Grasp Interaction Using Physiological Sensor Data

Raphael Wimmer
University of Munich
Amalienstr. 17, 80333 Munich, Germany
raphael.wimmer@ifi.lmu.de

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Abstract
The way we grasp an object depends on several factors, for example the intended goal or the hand's anatomy. Therefore, a grasp can convey meaningful information about its context. Inferring these factors from a grasp allows us to enhance interaction with tools and artifacts. Previous research on grasp interaction has focused on capturing grasps with grasp-sensitive surfaces. However, one may also capture the grasp a person applies by measuring physiological properties of the person. This paper provides an overview of sensing techniques and physiological properties that can be utilized for determining how a person grasps on object.

Keywords
grasp recognition, grasp, meaning, physiological computing, emg, sensors

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User interfaces – Evaluation/ methodology

Introduction
During evolution, humans gained the unique ability to grasp tools and apply them skillfully. Nowadays, a multitude of versatile or specialized tools extend

our manual abilities. Oftentimes, Human-Computer Interaction (HCI) also requires us to grasp objects - be it a computer mouse, a tangible user interface, or a mobile phone. Therefore, it seems straightforward to capture and utilize implicit and explicit information contained in these grasps. The way we hold an object is determined in part by what we want to do with it. If an interactive system can infer users' goals from the way they grasp an artifact, it can support these.

For example, a computer mouse could detect whether it is grasped with the left or right hand, and swap the meaning of the mouse buttons accordingly. Traditionally, research on grasp interaction has focused on capturing grasp signatures [9]. This approach makes it possible to build objects that react to certain grasps, without requiring any instrumentation on the user's part. However, it also requires every interactive object to be equipped with sensors. For applications where a user interacts with a large number of different objects, maybe even distributed across a large area, this approach does not scale well. Additionally, not all objects can be augmented with a grasp-sensitive surface.

Therefore, it makes sense to investigate another approach: instrumenting users and using infering grasps from physiological signals. Compared to grasp-sensitive surfaces, grasp interaction using physiological signals has a number of limitations and advantages. This paper presents an overview of physiological sensing techniques that might be used for capturing grasps and presents applications that might benefit from grasp sensing.

Inferring Grasp Patterns from Physiological Signals

The following overview focuses on grasp information that can be captured at various locations along the arm (Figure 1). A grasp can be described either as a certain hand posture (*form*) or as a group of contact points between hand and object (*function*). An overview of different grasp models has been given by Kang and Ikeuchi [2]. Except for the first one, all sensing techniques described below capture only hand posture.

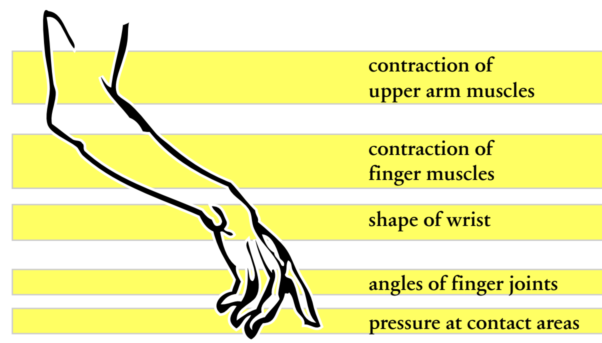

Figure 1: Information about a grasp can be captured at several points along the arm. Type and fidelity of the information vary, however.

Information about a grasp can be captured directly at the contact points between hand and object. For example, pressure sensors could be attached to palm or fingertips [4]. However, such instrumentation affects how people grasp: the sensors change the friction between hand and object and impede tactile feedback. When a user grasps an object, the force at the fingertips presses blood out of them, partially changing the skin color below the fingernail. From the resulting coloration, not only pressure but also shear forces can be determined [3].

Hand posture can be captured by measuring the angles of the individual finger joints. This is usually done by having the user wear a glove with embedded flex sensors [1]. Such a glove also impedes tactile sensation to a small degree. Alternatively, joint angles can also be determined by attaching an optical or electromagnetical marker to each joint and tracking these. As this technique requires a high-resolution tracking infrastructure, it is rarely suitable for real-life scenarios.

Another way of inferring hand posture is by monitoring changes in wrist shape. As the flexor tendons pass the wrist close to the skin, flexing a finger slightly changes the shape of the wrist's cross-section. These changes can be captured using a wristband with attached capacitive sensors. Rekimoto presented a prototype that is capable of discriminating two different hand postures [5], however, no study is reported. Such a wristband has the advantage that it can be worn without significantly impeding the user.

Another approach is recording electromyogram (EMG) data from extrinsic finger muscles in the forearm. Saponas et al. have presented several prototypes which capture hand gestures using surface EMG [6, 7, 8]. As EMG only measures muscle activity, it does not directly provide information about the actual hand posture. Under certain circumstances, it might be possible to indirectly infer the hand posture. Additionally, sEMG allows determining the amount of force that is applied by each finger. This approach has the advantage of capturing high-fidelity information about finger flexion without affecting the user's grasping performance.

Finally, measuring muscle activity at the biceps could allow for roughly determining the weight of an object that is being lifted. This information can be used to augment data from other sensors.

Each of the sensing techniques described above provides only partial information about a grasp. Therefore, the specific sensing technique to be used depends on the application.

Applications

Information about hand posture and grasp forces can be used to enhance explicit and implicit interaction with our surroundings in several ways:

Gestural user interfaces must avoid interpreting everyday gestures as explicit commands. With grasp information available, such user interfaces might ignore gestures that are performed while holding an object. Alternatively, the user interface could require that the user holds a certain or arbitrary object while performing a gesture.

Patients recovering from a stroke have difficulty grasping objects with adequate force. In this case, a grasp-sensing UI could tell them to increase their grasp forces if they are not holding the object correctly. Such a system might also tell craftsmen if they are correctly grasping a tool.

Knowing which object a user is holding, an assistive user interface could display or tell additional information or conduct supportive actions. Such a system could turn on the coffee machine once I pick up an empty cup, wirelessly authenticate myself once I grasp a door handle, or start counting everytime I do pull-ups. A lifelogging application could determine at which times someone drinks coffee, uses a computer mouse, or operates a mobile phone.

Finally, this information could also be useful for researchers from different disciplines. Logging which grasps people use over the course of a day would provide data that is helpful for improving prosthetics, and designing grasp-sensitive objects.

When implementing such systems, researchers need to consider the Midas Touch problem, however. A system that interprets every grasp as a meaningful input and acts accordingly will make interaction with the real world very irritating. Therefore, considerable thought needs to be put into adequate filtering mechanisms [9].

If these issues are taken care of, inferring grasp patterns from physiological signals may offer helpful context and novel methods for implicit and explicit interaction with everyday objects.

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