Hand tracking for an exoskeleton for home-based wrist and hand rehabilitation

Angelo Basteris

Farshid Amirabdollahian

Adaptive Systems Research Group
School of Computer Science
University of Hertfordshire, United Kingdom

1 Background

The SCRIPT project focuses on robot-assisted hand and wrist exercise for stroke survivors. However, gross movements of the arm are expected to contribute to higher functional recovery, and we hence incorporated the recognition of such movements within the system.
The first prototype of our passive-actuated orthosis fitted an inertial measurement unit, mounted on the forearm. Formative feedback gathered from 24 participants showed technical difficulties in having such movements recognized consistently. Such difficulties arose as a consequence of many factors such as limited amplitude and speed of motion, electromagnetic interference of other metallic parts in the surroundings and displacement of the IMU with respect to the hand.
We hence developed an alternative solution which provides information about the 3D position of the hand in space, by optically tracking a color marker.
The requirement of performing in a non-controlled environment such as the patients' homes raises potential issues for an optical tracking system, which we have taken into account in our design. Ambience lights (either artificial or natural) and objects in the surrounding workspace might interfere with such a system. Affordability is another driving requirement of our project. In this paper we describe a web-cam based system for home-based rehabilitation and show preliminary results from the calibration of such system.

2 Methods

In order to achieve the desired affordability of the final system, we decided to use an off-the-shelf webcam (*Sony Playstation Eye*, approx. cost of 20 euros) on top of a touchscreen display. The image is acquired and post-processed with a free open source software for computer vision (*OpenCV*, www.opencv.org), and the output of such post processing is fed to a software for therapeutic human robot interaction which controls some videogames.
The concept is that of measuring the 3D position of a marker placed on the back of the hand. **Error! Reference source not found.** shows a green marker mounted on top of the passive orthosis, with the webcam on top of the touchscreen. In order to prevent the color confusion, the markers (25 mm diameter) are easily replaceable by the therapist or the patient, who are

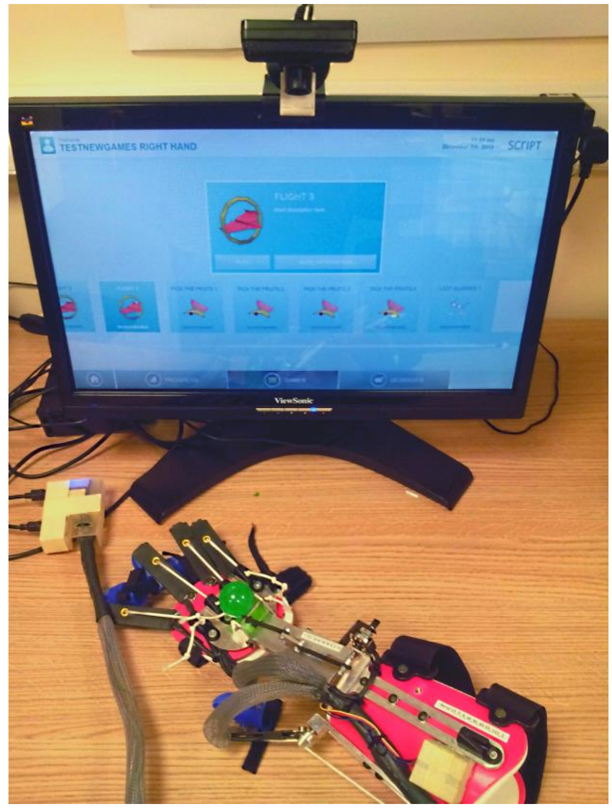

Figure 1. System for hand tracking based on webcam and passive marker

instructed to do so in case there are multiple areas of the desired color.
The tracking is based on the hue, saturation, values (HSV) representation of the picture. During a preliminary calibration phase (which happens prior to each session) the subject are required to hold their hand so that the marker appears in a specific point of the screen. At this time, the system identifies the corresponding HSV values as a reference. This makes our system less sensitive to changes in environmental light as those which could happen due to the presence of the sun.
The image is acquired at 100 Hz, with a resolution of 640x480. Areas with HSV values around the referemce are identified on each picure .
The centre of such areas depends on the position of the marker on the camera plane. We chose a spherical marker, so that the surface of its projection on the camera plate mostly depends on the distance from the focal point. Also, the spherical shape makes the area independent from the hand orientation. Thus, the antero-posterior and lateral movements are identified by the mean coordinates of the area on the picture, while vertical movements are estimated based on the size of the marker area.
Another concern was the possible presence of windows or other sources of light in the background. Hence, we decided to orientate the camera downwards as shown by **Error! Reference source not found.**2. Doing so, we center the field of view of the camera on the volume in which the hand moves. Also, we reduce possible interference due to objects in the background To tilt the camera downwards, we designed and produced a custom bracket which turns the camera 45

Figure 1. System for hand tracking based on webcam and passive marker

degrees downwards. We printed this tool with a 3D printer available at the University of Hertfordshire.

We assessed the size of the workspace and the optical deformation introduced by the tracking system by moving a green marker in 16 (4 rows, 4 columns) on a grid of size 5 cm.

3 Results

Figure 3 shows the setup used for assessment. From the picture, it is noteworthy that the workspace overcomes 0.5 m for both anteroposterior and lateral directions. From the same picture one can note the deformation due to the camera perspective, positioning and tilting. The vertical plane is indeed not normal to the camera axis. **Error! Reference source not found.**4 shows the acquisition while we moved the marker on the grid. The abrupt changes in the lateral and vertical coordinate represent respectively transition from among columns and rows. It is noticeable how in the center of the workspace (interval between approximately 20 and 90 s, figure 4 middle panel) the deformation due to the camera is not affecting the lateral component. Similarly, this is not an issue when considering the values of the same row for different columns (e.g. the top values in figure 4 bottom panel).

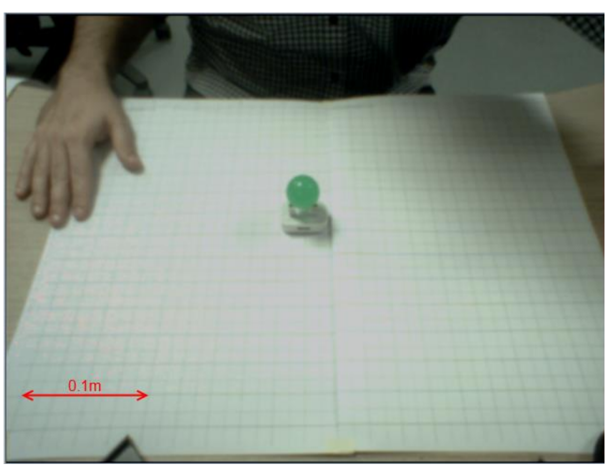

Figure 3.Calibration and workspace of the tracking system

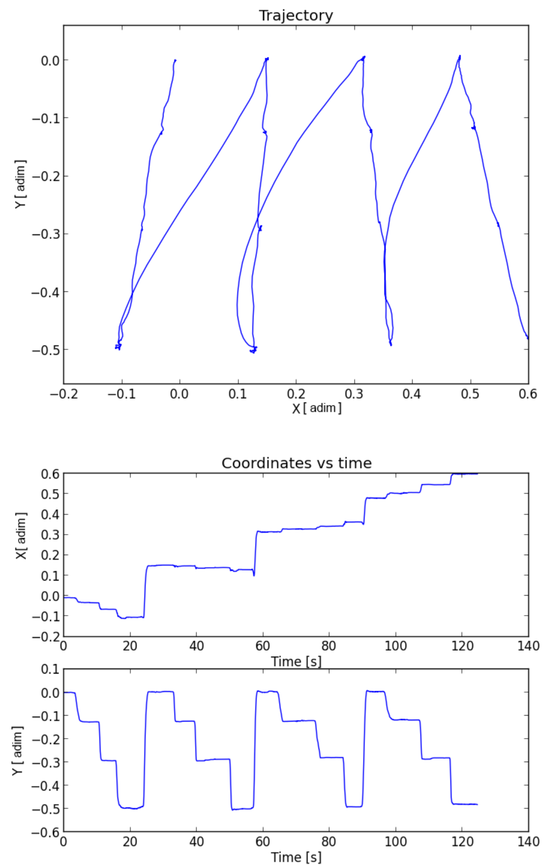

Figure 4. Trajectory and temporal progression of the coordinates of the marker in the calibration phase

4 Interpretation

We designed a system which allows tracking of the hand with affordable solutions to problems which could be encountered in a domestic set up.

Our preliminary experience and results show that the system provides a workspace large enough for the practice of rehabilitation exercises and that despite the distortion due to the camera optics the position of a color based marker can be acquired. Such distortion could be corrected with direct linear transform, by using the calibration data shown in this work.

Future work include formative evaluation of our system with subjects with stroke.

References

References follow ASME style, described in See the “Writing a Technical Paper or Brief” section, under Guidelines at the ASME Journal Tool Author Help (http://tinyurl.com/43chze9)