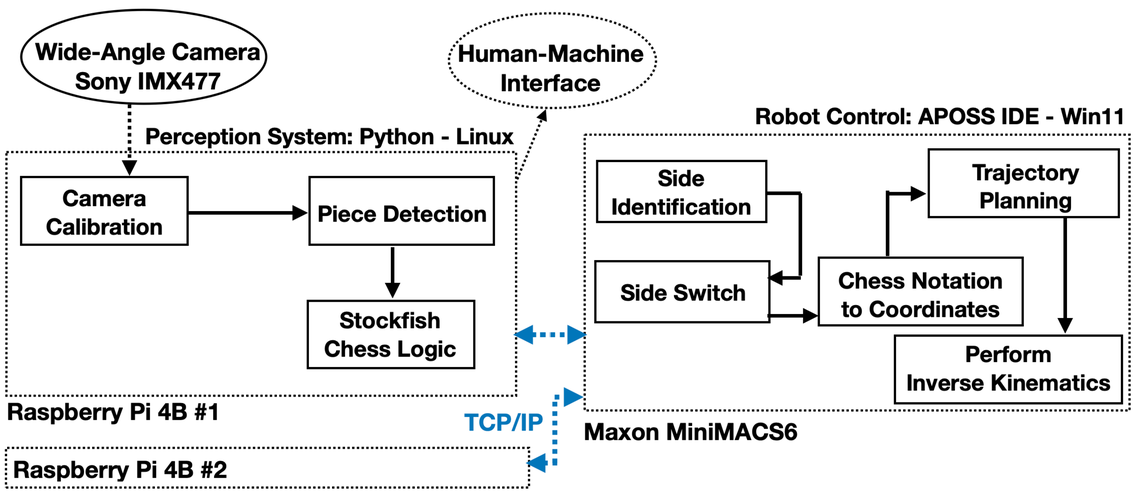
HSLU Hochschule Luzern

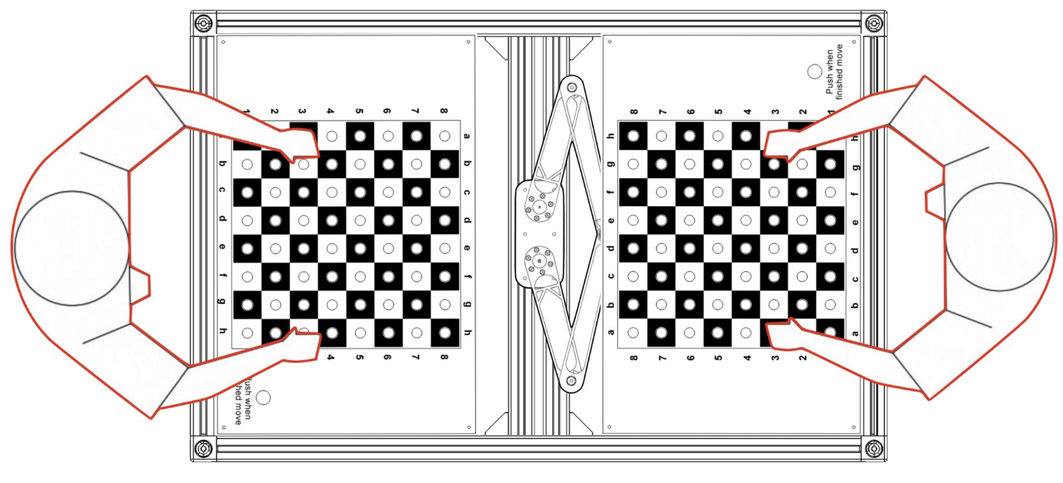
Technik & Architektur
Master-Thesis – Mechatronics & Automation

Master of Science in Engineering - Mechatronics & Automation

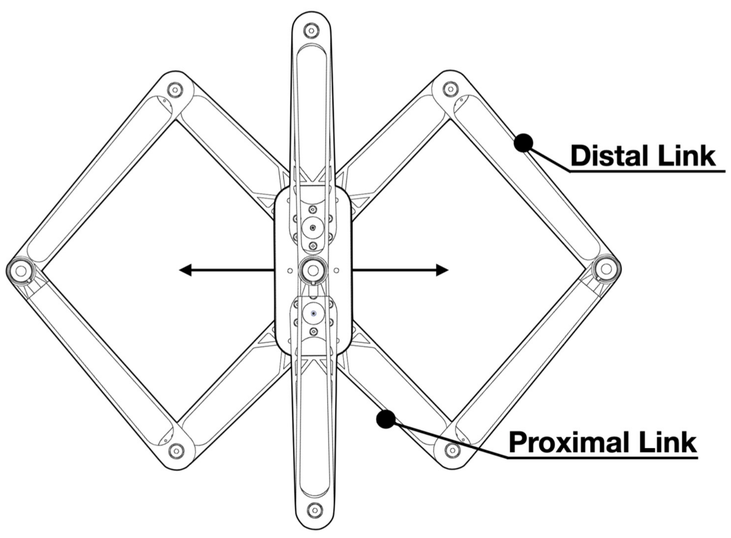
Human-Robot Interaction with a Dual-Arm parallel SCARA



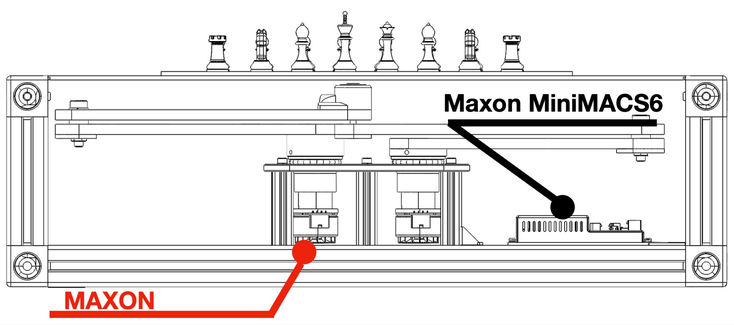
Hardware and Software Framework



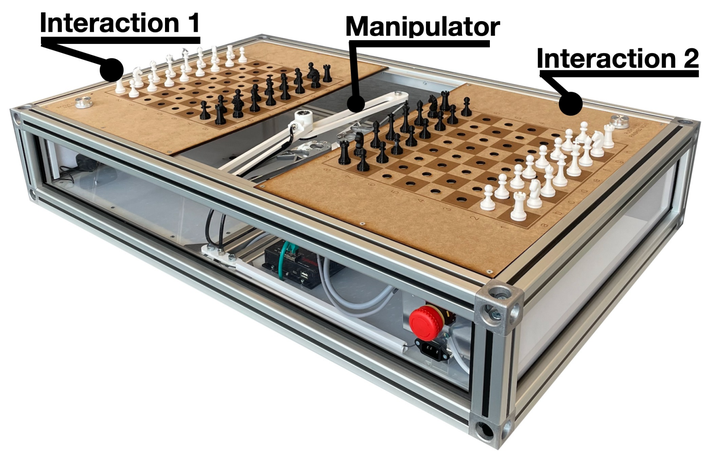
Interaction with two individuals



Dual-Arm parallel SCARA – Side Switch



Maxon Motors AG – Motion Control



Interactive Mechatronic System - Prototype

Problem Description

A significant proportion of the literature on collaborative robotics focuses on ensuring safe human-robot interaction. However, providing adequate safety for human-robot interaction in the same workspace remains a significant challenge, as achieving complete safety is not feasible. Approaches to achieve this safety include both design and motion planning strategies. Existing contributions to human-robot interaction in board games typically involve collaborative robots or serial manipulators, which can limit the mobility and efficiency of the overall interaction, including safety concerns.

The literature shows a gap in safe interactive solutions that allow efficient interaction without the possibility of direct physical contact between humans and robots. As a result, there is a need to develop safe and efficient interactive systems that address the limitations of existing solutions and minimise the risk of accidents. Especially where collaborative systems are not essential. Therefore, this thesis will address the research question of investigating the key factors and challenges involved in developing an interactive mechatronic system that ensures safety by design. It will explore the use of a dual-arm parallel SCARA manipulator to enable transitions between two interactions.

Materials and Methods

The research presents a comprehensive methodology focusing on safe and reliable human-robot interaction in the context of a chess game environment. The key hardware and software frameworks of the system are Raspberry Pi 4B units, a Maxon industrial motion controller, a graphical user interface and a high quality SONY IMX477 wide-angle CMOS camera. A key element of the system is a perception system that combines computer vision with OpenCV and chess logic with Stockfish. The perception system consists of several stages: Chess board recognition, camera calibration, chess piece identification, logic verification and move generation. The core mechanical component is a dual-arm parallel SCARA manipulator, which requires an intensive design process to enable seamless switching between two interactions by passing through a singularity. To combine all these frameworks, a TCP/IP communication protocol based on a server-client architecture is used to allow two independent interactions.

Results

The main evaluation includes autonomous interaction, seamless transition between two humans and execution times for different chess moves.

The summary of manipulations includes 378 manipulations, with an autonomous success rate of 96.83%, error correction interventions and other errors. Furthermore, the execution times for chess moves underlines the efficiency: simple pawn moves take an average of 4.56 seconds and the generation of countermoves only 0.78 seconds. The evaluation also highlights the importance of responding to deviations from expected human behaviour. While valid movements are recognised, unintended or manipulative actions pose challenges for the system. Improvements can provide even more natural human-system interaction.

Overall, this research realised safe human-robot interaction through a dual-arm parallel SCARA manipulator that prioritises safety by design. The integration of AI through chess and robotics provided dynamic, simultaneous interactions and reduced human risks.

Alex Petrovic, BSc
Supervisors: Prof. Dr. Björn Jensen
Dr.rer.nat. Andrea Mizelli-Ojdanic, MSc
Expert: Dr. Raphael Zimmermann

FH Zentralschweiz

FH University of Applied Sciences TECHNIKUM WIEN

maxon