Project Proposals for Doctoral Researcher Positions 2025

ID04: Knowledge Graph Reasoning for Generalized Surgical AI (Lena Maier-Hein, Karl-Friedrich Kowalewski)

Heidelberg, DKFZ, Intelligent Medical Systems

Death within 30 days after surgery has recently been found to be the third-leading cause of death worldwide, with research suggesting that a large proportion of these deaths are due to surgical error. The newly established domain of Surgical Data Science [Mai22] aims to address this issue, yet, clinical translation of data science methods remains limited due to challenges in generalization and adaptability across diverse surgical environments. To bridge this gap, this project proposes a novel approach that integrates knowledge graphs (KGs) with Vision-Language Models (VLMs) to achieve a generalized understanding of unannotated surgical procedures. KGs serve as structured representations of surgical instruments, anatomical structures, and procedural steps, enabling AI models to infer contextual relationships during real-time surgical scenes. Through multi-modal learning, we aim to extend the zero-shot capabilities of VLMs to interpret complex, unseen surgical actions by leveraging hierarchical reasoning and contextual awareness embedded in the KG.

To implement the project, we have access to a multi-center world-wide unique video data set of unprecedented size comprising more than 10,000 videos annotated with procedural information and (partially) frame-based annotations related to procedure steps and adverse events. This unique resource combined with our domain expertise and innovative use of KGs, has the potential to set the stage for groundbreaking advancements in surgical scene understanding and generalization, enabling robust AI-driven decision-making across diverse surgical procedures and institutions.

Requirements:

- Well-founded programming skills in Python or C++
- An excellent Master's degree in the field of Informatics, Physics or Mathematics
- Experience in deep learning-based methodology especially Graph Neural Networks
- Excellent ability to work in teams and high intrinsic motivation

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