Department	Electrical and Electronics Engineering
Master thesis title:	The implementation and testing of high-torque closed loop actuator for an exoskeleton device
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Thesis background:	With recent research and development of personal wearable robotic devices used for rehabilitation of patients with spinal cord injuries and other neurologic conditions that limit mobility showing great progress, need for lower priced versions of these, so far limited to only most prestigious rehabilitation institutions also arises. Development of the low cost and open-source exoskeleton device's main problem is implementation of the high torque and low backlash closed loop actuator. Previous attempts at creating this device had always been partially successful in this department. Size, weigh and power consumption of the actuator module are key for solving the entire system. With development of the actuator rest of the build falls down on solving comparatively simpler robotics problems of mechanical construction and overall control system.
Thesis objective:	Multi degrees of freedom robots enable a distributed interaction on the whole assisted limb and can exploit a large amount of sensory feedback data, potentially

providing new capabilities within standard rehabilitation sessions [1].
Development of the exoskeleton as an multi degree of freedom robot needs to start with development of high torque and precisely controllable actuator. Research that has been done on similar requirement prosthesis by researchers from Universities of Mostar and Sarajevo, showed that hydraulic power system is a way to go, since both electric and pneumatic actuators did not meet size/power ratio [2].

Actuator unit consisting of a reversable hydraulic piston powering a revolute joint of the robot with integrated rotary encoder needs to be developed. Each actuator is to have its own position control MCU running PID controller. This would simplify control of the system with multiple actuators by the central motion controller.

Additional actuators can be added to the same motion controller and setpoint for each actuator can be passed trough I2C or some other communication protocol. Status of the actuator, its current position, work state and any additional parameters are sent to the motion controller for further processing.

Motion controller is going to use an absolute encoder, most likely MPU6050 inertial measurement unit [3], to determine the reference angle of the exoskeleton.
To be able to control the entire system and achieve predetermined motion cycles inverse-kinematics model of

	the exoskeleton needs to be created. This will allow simple creation of motion routines with for example CNC toolpath generation software. Motion controller will take the user input from HID, joystick for example, and it will initiate predetermined motion routine. Coordinates of the end effector will be taken from motion routine and inverse kinematics model will provide angles for the both actuators. Closed loop actuator will take the angle as an input, and a PID algorithm will extend or retract the hydraulic cylinder in order to achieve the desired angle.
Literature:	[1] T. Proietti, V. Crocher, A. Roby-Brami and N. Jarrasse, "Upper-Limb Robotic Exoskeletons for Neurorehabilitation: A Review on Control Strategies," *IEEE Reviews in Biomedical Engineering 9:1-1,* 2016. [2] M. Rupar, Z. Jelacic, R. Dedic and A. Vucina, "Power and Control System of Knee and Ankle Powered Above-Knee Prosthesis," in *4th International Conference "New Technologies NT-2018*, Sarajevo, 2018. [3] TDK. [Online]. Available: https://invensense.tdk.com/wp-content/uploads/2015/02/MPU-6000-Datasheet1.pdf. [Accessed 2021]. [4] A. Widodo, A. Muzakki and F. Baskoro, "A 2-DoF Robot Arm Simulation for Kinematics," *Advances in Social Science, Education and Humanities Research,* vol. 242, 2018.