A prosthetic hand designed for human interaction to allow for the user to detect touch. This is done through capacitive touch sensing, through a weaved fabric or capacitive surface 2 attached to the prosthesis 6. When the surface is touched the information is delivered to the wearer through vibration, pressure, or heat as feedback using actuators 4. Pressure sensors 3 can be added to fingertips of the prosthesis. The micro-controller 1 processes all data and signalling between the sensors and actuators. The micro-controller is powered by a battery 5.
Figure 7

Figure 8 Example Image of conductive weave
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VELCRO (RTM)
Title
Prosthetic Hand for Human Interaction through haptic feedback

Background
Prosthetics currently focus on designing prosthesis that attempt to be as close to a real hand as possible. This is done either functionally or aesthetically. The function focuses on dexterity and providing users with different positions of the hand. This invention provides an alternate approach to the design of prosthesis, focusing on human interaction and sharing of emotion in a physical manner. The invention uses a mixture of form and combination of materials and technology which provide users and people interacting with the prosthesis to feel less of a stigma when in contact. In the context of dancing the person wearing the prosthesis will be able to feel the pressure on the hand holding onto their partner, and the person interacting with the amputee to feel a soft/warm prosthetic arm that holds the comfortably.

There are researchers and companies attempting to integrate touch sensations to prosthesis, however, the products that are offered are expensive or require surgical procedure to alter the nervous system. This invention instead looks at the way the human brain is “plastic” and capable of adapting to changes in the body. Similar to how we learn to adapt to wearing skis or riding a bike, (where the way we move around and feel the sense of balance change requiring the mind to learn how to interact with the world with the altered sense), by providing controlled haptic feedback it allows amputees to interact with people in a way they were incapable of today. Unlike existing inventions, this device looks at the emotional delivery of haptic information, and does not require high resolution of tactile information. There is no need to know the exact pressure on each finger and thus, this invention require low-cost off the shelf sensors to construct and not a specialised finger for prosthesis.
Disclosure of Invention

In accordance with one aspect of the present invention, a prosthesis senses touch when a person holds the amputees prosthetic arm. The touch can be sensed through various combinations of sensors and electronic circuits. Here a novel sensing method is capacitive touch, which allows for the differentiation of touch between a human and object. Capacitive sensing uses the human body’s capacitance detect touch. It will also detect anything that is conductive, thus daily objects that are not metallic can be sensed differently. Pressure sensors can be used in combination, allowing for pressure sensing of human grasp or object interacting with the hand. The capacitive touch can be laid out on the prosthesis to allow for multiple position sensing on the arm to allow recognition of stroke or grasp. The capacitive touch sensing may be realised in the form of a fabric or layer that overlies the prosthesis or is incorporated into the surface of the prosthesis. The fabric may be a customised weave including combination of conductive, semi-conductive or tactile wires or threads, for example steel wires, conductive thread and silk thread, to provide rigidity, softness and visual enticement to touch. The wires allow for capacitive sensing. The touch sensed in the manner described above can be converted into a haptic feedback that is sensed by the wearer. This haptic feedback may be in the form of a vibrating motor, a pressure applicator, for example a cuff that can be inflated or deflated, or a heating pad so that the wearer can feel the heat associated with the touch. Haptic feedback can also be in audible or visual form. The combination of haptic feedback can be altered depending on the context of use of prosthesis. Thermistors to sense temperature in combination with human touch on the skin for contexts for mothers caressing their child, or pump to pressurize an air cuff to provide sensual pressure grip feedback.

Pulse width modulation is used to alter the effect of feedback to communicate different touch scenarios to the user. The circuit is also possible to be built in a low cost analogue module, which require no micro-controller.

The prosthesis uses two different materials for the surface and the core to provide a soft feeling of touch, which is more human and less like an object. The prosthesis has a smooth surface created by rotation moulding polyurethane, with shore hardness A70 (polyoptic 1470). A softer core is then injected within, this can vary depending on preference and can be in the form of foam or solid. Shorehardness 40A is recommended, (polyflex 40 or procell S5). The mould of a stump with relevant clearance accounting for the haptic feedback devices should be considered before pouring the core.

To identify human interaction capacitive sensors are used. For the current version of the prosthesis a custom weaved fabric was created to create a capacitive surface that is elegant and unavailable to the market. Some of the wires may be insulated to provide extra functionality in connecting to the sensors on the palm, thus linking it to the micro-controller. Capacitive sensors can be in any form, either fabric or wires passing through the prosthesis. It can be used in combination with other technologies, such as thermistor, force resistive sensor (pressure sensor), bend sensor, conductive foam, IR distance sensors, camera, humidity sensor, heart rate monitor. Capacitive touch can identify different ways the person interacts with the prosthesis, with different threshold values that can be set to identify and process the information to the wearer through the actuators. By adding separate connections to the conductive surface, the location of touch can also be identified to differentiate touch. A grasp can be differentiated from a stroke.
Feed back method from the capacitive sensing can be in the form of audio, visual, haptic information. This can be in the form of a module that is attached to the arm as a cuff which links onto the prosthesis, or integrated within the prosthesis.

The form of the prosthesis is purposefully looking less real, by connecting the fingers together with soft features. This makes the prosthesis have less of a stigma to interact with.

**Detailed Description**

A capacitive surface (2) is attached onto a prosthesis (6) through temporary or permanent attachment methods. Pressure sensors can be embedded within the core of the prosthesis in desired locations of the hand (3) through placing them within the structure of the hand which or after by creating sections to attach them into. A micro-controller (1) may be used but an analogue circuit could also be created in place of this. A battery (5) powers the circuit, with a switch to turn the system on and off. Haptic feedback to the wearer can be delivered through various actuators (4) such as vibration motors, peltier elements, nichrome wire or pressure bags. These can be embedded within the prosthesis (4) or worn as a cuff (23) in Figure 7, attached by power supply cable (24) or can also be controlled via wireless communication. The actuators can be either surface mounted or embedded into the prosthesis during its construction with connection to the microcontroller.

The circuit shown in Figure 2 uses a standard circuit symbols for the haptic sensing prosthesis. In place of actuator (7), a vibration motor, peltier element, nichrome wire, pressure bag, led can be used. In place of the sensing unit (8) any material that varies its resistance to pressure, light, sound, vibration can be used. The micro-controller will process the variations in pressure or touch and deliver the information to the wearer through pulse width modulation to control the intensity of the feedback. The feedback can also be in the form of patterns or pulses of varied intensity to add emotion to the touch.

Figure 3 shows a standard circuit for capacitive sensing. (11) can be any conductive surface. The wire (12) can weave into the material or be attached with a connector. Figure 4 shows an example of how the conductive surface may be constructed. It can be created from a weave or knit of conductive material (13) with a non conductive material (14) such as cotton thread or silk thread.

Figure 5 shows how the conductive fabric attaches onto the prosthetic hand. The surface can be mounted onto the prosthesis with adhesives, or with hooks or velcro (15) which acts like a glove to the prosthesis. It allows the wearer to change the aesthetics of the prosthesis depending on their needs of the day.

Figure 6 shows the material construction of the prosthesis. Polyurethane with shore hardness of 70A is used on the surface (19) by creating a mould and using a rotational moulding process to provide nice touch surface. A softer core of shore hardness between 10 to 40A is used (18) to bring the product to life. Construction of the stump attachment (17) needs to consider the clearance for haptic device to be integrated in the stump socket. Nichrome wire (21) can be placed within the prosthetic between the two surface of polyurethane to warm the hand up to make it more inviting to touch. The nichrome wire is powered by a battery and controlled by a micro-controller (20).
The things that are known: (Prior Art)

US3751733A discloses a prosthesis capable of detecting touch. It is a prosthesis a “prosthetic device having sensing means supported within the digits thereof for detecting tactile stimuli, and a slave unit driven in response to the detected stimuli for stimulating sensory organs within the stump of a truncated appendage.”

The current invention differs from this invention, which describes the use of solenoids and resistive heating as the main method of feedback. The current invention focuses on the human interaction aspect and capacitive sensing is a novel method of sensing touch for prosthetic devices. Thus its sensing linking to the actuation of coin cell vibration motors, heating element, or pressure bags is also novel.

Patent US2008200994, is a prosthetic device which conveys sensory information from the prosthesis from a distal location to a proximal location of the body. It provides the wearer with pressure feedback through a motor driving a movement of a pressure pad. The current invention differs because of the location of feedback, method of delivering haptic touch information and also method of sensing.

PatentCN 102379760 A is a prosthesis for tactile feedback for a myoelectric prosthetic hand, with capability of sensing the exact directional sense of touch (X-, X+, Y-, Y+, Z-, Z+) . The current invention differs because it is applicable to all types of prosthesis, and because it does not require such high resolution of feedback information. Increase in sophistication of sensing lead to more complex processing requirements and higher costs.
Claims

1. A prosthesis capable of detecting touch, the prosthesis comprising:
   a. at least one sensor responsive to changes in capacitance in the vicinity of the prosthesis and that
      is configured to provide a signal in response to such sensitive capacitance change;
   b. a haptic feedback that can be sensed by the body of the prosthesis-wearing user and that is
      capable of receiving the signal from the at least one sensor and providing a sensation to the user
      in response to the signal.
2. A prosthesis as claimed in claim 1, wherein feedback is in the form of a vibrator, a pressure pad
   or cuff, a heating or cooling pad, a sound generator, e.g. a loudspeaker, or a light generator.
3. A prosthesis as claimed in any preceding claim, wherein the vibrator is in the form of a vibration
   motor, and/or the heating or cooling pad is in the form of a Peltier element or in the form of a
   heating wire, e.g. a nichrome wire
4. A prosthesis as claimed in any preceding claim, wherein the feedback is provided within the
   prosthesis or as a separate element.
5. A prosthesis as claimed in any preceding claim, wherein the at least one sensor includes a further
   sensor selected from a pressure sensor, a heat sensor.
6. A prosthesis as claimed in any preceding claim, wherein the at least one capacitive sensor is
   incorporated in a sheet, e.g. a woven fabric, that fits over the prosthesis.
7. A prosthesis as claimed in any one of claims 1 to 5, wherein the at least one sensor is incorporated
   into the surface of the prosthesis.
8. A prosthesis as claimed in claim 6 or claim 7, wherein the at least one sensor used is in the
   form of a surface comprising conductive wires, e.g. conductive wires or thread that can provide
   capacitive sensing, and tactile threads, e.g. silk threads, to provide rigidity, softness and visual
**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

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<th>Category</th>
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<td>US2008/200994 A1 COLGATE et al - Whole document relevant</td>
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- A Member of the same patent family
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- P Document published on or after the declared priority date but before the filing date of this invention.
- E Patent document published on or after, but with priority date earlier than, the filing date of this application.

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKPC:

- Worldwide search of patent documents classified in the following areas of the IPC
- A61F

The following online and other databases have been used in the preparation of this search report

- EPODOC, WPI, Internet keyword search
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