecular structures that are used to identify medical conditions, imaging biomarkers are information structures in medical images that can help with diagnosis and treatment planning, formulated in terms of features that can be computed from the imaging data. Imaging biomarker discovery is a highly challenging task and traditionally only a single hypothesis (for a new biomarker) is examined at a time. This makes it impossible to explore a large number as well as more complex imaging biomarkers across multi-aspect data. In the VIDI project ("Visual Data Science for Large Scale Hypothesis Management in Imaging Biomarker Discovery"), we research and advance visual data science to improve imaging biomarker discovery through the visual integration of multi-aspect medical data with a new visualization-enabled hypothesis management framework. We aim to reduce the time it takes to discover new imaging biomarkers by studying structured sets of hypotheses, to be examined at the same time, through the integration of computational approaches and interactive visual analysis techniques. Another related goal is to enable the discovery of more complex imaging biomarkers, across multiple modalities, that potentially are able to more accurately characterize diseases. This should lead to a new form of designing innovative and effective imaging protocols and to the discovery of new imaging biomarkers, improving suboptimal imaging protocols and thus also reducing scanning costs.

Advanced Neuroimaging The aim of the advanced neuroimaging project is to develop and apply novel approaches of quantitative imaging in studies of the human central nervous system. Deep learning and medical visualization are core activities performed in close collaboration with the respective Centre projects in machine learning and visual data science, respectively.

The advanced neuroimaging project is an umbrella project for three subprojects. The GEMRIC project - Global ECT-MRI research collaboration - aims at investigating changes in brain structure and function following electroconvulsive therapy (ECT), in order to identify treatment mechanisms but also to identify predictors of clinical response. The project involves multiple research groups in Europe, Asia and the US, that collectively group their clinical and neuroimaging data in order to overcome limiting sample sizes and hence have established the world's largest sample of data before and after ECT treatment. The multimodal neuroimaging subproject includes development and application of novel imaging approaches (diffusion, perfusion, spectroscopy) targeted at investigating the integrity of the microvasculature and neuroinflammation in selected neurological and neuropsychiatric applications. The final subproject, financed through an advanced grant from the Norwegian Research Council, aims at revisiting fMRI methodology.