**Beyond Humanoid Prosthetic Hands: Modular Terminal Devices That Improve User Performance**

**Points For the Presentation**

* **Problem:** Myoelectric prosthetic hands often lack functionality and are rejected by users due to the limitations of replicating human hand form and function.
* **Solution:** Task-specific, modular, non-humanoid devices that replace individual fingers on a base prosthetic hand. Four devices were developed:
  + Flicking device
  + Screwdriving device
  + Flat object grasping device (suction cup)
  + Paper cutting device (scissors)
* **Evaluation:** Compared the non-humanoid devices against a humanoid prosthesis (OLYMPIC hand) in terms of:
  + Task performance
  + Compensatory motion
  + Perceived task load (NASA-TLX)
* **Results:** The non-humanoid devices outperformed the humanoid prosthesis in all tasks, reducing completion time, increasing accuracy, decreasing compensatory motion, and lowering mental and physical demand. Case studies with two participants with upper limb difference (ULD) generally aligned with the control group results.
* **Conclusion:** Task-specific, non-humanoid prostheses can significantly improve functionality, usability, and comfort compared to conventional humanoid designs, offering benefits for users' physical capabilities and social interactions.

**Points For the Understanding**

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**INTRODUCTION:**

Millions globally suffer from upper limb difference (ULD), impacting their capabilities. Myoelectric prostheses offer a solution by utilizing electromyography to control artificial hands. However, despite advancements, multi-articulating myoelectric hands show minimal benefit over simpler prostheses, leading to user dissatisfaction due to limited functionality and dexterity. The anthropomorphic design, aiming to replicate human hands, is constrained by mechanical and control limitations. Functional, non-humanoid designs are rare but could offer advantages, especially with modularity for task-specific applications.

**USES:**

It introduces four open-source modular non-humanoid devices for flicking, screwdriving, picking/placing flat objects, and cutting paper. These devices replace fingers on the OLYMPIC hand, a modular prosthesis. The devices are designed to perform tasks that are difficult for conventional humanoid prosthetic hands. Each task requires complex coordination at the joint level of a humanoid hand in order to produce a relatively simple task-space output. The devices are designed to perform actions that have meaningful social and functional uses in many areas of daily life, but are difficult-to-impossible with conventional prostheses: flicking, screwdriving, picking and placing small flat objects, and using scissors.

**ADVANTAGES:**

* Non-humanoid designs improve task performance, reduce user compensatory movement, and decrease task load compared to humanoid prostheses.
* Case studies validate these benefits, emphasizing the importance of monitoring user task load for positive rehabilitation outcomes.
* Humanoid prostheses were outperformed by non-humanoid devices in all tasks.
* Non-humanoid terminal devices reduced compensatory motion, allowing participants to complete timed tasks and precision tasks with higher accuracy.
* These reductions in mental, physical, and frustration demands.

**DISADVANTAGES:**

* Functionality for individual tasks limited by device specificity.
* Need for end effector change for daily functionality.
* Desire for anthropomorphic appearance for social acceptance.

**Key Points:**

* **Problem:** Myoelectric prosthetic hands have high rejection rates due to limited functionality and anthropomorphic design constraints.
* **Solution:** Develop and evaluate modular, non-humanoid terminal devices tailored for specific tasks.
* **Devices:** Four devices were created for flicking, screwdriving, picking/placing flat objects, and cutting paper, designed as replacements for fingers on the OLYMPIC hand.
* **Methodology:** A control group study with participants without ULD compared non-humanoid devices against a humanoid prosthesis, measuring task performance, compensatory motion, and perceived task load. Case studies with two participants with ULD were also conducted.
* **Results:** Non-humanoid devices significantly improved task performance, reduced compensatory movement, and decreased task load compared to the humanoid prosthesis.
* **Conclusion:** Task-specific, non-humanoid terminal devices offer a promising approach to enhance prosthetic hand functionality and user satisfaction. They may also improve quality of life by facilitating social interactions.
* **Future Work:** Further research is needed to optimize the mechanical implementation of these prostheses, explore haptic feedback, and investigate the psychological embodiment of non-humanoid prostheses.

**Prosthetic Limb Attachment via Electromagnetic Attraction Through a Closed Skin Envelope**

**Points For the Presentation**

This paper introduces a new prosthetic limb attachment method using electromagnetic attraction between a bone-anchored ferromagnetic implant and an external electromagnet, aiming to address issues with current socket-based methods.

* **Problem:** Current socket-based methods cause heat, tissue damage, and pain, leading to patient dissatisfaction and high abandonment rates.
* **Solution:** A system with a subcutaneous ferromagnetic implant in the residual bone and an electromagnet in the socket. The attractive force is controlled by modulating electrical current.
* **Design Framework:**
  + Biomechanical analysis to model socket forces during walking.
  + Cadaveric dissections to inform implant design (size, shape, coverage).
  + In silico electromagnet design balancing force, mass, and power.
  + Benchtop validation for power and thermal feasibility.
* **Results:**
  + Simulations matched physical electromagnet performance (4.2% error).
  + Estimated 33W average power for prosthesis suspension during gait.
  + Simulated skin temperature increases of 2.3 °C after 200 steps and 15.4 °C after 1000 steps.
* **Significance:** Demonstrates the feasibility of electromagnetic attachment, potentially increasing comfort and improving residual limb health.
* **Future Work:** Optimization to reduce heating during longer use. A cost function is proposed for optimization based on force, mass, and zero-current force, allowing for application-specific customization.

**Points For the Understanding**

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**INTRODUCTION:**

The pursuit of advanced robotic prosthetic limbs faces a significant challenge: the limitations of current socket-based attachment methods. These methods often lead to discomfort, tissue damage, and pain, resulting in patient dissatisfaction and high abandonment rates, disproportionately affecting underprivileged communities. Addressing the drawbacks of soft-tissue suspension, such as pistoning and skin irritation, and the risks associated with percutaneous osseointegration (OI), including infection, a novel socket suspension paradigm is introduced. This system utilizes electromagnetic attraction between a subcutaneous ferromagnetic implant in the residual bone and an electromagnet in the socket. This approach aims to transfer suspension loads directly from the prosthesis to the bone while maintaining a sealed skin envelope.

**USES:**

The electromagnetic attachment system is designed for prosthetic limbs and offers a potential solution to challenges associated with traditional socket-based attachments and percutaneous osseointegration. By employing a subcutaneous ferromagnetic implant and an external electromagnet, the system aims to improve comfort, reduce tissue damage, and minimize infection risks for individuals with amputation. This system has utility in transfemoral amputations and could be adapted for various amputation levels.

**ADVANTAGES:**

The primary advantage of this electromagnetic attachment system lies in its potential to mitigate the drawbacks of existing prosthetic attachment methods. Unlike socket-based systems, it transfers suspension loads directly to the bone, reducing pistoning and associated tissue breakdown. Compared to osseointegration, it maintains a sealed skin envelope, minimizing infection risk. Additional benefits include:

* **Improved Comfort:** By reducing pressure on soft tissues.
* **Enhanced Limb Health:** Prevents skin ulcers and irritation.
* **Customizable Attachment:** Attractive force modulation via electromagnet control.
* **Reduced Healthcare Costs:** By minimizing visits to prosthetists and complications.
* **Potential for wider applicability:** Circumvents limitations of OI in dyscalculic amputations.

**DISADVANTAGES:**

Despite its potential advantages, the electromagnetic attachment system also presents certain disadvantages and challenges:

* **Power Requirements:** Suspension during gait requires electrical power, necessitating a power source and potentially leading to heat generation.
* **Heating Concerns:** Prolonged use may result in increased skin temperature, requiring thermal management strategies.
* **Electromagnet Mass:** The added mass of the electromagnet in the socket could impact user comfort and mobility.
* **MRI Incompatibility:** The ferromagnetic implant renders the system incompatible with magnetic resonance imaging (MRI).
* **Dependence on technology:** Reliance on a functioning electromagnet for secure attachment.

**OVERALL SUMMARY**

The study offers a design framework for an electromagnetic prosthetic attachment system that employs an external electromagnet for direct skeletal connection and a bone-anchored ferromagnetic implant. Tested using electromagnetic simulations, cadaveric dissections, and biomechanical analysis, the device demonstrates the viability of supporting a prosthesis while walking with controllable power needs and little heating. The method enhances the functionality, comfort, and health of prosthetic limbs and presents a viable substitute for conventional socket-based and Osseo-integrated options.