Teleoperated Semi-Autonomous Control of the LWR and a Humanoid Hand via the *Myo* Armband

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***Abstract*— In this paper we describe a teleoperation system, which controls a semi-autonomous 7 degrees-of-freedom robot arm equipped with a five-finger hand via a *myo* armband, utilizing the gyroscope and EMG sensor data. An object manipulation scenario including grasping and object moving are used to pre-evaluate the benefits of such a setup.**

I. INTRODUCTION

The design of prosthetic and assistive devices covers various questions related to mechanical construction, system integration, control, user-feedback and sensor interfaces. It might be possible to perform early evaluations of specific control approaches and sensor interfaces by interpreting the considered prosthetic system as a teleoperation setup, where voluntary user input results in a desired behaviour of the slave device i.e. a robot arm, emulating a prosthetic device. Several approaches exist in the area of teleoperation that one can get inspiration from, varying in the slave devices as well as the used sensor interface. The joint angles of a human arm (wrist and elbow) for example can be measured by potentiometers integrated into an exoskeleton. These joint angles are used to calculate a corresponding trajectory for a robot arm, which performs a desired gesture [1]. Other setups are using visual tracking systems to perform sufficient robot movements [2]. Kim et al. worked on utilizing marker-less tracking systems such as Kinect or Leap Motion to control a virtual robot arm [3].

Other approaches leverage EMG sensors for tracking muscle activity and provide or support the control of a teleoperated slave device (mainly robot arms) [4], [5], [6]. Ajourdani et al. apply a combination of EMG data for adapting stiffness in combination with a visual tracking system for a teleoperation setup with an LWR [7]. This stiffness tuning can e.g. be used for grasping control of a humanoid robot hand [8], [9].

Since recently, also the *myo* armband is used to control teleoperated systems. It is a wearable wireless device, which provides sensor data of muscle activity together with its orientation and acceleration based on EMG, gyroscope and acceleration sensors. Teleoperation setups that make use of the *myo* armband are varying from mobile robot control [10], combined systems using *myo* and haptic devices to control the manipulators of the Baxter robot [11] to the control of virtual robot arms by the gyroscope, accelerometer and EMG sensors of the *myo* armband within a prosthetic research context [12], [13].

Based on these approaches we designed a teleoperation setup that makes use of a *myo* armband to control a semi-autonomous robot arm equipped with a humanoid robot hand. A basic object manipulation experiment was conducted for preliminary evaluation. The results of these experiments are sought to help improve the design and control of our approach. Ultimately, it shall serve as a complete prosthesis and teleoperation setup, as well as simplify early evaluation of prosthetic controllers.

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II. SYSTEM SETUP

The setup consists of an LWR IV+ [14], a humanoid hand (Dextrus Hand) [15], [16] attached to it and a Myo-bracelet. A human user wears the bracelet on his lower arm and controls the robot arm and the hand. Figure 1 provides a functional overview of the setup.

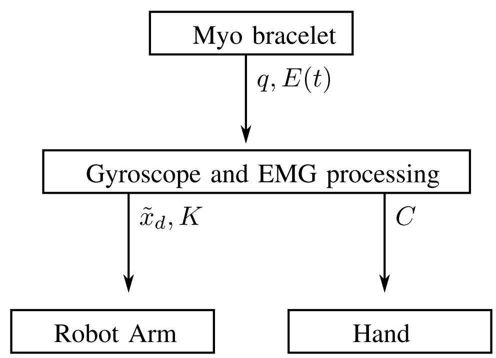

Fig. 1. Overview of the teleoperation setup. The myo bracelet provides a quaternion q and EMG data $E(t)$. This data is processed into usable commands for the robot arm and the hand.

We make use of the integrated gyroscope to determine the position, as it proved to be more reliable than the IMU. In order to extract a desired pose for commanding the robot, we project a vector n that coincides with the z-axis of the gyroscope onto a virtual plane P, see Fig. 2. To calculate n we use the quaternion q from the bracelet, which yields the relative orientation with respect to the initial orientation when activating the system. The projected point ${}_M x_p$ is then calculated in frame M and transformed into the robots base frame B. It is then filtered and used as a set point for the impedance controller of the robot arm. Furthermore, the rotation around the z-axis is directly mapped onto the last joint of the robot, hence the human user rotates the artificial hand with a rotation of his own hand.

Considering the robots dynamics

$$M(q)\ddot{q} + C(q, \dot{q})\dot{q} + G(q) = \tau_u + \tau_{ext} \quad (1)$$

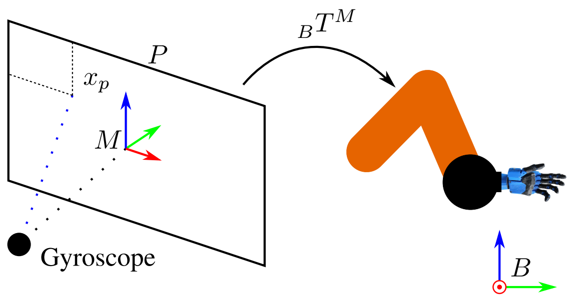

Fig. 2. The black dotted line indicates the initial orientation of the gyroscope while the blue dotted line shows the current orientation. The intersection of this line with the plane P yields the desired position $_Mx_p$ which is then transformed into the robots base frame B.

the impedance control law

$$\tau_u(t) = -J(q)^T(Ke(t) + D\dot{x}(t)) + \hat{g}(q) \tag{2}$$

is given. Here, K refers to the positive diagonal stiffness matrix and $D(q)$ to the damping matrix calculated by a separate damping law. Furthermore, the position error $e(t) := \tilde{x}_d(t) - x(t)$, where $\tilde{x}_d$ is the filtered version of $_Bx_p$ and the gravity compensation $\hat{g}(q)$ is given.

Furthermore, the EMG-level $E(t) \in \mathbb{R}^n$ is being used to control the hand and determine the stiffness matrix K. To calculate K we took the average $\bar{e}(t)$ of the eight signals in the vector $E(t)$. Since $\bar{e}(t)$ is still a rather noisy signal we do not map it directly to K but use several stiffness levels that correspond to intervals of $\bar{e}(t)$, i.e there is a set $\mathcal{S}$ of pairs $(\mathbb{I}, L)$ where $\mathbb{I}$ denotes a half-closed interval of $\bar{e}(t)$ and $L \in \mathbb{R}$ a specific value for the stiffness.

The hand is controlled with a set of commands $C = \{c_1, \ldots, c_n\}$. The chosen command depends on $E(t)$, i.e. there exists a $\Phi : \mathbb{R}^n \rightarrow C$. Such a command could for example be the opening or closing of the hand.

III. EXPERIMENTS

The experiment focuses on tele-operated object manipulation via the robot arm and the robot hand, controlled by the myo armband. The set-up comprises the Dextrus Hand mounted on an LWR IV+, a test subject wearing a myo armband, one bottle and one cup placed on a small box and two tables (see figure 3). The bottle is filled with a defined level of water. Bottle and cup are prepared with sandpaper to simplify object grasping. The experimental test subject is placed close to the robot, to ensure a sufficient viewing area on bottle, cup and robot hand. The experiments have been led and overwatched by two experimenters. Experimenter 1 monitored the robot and executed the myo armband calibration. Experimenter 2 explained the experimental task and documented the time needed for every trial.
The test subjects had to execute three tasks: (1) grasp the bottle, (2) pour water into the cup and (3) place the bottle back on the box. All experiments have been done with 8 test subjects. Five trials were done with every test subject.
One complete experiment contains the following steps:

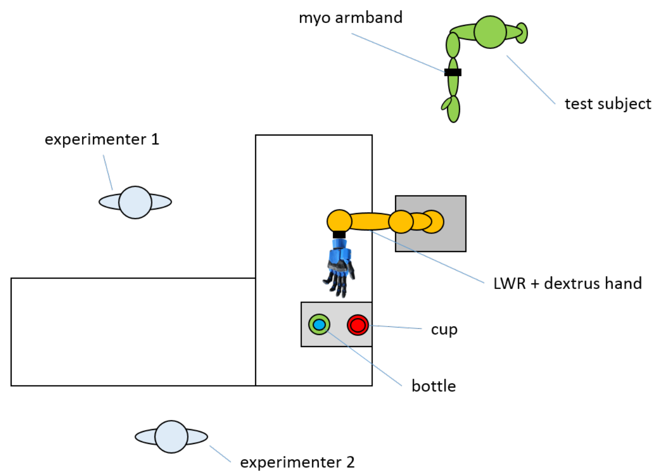

Fig. 3. Experimental Setup containing the object manipulation task, executed by a LWR with a robot hand, controlled via a myo armband. The task is to grasp a bottle, pour water into a cup and place the bottle on a table.

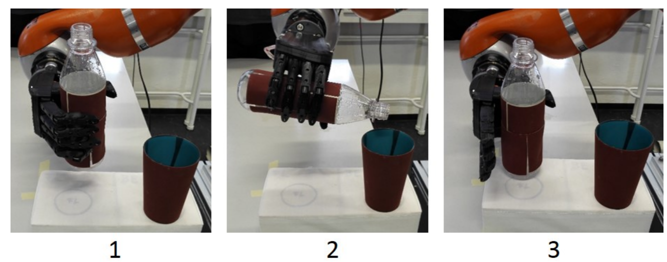

Fig. 4. The experimental task contains the three steps 1: grasp the bottle, 2: pour water into the cup and 3: place the bottle back on the box.

- explanation of the experimental task
- calibration of the myo armband
- one minute training
- experimental trial (5x):
  - kick-in gesture (start robot)
  - grasp the bottle (subtask 1)
  - pour water into the bottle (subtask 2)
  - place the bottle on the box (subtask 3)
  - kick-out gesture (stop robot)

The three sub-tasks were independently validated for success and failure. A failure was defined if no water was poured or the bottle was dropped. Kick-in and kick-out gesture mark start and end point of the time measuring. A double finger tap gesture is used to define kick-in/out gesture controlled by the myo armband.

IV. RESULTS

In the following we show an overview of the results from our preliminary experiments and evaluate the potential of the current setup for teleoperation.

Table I shows the results of the experiments. As can be seen 12 out of 40 trials were completely successful. The most problems occurred with pouring the water when the rotation around the axis of the arm has to be applied while

TABLE I

THIS TABLE SHOWS THE RESULT FROM THE EXPERIMENTS. THE LINE-SEPARATED COLUMNS HOLD THE FIVE TRIALS FOR THE RESPECTIVE SUBJECTS. THE SUBCOLUMNS INDICATE SUCCESS OR FAILURE FOR THE PARTIAL TASKS. GB: GRASP BOTTLE, PW: POUR WATER, PB: PLACE BOTTLE. TIME IS PROVIDED IN SECONDS IF ALL THREE TASKS HAVE BEEN SUCCESSFUL.

Subject	1				2				3				4			
Trial	GB	PW	PB	t [s]	GB	PW	PB	t [s]	GB	PW	PB	t [s]	GB	PW	PB	t [s]
1	s	f	f	–	s	f	s	–	s	f	f	–	s	f	s	–
2	s	s	s	57	s	f	s	–	f	f	f	–	s	s	s	85
3	s	s	s	48	s	s	s	53	s	f	s	–	s	f	s	–
4	s	f	s	–	s	s	s	51	f	f	f	–	s	f	s	–
5	s	f	s	–	f	f	f	–	s	f	s	–	f	f	f	–

Subject	5				6				7				8			
Trial	GB	PW	PB	t [s]	GB	PW	PB	t [s]	GB	PW	PB	t [s]	GB	PW	PB	t [s]
1	s	f	s	–	s	s	s	77	s	s	s	55	f	f	f	–
2	s	s	f	–	s	s	s	65	s	s	f	–	f	f	f	–
3	s	f	f	–	s	f	f	–	s	f	s	–	s	s	f	–
4	s	s	s	61	s	s	s	29	f	f	f	–	s	f	f	–
5	s	s	s	48	s	s	s	33	s	f	s	–	s	s	f	–

holding a specific cartesian position. Most subjects were able to almost always successfully grasp the bottle even in the first trial which indicates that our approach is intuitive for at least simple tasks with a low dimensionality of motion.

Furthermore, several subjects reported difficulties when controlling the hand due to false muscle activity recognition and some design issues related to the thumb of the hand.

V. CONCLUSION

In this paper we presented an approach to operate a robot arm with an anthropomorphic hand via a low-cost EMG bracelet, namely the myo bracelet. To evaluate whether this approach can be suitable we implemented a simple test scenario where human users had to move the robot arm within a plane and control the hand to pour water from a bottle into a cup.

In summary, we found the approach to be promising, since most subjects were able to handle the system reasonably well after only a few trials. Although more complicated movements that involve rotation of the wrist still pose a problem. Our next steps involve implementing a new mapping for the control of the hand to cope with false muscle activity recognition as well as exploring more intuitive mappings between the humans and the robots motion space.

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