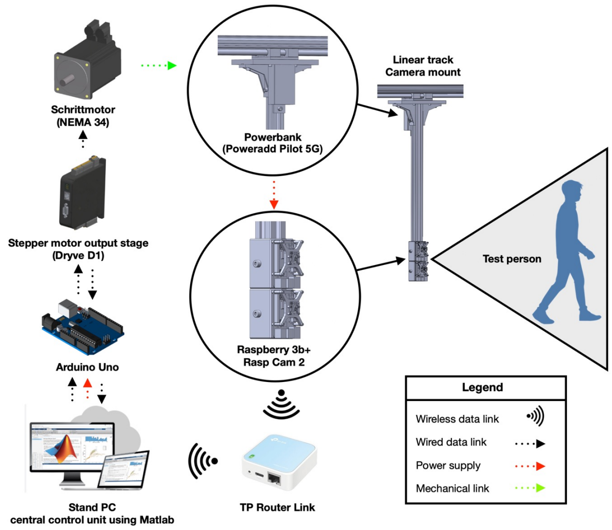
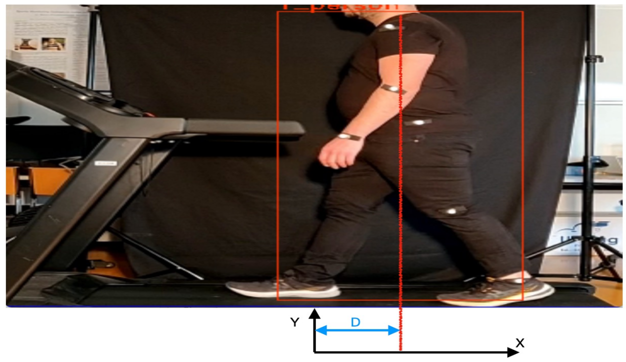
Master of Science in Engineering 2201 - Mechatronics & Automation

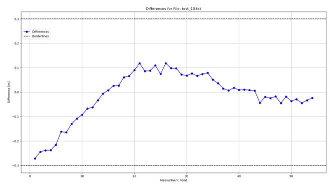
Smart Linear Tracking in 2D Gait Analysis with YOLO and PID



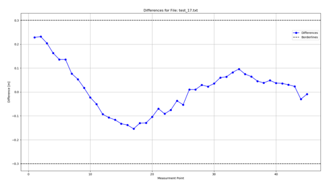
System components overview



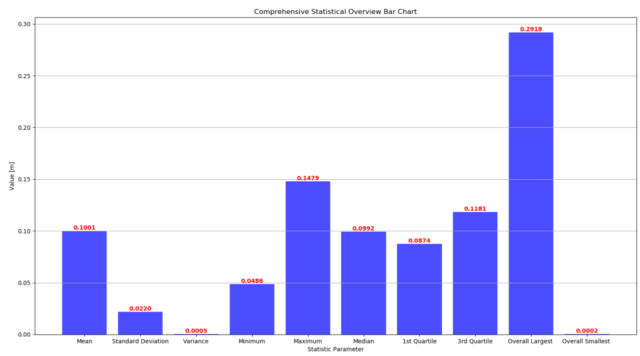
Distance calculation visualization with bounding box and camera frame



PID Controller Response (negative Initial Difference)



PID Controller Response (Positive Initial Difference)



System Parameter of the accuracy evaluation

Problem definition

As existing gait analysis systems are relatively expensive, which poses a challenge for smaller clinics, this paper focuses on the development of an affordable fully automated 2D gait analysis system.

The motivation for this work is based on a project at the University of Applied Sciences Technikum Wien, where a linear rail was equipped with a camera to create a low-cost gait analysis system. While walking, the camera moves parallel to the test person and records their movements. Currently, the linear rail operates at a fixed speed, which leads to deviations in the recording and makes a meaningful gait analysis more difficult, as the test subject is not evenly centred.

To exploit the full potential of the system, it is necessary to implement a fully automatic mode. In this mode, the speed of the linear rail is regulated depending on the walking speed of the subject so that the subject is always in the centre of the camera image. Such an implementation is essential for performing thorough biomechanical analyses during gait.

Solution concept

The fully automatic mode was implemented via a real-time control loop. Two Raspberry Pi's with a Raspberry Camera Module 2 modules each are mounted on the linear track in such a way that the test subject is in the plane of motion of the camera. One camera records the person and sends the frames to Matlab via WIFI. In Matlab, the person detection algorithm YOLO3-Tiny-COCO calculates the distance between the center of the camera and the test person. This distance serves as input for the PID controller, which adapts the speed of the NEMA 3 stepper motor via the frequency. The second camera records the test subject at 50 frames per second via SSH and provides a data set for later analysis. This dual camera system ensures optimal tracking of the subject in real time while storing high-quality data for in-depth studies.

Results

The implemented 2D gait analysis system achieved excellent performance values, which were determined in 24 test trials with 6 different participants. The mean deviation of all subjects was calculated to be 10.01 cm and the low standard deviation of 2.2 cm and the variance of 0.5 mm underline the precision in position maintenance. The average deviations per test gait ranged from 4.86 cm to 14.79 cm. The recording of the deviations during a test run emphasizes the effectiveness of the implemented control loop. The system showed robust real-time control with different running styles of the different participants.

In summary, it can be said that all defined requirements were successfully met and that the system, with a total price of €4755, represents a cost-effective and competitive alternative in the field of gait analysis technology for smaller clinics.

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