Activity Classification by Use of Tool Related Signals

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***Abstract*— Active exoskeletons whose operating principle is based on active elements such as electric motors have the advantage of being able to adjust to changing loads on the user. However, it is necessary to recognize at what time and at what height the user wants to be relieved. To develop a suitable control strategy, this article presents a method to distinguish between the different work steps based on the kinematic parameters of the tools used during the work process. For this purpose, the signals of a 9-DoF IMU and a force sensor are used. Based on their signals, different threshold-based classifications can be performed. The activity are divided in: usage of a tool, usage of a tool in a overhead position and activation of a tool. The used approach to identified those activities can be used in future work to develop a control approach for an active exoskeleton.**

I. Introduction

Passive Exoskeletons are already tested and used in industrial applications [1], [2]. However, due to the permanent effect of the force on the user, passive exoskeletons do not adapt to the individual work steps and can lead to discomfort [3]. Here active exoskeletons can adapt to the changing loads and can apply the support force just when it's needed [4]. To estimate the point in time when and how much the user wants to be supported, different strategies are followed at the moment. The usage of biosignals from the users to estimate the load on the users is one strategy. Muscle activity signals are used for this [5]. But because of the unsteady signals a classification is needed to differentiate between the different states. Different kind of algorithms are used for this tasks like the usage of a neural network [6]. Another approach is the usage of the signals of the used tool. Based the electric current of the used tool the time between switching support levels can be detected [7]. Still the problem of the support determination is not solved satisfactorily. This article presents a concept of using the kinematic parameters of the used tool to determine the different states of the working process.

II. Methods

A. Experimental Setup

A situation were heavy physical tasks happen is the construction process of the rail system for routing electrical cables in a building. Here heavy tools are needed for the process of mounting the necessary construction at a wall and ceiling. In the context of the Exoworkathlon™ a new parcours is developed to simulate this situation [8]. During the parcours, the person must perform the following activities,

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Fig. 1: Sensor system placed on hammer drill (left) and drill (right)

among others: The simulation of the drilling process with the hammer drill in a wall and the ceiling. Another acitvity is the mounting of the structure of the rail system on the wall with the help of the drill. These activities are of particular interest and will be examined in more detail because an electrical tool is used here. On the hammer drill and the drill a sensor system is mounted to capture the kinematic parameters. The used tools with sensors are shown in figure 1. In the sensor system a 9-DoF inertial measurement unit (IMU) is included as well as a force sensor which is placed on the trigger of the tool to detect the activation of the tool. The signals are send via a BLE communication to a central station. A power bank is also attached to the tool for the power supply of the sensor system.

B. Activity classification

As mentioned before the different activities which should be differentiated are: The usage of a tool and further classification in which tool is used, the activation of a tool and the further classification in which tool is activated and lastly if the tool is used for work in an overhead position. For the classification different signals are used. To detect the usage of a tool the norm of the gyroscope vector over all three axis is used. In that way the orientation of the tool and the sensor system is not relevant and with this the smallest movement of the tool can be detected. When a specific threshold is exceeded the activity of usage is recognized. This was done for the drill and in the same way for the hammer drill. The class of activation of the tool is based on the signal of the force sensor placed on the activation trigger of the drill. As soon as a user push the trigger and a specific threshold is exceeded the activation activity is recognized. To distinguish the in ceiling drilling process from the in wall drilling process, the acceleration signals of the tools are evaluated. Here the acceleration due to gravity is used as a reference. When the measured acceleration along the specific axis exceeds a threshold, the activity is classified as

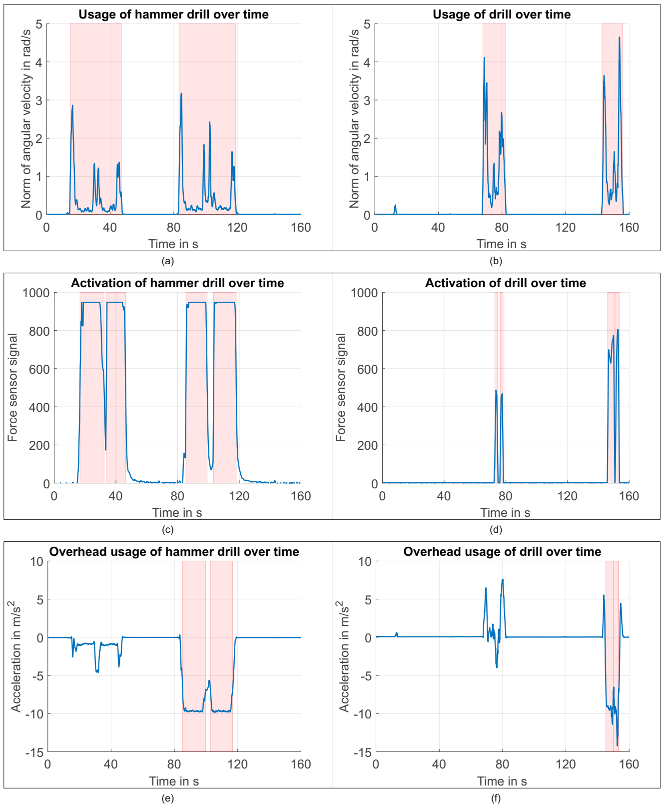

Fig. 2: (a) Usage of hammer drill, (b) Usage of drill, (c) Activation of hammer drill, (d) Activation of drill, (e) Usage of hammer drill overhead, (f) Usage of drill overhead

working in a overhead position.

III. Results

In Figure 2 the different results of the measurement are shown. The colored area show the classified activity for the corresponding case.

1) Tool Usage: In figure 2 (a) the norm the gyroscope for the hammer drill and in figure 2 (b) the norm the gyroscope for the drill is shown. Also the indication of the usage of the drill is shown. At the start of the experiment the users is doing the drilling process in the wall and afterwards mounts the basis structure with the help of the drill. Then the simulation of the drilling process in the ceiling and the mounting of the basis structure for the ceiling is done by the user.

2) Tool activation: For the activation the signal of the force sensor for the hammer drill placed on the activation trigger is shown in figure 2 (c). The maximal value is reached, which results in a plateau while activationg the hammer drill. The activation of the drill is shown in figure 2 (d). Here it can be seen the activation periods are shorter compared to the hammer drill.

3) Tool overhead usage: To detect if the user works in an overhead position, the acceleration signal of the IMU is used. Because of it's orientation the consideration of just one axis is enough for the application. For the hammer drill the acceleration signal is shown in figure 2 (e) It can be seen, that the user lowers the drill and holds it in a more horizontal position between the two drilling processes. The acceleration signal of the drill, shown in figure 2 (f), indicates that the sensor system attached to the drill detects a greater acceleration compared to the usage of the hammer drill. The classification based solely on the acceleration from one axis is therefore more complex and another signal is needed to classify the overhead usage of the drill.

IV. Conclusion & Future Work

In this paper a concept was proposed to classify different activities during the construction process of a rail system for routing electrical cables. The used tools of the parcours, were equipped with sensors to measure kinematic parameters and the activation. Three different activities were than examined: The usage of a tool, the activation of the tool and the work in a overhead position. With the use of the norm of the velocity of the tool a statement to the usage of the tool can be made. The activation of the tool was detected by the force sensor placed on the activation trigger of the tool. A distinction between the work in a overhead position sorely based on the acceleration signal was for both tools possible. For the used drill more signals should be used to detect a overhead position. Since most exoskeletons only support along the longitudinal axis of the user, this distinction is necessary for later control of an exoskeleton. This is to prevent unintentional pushing of the arm along the longitudinal axis and therefore complicating the process of drilling into a wall. Based on this information the next steps are to create a control method for an exoskeleton which can support a user while doing the same simulated process.

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