# The SoftGlove: A Tool for Posture Reconstruction of Robotic Hands in Challenging Scenarios

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***Abstract*—This paper presents a waterproof sensorized glove, the SoftGlove, intended to reconstruct the posture of a robotic hand even in conditions of low-visibility as severe as in the underwater environment. The reconstruction strategy implemented by the SoftGlove is based on a set of inertial motion units (IMUs) and on a complementary filter able to compute the relative orientation between two or more IMUs. The quality of the reconstruction is visualized for a full soft robotic hand wearing the SoftGlove. It is shown how this measurement system gives significant results in terms of accuracy, and its application affordability in many structures due to its mechanical robustness, small sizes of the employed sensors and reduced computational cost. Finally, examples of use of the system are reported in underwater environments.**

***Index Terms*—Sensoryzed gloves, posture reconstruction, grasping, field robotics**

## I. Motivation

Most often a robot that interacts with an unstructured (and maybe dangerous) environment experiments also problems on its vision system, which impede operating in low visibility conditions (e.g. in presence of dust, smoke and mud). In these cases, a sensorization of the robotic hand enabling its posture reconstruction would provide particularly useful. Such hand would act as a probe during a manipulation task or while exploring the environment. This could support a human operator teleoperating the robot and enhance the system robustness to various realistic environments where robotic intervention still falls short.

As a motivating example consider underwater manipulation. Here, due to the particularly challenging environmental conditions that complicate image matching and analysis, most computer vision methods cannot be employed directly [1], [2]. This technological limits on underwater robotic manipulation and vision render human skills still needed, endangering the worker health. Similar reasoning applies e.g. to field activities [3] and intervention scenarios [4].

To overcome these limitation, we present the SoftGlove, a waterproof sensoryzed glove which enables a IMU-based pose reconstruction method (for a detailed survey on the sensoryzed gloves developed in this years, see [5]). The posture reconstruction algorithm, inspired by the work of Santaera et al. [6], is based on an extension to a Complementary Filter (i.e. the Madgwick filter [7]) which is able to compute the relative orientation between two IMUs.

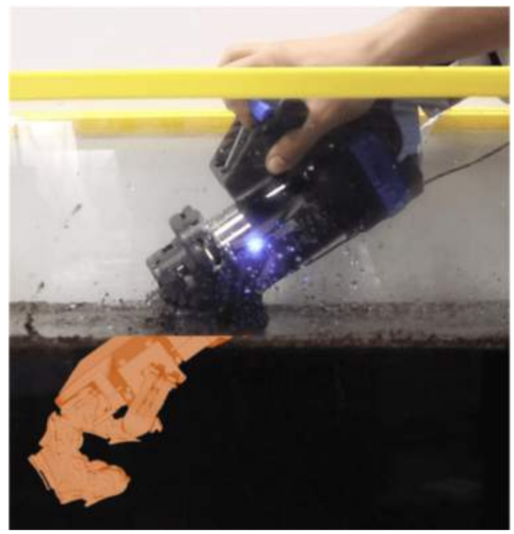

Fig. 1. The reconstruction of a robotic hand pose allowed by the custom-made sensorized glove presented here. The picture shows the virtual reconstruction of the grasp superimposed to the non-visible robotic hand wearing the glove, while submersed in mud.

The method was tested in the reconstruction of the full posture of a 19-DoF soft robotic hand, the Pisa/IIT SoftHand [8].

## II. Hardware

The SoftGlove, shown in Fig. 2a, employs 17 IMUs. The sensors are arranged to form a total of 6 chains: 5 for the fingers plus one for the hand reference frame composed by the two IMUs on the hand back and wrist. The IMUs are placed on custom-made supports, glued to the glove, and are connected by small wires which are sewn on the glove tissue, in order not to hinder the movements of the hand and to enhance the mechanical robustness of the circuitry. Each IMU chain is in turn connected with its first element to a custom-made electronic board that acquires the sensor readings and performs the filtering process. The board is a Cypress PSoC

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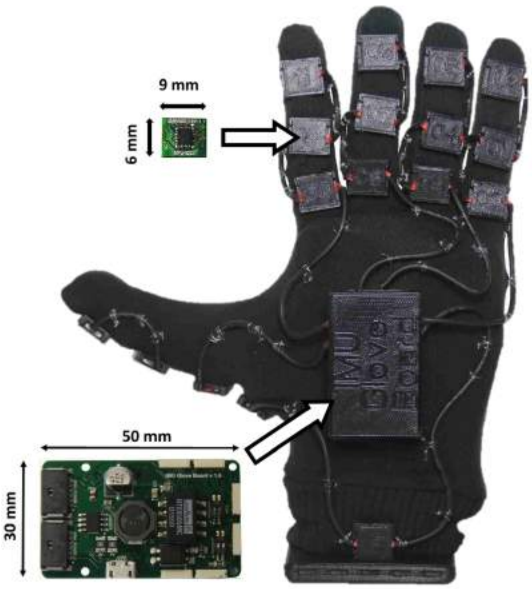


(a)

(b)

Fig. 2. Figure a) shows the SoftGlove worn by a Pisa/IIT SoftHand, with some circuitry details, before the waterproofing. Figure b) shows its waterproof version, mounted on the waterproof SoftHand.

("Programmable System on Chip")[1], which is a low power ARM ®Cortex - M0 based.

More details about the basic electronic network can be also retrieved in [9] and from the NMMI website[2].

### A. Waterproofing

To render the SoftGlove waterproof, the approach known as *potting* was used: all the electronics were encased in a water highly-resistant (polyurethane) resin. By encapsulating the entire device, resins can form a complete barrier against harsh environments and also offer mechanical protection, achieved through the mass of the resin surrounding the unit, improving the SoftGlove robustness. The final result is shown in Fig. 2b.

[1]http://www.cypress.com/part/cy8c3246pvi-147

[2]www.naturalmachinemotioninitiative.net

## III. Application Examples

To show the potential of our method and of the SoftGlove, we enabled a visual reconstruction of the gloved hand kinematics via the angles computed by the filter. Thus, the reconstructed model and the real hand can be visually compared. The proposed strategy was implemented in a ROS framework and the SoftHand kinematic model was visualized through *rviz*.

After a qualitative validation of the filter on the glove, different use cases were simulated in laboratory employing a gloved Pisa/IIT SoftHand controlled by a human operator. All use cases are shown in Fig. 3 and in the attached multimedia material. To address the motivating examples recalled in Sec. I we considered several realistic environments, in air, underwater, and in presence of mud. In air several complex objects, some of which are shown in Fig. 3a-3c, were grasped by the gloved SoftHand. Contemporaneously, the hand pose was reconstructed and visualized through *rviz* (the grasped objects are not visualized).

After testing the functionality of the encased electronics while submerged in water, the waterproof glove was mounted on a waterproof version of the SoftHand [10]. Then several objects flooded in a water tank were grasped by the gloved hand, as shown in Figg. 3d-3f.

Finally, to reproduce a near zero-visibility scenario, the water tank was filled with mud. An object was placed in the tank, hiding it from sight. Then the operator controlling the SofHand had to find the submerged, non-visible object. The task was accomplished by closing the hand and recognizing when it actually grasped something, observing the contemporary reconstruction on *rviz*. This experiment is shown in Figg. 3g-3j, where the hand pose reconstruction has been overlapped to the camera recording in different moments: in (g) the hand fingers get deformed by the bottom of the water tank, in (h) the hand closes empty, while in (i) the hand grasps the object, which is visible in (j).

## IV. Conclusion

In this paper, we presented a waterproof sensorized glove able to reconstruct the posture of a robotic hand, based on a Complementary Filter which computes directly the relative orientation between two Inertial Measurement Units.

The proposed tool appears to suit well to the soft robotic hand pose reconstruction problem, where direct measurements of the joint angle values through conventional measurement systems are impractical. Due to its mechanical robustness, the small size of the employed sensors, and a waterproofing procedure, it is effective in challenging field applications (e.g. in the presence of water, mud, smoke etc.).

Moreover, its application is viable in many structures (see e.g. [11], where a similar architecture is used to reconstruct the posture of a soft robotic foot sole).

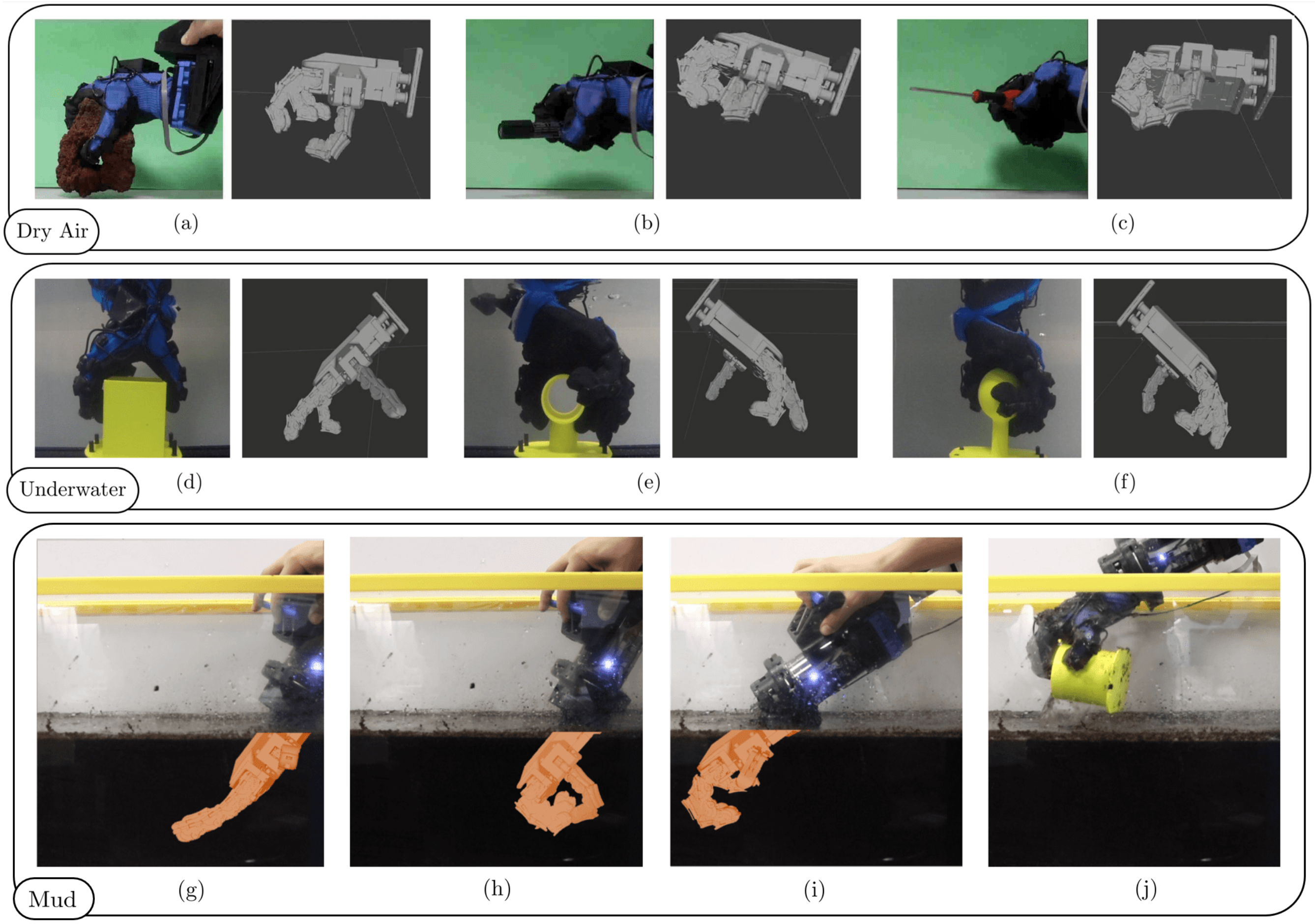


Fig. 3. Use case experiments. a-c) Details of the real and reconstructed posture of the Pisa/IIT SoftHand during the grasping of a) a stone, b) a marker pen and c) a screwdriver. d-f) Real and reconstructed posture of the waterproof Pisa/IIT SofHand, equipped with the waterproof version of the SoftGlove, while it is grasping d) a box, e) a cylinder and f) a sphere underwater. g-j) Overlapping of the real and reconstructed posture of the waterproof Pisa/IIT SofHand, equipped with the waterproof version of the SoftGlove, during the grasping of a cylinder submerged by mud.

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