Project type: Research project
Proposal title: Assisted Function Exoskeleton, AFES
Name of involved staff: This project will be led by Mikael Ekström (robotics, material physicist) together with Nikola Petrovic (dependability, health technology, sensor systems), and Martin Ekström (electronics, communication, sensor system). The student involved will be Pontus Sundqvist who is a master student from the master of science in engineering program (civilingenjör) in dependable systems, and PhD candidate after the first year.

Introduction

The proposed project is combining the research areas of robotics, health technology, and dependable systems, with a strong connection to the master education programs in robotics, dependable systems, and embedded systems. The project aims at developing a smart upper body exoskeleton that can be used in fields like agriculture (e.g. fruit and berries picking), industry application (e.g. assisting in heavy lifting), and health technology (e.g. heavy and/or steady lifting and assistance by holding a leg at surgery).

In order to ensure the usefulness, safety, and trustworthiness of the proposed system in the project, will the exoskeleton be equipped with a number of sensors, actuators, and embedded computing capabilities. These components will enable the system to assist the person using it in a manner that is appropriate for the given situation [1]. In this project, it will be important to include the humans in the loop when designing and optimising the algorithms for assistance [2]. There will also be a need for proper certification of the system to ensure the trustworthiness.

The intended use of the AFES system is to provide assistance for the arms of the human torso. This means that the device can help in tasks such as lifting heavier objects (up to 25kg) than what the person wearing the device would normally be capable of. Additionally, it can assist in holding a load steady over a longer period of time, preventing fatigue and exhaustion that may occur in a human not wearing the medical device.

The expected outcome of the project is a functional prototype of a smart upper body exoskeleton. This prototype will be designed and constructed in accordance with the required certification standards. Ensuring trustworthiness is crucial, and to achieve that, the AFES system will be developed with adherence to standards and regulations right from the beginning of the project. To be able to build the design lightweight while still strong will, in cooperation with IPR (Eskilstuna), the parts be done using carbon fibre reinforced extruded and/or casted plastic.

The final product of this project will be great “show case” for the cross disciplinary research done at IDT (and MDU).

Brief related work

The goal of this project is to propose and construct a smart exoskeleton design that complies with medical standards and EU regulations, to demonstrate its feasibility. Currently, there is limited research available that has considered certification standards during the development of an exoskeleton system with the same intended purpose and function. The work that is most closely related to this area is Cyberdyne’s “HAL FOR MEDICAL USE SINGLE JOINT TYPE (EU MODEL)” (https://www.cyberdyne.jp/english/products/SingleJoint_medical.html). However, this work does not share the same function, design, or purpose as the proposed project. Much of the state-of-the-art research in this field differs significantly from the goals and intended purpose of the AFES project. Many of these studies focus on improving endurance in an assistive manner rather than enhancing human lifting capacity [3, 4]. Additionally, the suggested designs in the state-of-the-art research are in many cases cumbersome, heavy, and large in size [5, 6].

For this project, all attributes of dependability will be considered and will continue to be important throughout the development of the system. During the spring of 2023, a clinical investigation was conducted for the AFES system with the aim of providing the preliminary requirements for the system by the end of June 2023. The feasibility of the system and its compliance with standards and regulations were investigated during this clinical investigation. Multiple analyses were carried out according to ISO 14971, ISO 24971, ISO 14155, EN 62366, and ISO 13485 to ensure the correct development of the system.

The results of these analyses, combined with European regulations, were used to formulate the preliminary requirements, which serve as guidelines for modelling and building the system. The intention is to minimize errors during modelling and prototyping by providing clear instructions. This approach will significantly reduce the time required to archive results and nay also decrease associated project costs. The preliminary requirements are expected to be finalized before the start of the project.

References

1. Slade, P. et al. “Personalizing exoskeleton assistance while walking in the real world”, Nature 610, 277–282 (2022). https://doi.org/10.1038/s41586-022-05191-1

2. Zhang, J. et al., “Human-in-the-loop optimization of exoskeleton assistance during walking”, Science 356,1280-1284(2017). DOI:10.1126/science.aal5054

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4. S. Bai, S. Christensen and M. R. U. Islam, "An upper-body exoskeleton with a novel shoulder mechanism for assistive applications", 2017 IEEE International Conference on Advanced Intelligent Mechatronics (AIM), Munich, Germany, 2017, pp. 1041-1046, doi: 10.1109/AIM.2017.8014156.

5. A. Ebrahimi, "Stuttgart Exo-Jacket: An exoskeleton for industrial upper body applications", 2017 10th International Conference on Human System Interactions (HSI), Ulsan, Korea (South), 2017, pp. 258-263, doi: 10.1109/HSI.2017.8005042.

6. Huysamen, K., Bosch, T., de Looze, M., Stadler, K. S., Graf, E., & O'Sullivan, L. W. (2018). “Evaluation of a passive exoskeleton for static upper limb activities”, Applied Ergonomics, 70, 148-155. https://doi.org/10.1016/j.apergo.2018.02.009

Scientific challenges addressed

There are several scientific challenges that need to be addressed in this project, encompassing hardware (mechanical and electronics) and software (AI and sensor systems), while considering the certification standards for the entire system. The most prominent challenges are:

- Compliance with appropriate standards during the design and testing phase of the system, with human involvement.
- Designing the physical structure of the complete system to provide support without being excessively heavy or bulky, while adhering to certification standards.
- Developing AI methods and sensor systems to enable intelligent and reliable assistive support within the system.
- Designing and implementing a sensor system for detecting the nutritional status of plants, fruits, etc.

These challenges represent significant aspects that require scientific attention and expertise throughout the project.

Approach (how will the challenges be addressed?)

To tackle the challenges, a specific approach will be adopted. In the autumn of 2023, as part of the fifth-year robotics course, robotics students will develop an initial simulation for the AFES system. This simulation will serve as a validation tool before proceeding to the next phase: building a prototype. The prototype will be constructed in accordance with predetermined requirements established prior to and during the development process. Additional requirements may be identified and incorporated as potential issues arise during development. It is crucial to ensure strict adherence to the requirements throughout the development process. Documentation for the clinical investigation will be continuously updated as the project progresses. In the spring of 2024, the remaining work for the clinical investigation will be carried out, including verification and quality analyses, as part of a master's thesis. This phase will culminate in the completion of the clinical investigation, providing insights into the feasibility and functionality of the AFES system.

The project's ultimate goal is to design an exoskeleton system capable of providing smart and reliable assistive functions in various work environments such as agriculture, medical, construction, or warehouse work. The area of research is strongly coupled with some of the master programs at the university, Robotics, Dependable Systems and Embedded Systems. The project will be greatly benefited by this close collaboration between research and education.

This project may also aid in finding competence for future continuation of the research work of the project, as the school, and university as a whole, has plenty of experience regarding most of the subjects that can be involved in the AFES project research.

The local context (the team that primarily will work with the PhD-candidate, PostDoc or in direct connection to the project, related work/ongoing projects locally and other persons working on similar topics that the PostDoc will benefit from interacting with)

The research in the project will be done in close collaboration with the robotics and health technology research groups. The project is also related to the ongoing research project RECOG, in which A.I. algorithms on reconfigurable hardware (FPGA) are used together with an artificial hand for innovative brain-training for people with cognitive deficits

Potential/planned external collaboration (if any)

This project is initiated within the STINT student project between MDU, UdeA (Medellin, Colombia, and UTP (Panama city, Panama) as a potential collaboration research project. It will be run in close collaboration with master students from MDU (robotics and embedded systems) and UTP (mechatronics and robotics). Interest has also been shown from UPM (Madrid, Spain) to include MDU and UTP in a H2020 application for assistive exoskeleton in agriculture use. There are also, of course, possibilities to connect this to the research and education at other schools, e.g. the physio therapists.