A helping hand

Worldwide, there are more than three million people who have had one or both arms or hands amputated, and the vast majority of these are in developing countries.

Since commercially available prostheses are very expensive – starting at about R300 000 for myoelectric prostheses but exceeding R1 million for advanced models – many amputees use a hook or claw prosthesis, or nothing at all. Here, *Quest* explores some initiatives at local universities to develop more functional yet affordable options.

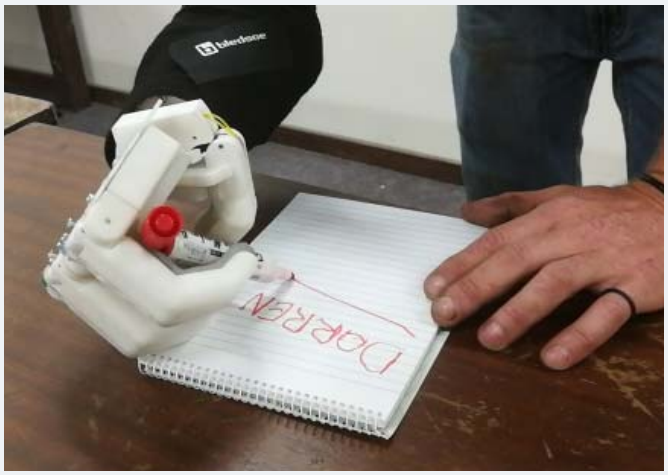
'Myoelectric' = relating to electrical signals generated by muscles

Touch Hand

In 2013 Drew van der Riet set out to develop a low-cost prosthetic hand for his Master's project in mechanical engineering at the University of Kwazulu-Natal (UKZN). By the end of that year, he had invented the 3D-printed Touch Hand, so named because it incorporates an innovative sensory feedback system that restores an amputee's sense of touch, allowing for the detection of pressure, vibration and temperature. Movement of the hand relies on electromyography (EMG), which means that it is controlled by electrical signals generated by contracted muscles in the residual forearm.

Drew formed the company Touch Prosthetics with his supervisor, Professor Riaan Stopforth, who heads the Stopforth Mechatronics, Robotics and Research Lab in UKZN's Department of Mechanical Engineering. In mid-

Drew van der Riet, Greg Jones, amputee John Harris and Riaan Stopforth following testing of Touch Hand 2 in 2015.



Amputee Darren Hauptfleish writes his own name during testing of Touch Hand 4.

2014 another Master's student, Greg Jones, joined them to work on a second iteration. Touch Hand 2, completed in mid-2015, featured jointed fingers with segments that could be individually moved via cables, driven by a printed circuit board (PCB) housed in the palm. Six motors and three torque and speed settings meant that the hand could perform a variety of gestures and grips.

"Touch Hand 1 was very rough in terms of looks, because there were lots of wires sticking out," explains Prof. Stopforth, who acts as CEO of the company (Drew remains involved but relocated to the USA in 2016 to work at Apple, initially). "We then developed Touch Hand 2, which looked like a human hand, but the amputees who assisted with the testing indicated that they do not really want the resemblance to a human hand, but they needed it to be more functional for their daily activities. So Touch Hand 3 was developed, with better functionality, but we still needed to improve on this."

"Touch Hand 4 was developed in a collaborative effort with the mechatronics team led by Prof. Theo van Niekerk at Nelson Mandela University (NMU), and underwent testing in December 2018. An NMU Master's student, Kiran Setty, worked with BunnyCorp on the design aspects to improve the functionality of the hand. Rapid 3D assisted us with the optimisation for the 3D printing aspects of the research, while numerous other companies in South Africa assisted with components."

"At the moment there is another NMU mechatronics student, Kyla Purdon, working on the EMG electrodes, and the control of the hand accordingly. She is also optimising some of the aspects we felt were important to improve upon, following the tests we conducted."

The advantages of the Touch Hand, apart from its low cost, are that it is highly customisable and upgradeable. The prosthesis would be specifically made for each amputee and uniquely suited to their individual needs and budget, with different choices in batteries, motors and other electronic components. Each component can be upgraded separately, meaning that it would be easy and affordable to stay up-to-date with the latest technology. In addition, the modular design means that any damaged components can be replaced, rather than the entire Touch Hand.

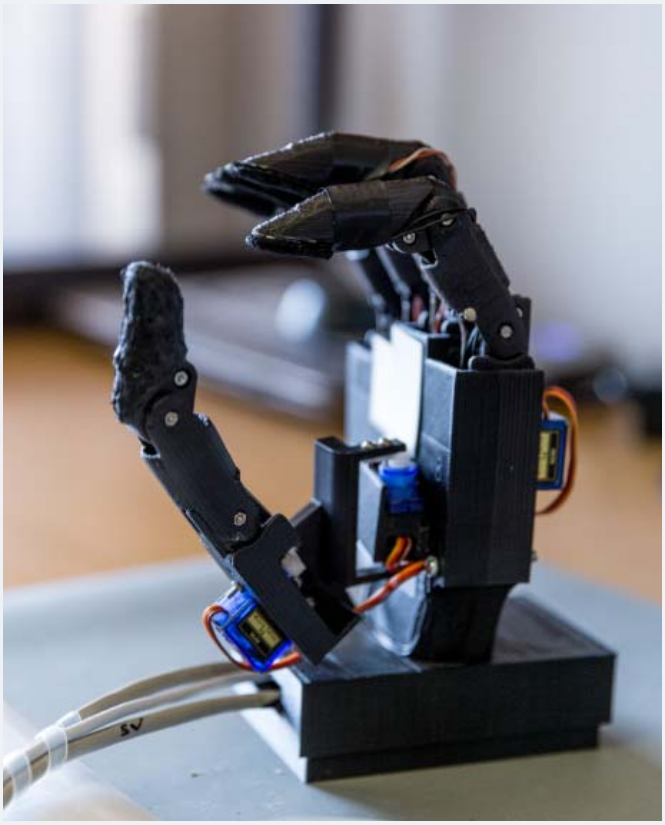
The Touch Hand team has been invited to participate in Cybathlon 2020 in Zurich, Switzerland, in May 2020, but will not be able to attend without sponsorship to cover the costs involved. The event is billed as a unique championship in which people with physical disabilities compete against one other to perform everyday tasks using state-of-the-art technical assistance systems.

"Attending the Cybathlon is important to us, as it is not only a way for us to represent South Africa, but also for us to compare the performance of our Touch Hand with other hands developed around the world," says Prof. Stopforth. "We hope that once we have been able to compete, a company will see the value of such a product and – with their infrastructure already in place – assist in the production and also subsidise the cost of the hand, so that people in South Africa and Africa can benefit from it."

- For more information, and to view a video of the Touch Hand in action, see: www.touchprosthetics.com

3D Prosthetic Hand

At the University of the Witwatersrand (Wits), lecturer Abdul-Khaaliq Mohamed and his students in the School of Electrical and Information Engineering have been developing their '3D Prosthetic Hand', the name referring to the fact that it is 3D printed. The project started in 2014, although the concept was conceived in 2008, when Mr Mohamed was searching for a topic for his Master's



The 3D Prosthetic Hand has not yet been integrated into a socket so it cannot be worn, but the fine-tuned grip control allows testers to hold a marble, a pen or even a thin plastic cup without crushing it.

Abdul-Khaaliq Mohamed with the 3D Prosthetic Hand.

research. He wanted to do something involving machine learning and artificial intelligence in the human body, and came across the idea of using thoughts to control a robotic hand. He ended up restricting his Master's project to an analysis of brain signals involved in hand movement, using electroencephalograms (EEG) that measure the brain's electrical activity via electrodes placed on the scalp. Subsequently, he started the 3D Prosthetic Hand project so that his undergraduate students could take on aspects of its development as their required final-year project.

At this stage the hand is not controlled directly by brain signals, but by electromyography (EMG), like the Touch Hand. Electrodes are placed over the biceps and triceps muscles on the upper arm, and the electrical activity associated with muscle contractions sends signals to the hand, making the fingers move. A feedback system from sensors on the fingertips causes vibrations in a cuff worn on the upper arm, so that the user can learn to grip objects with the correct amount of pressure. The hand is not yet integrated into a socket, so it cannot be worn as a prosthesis, but Mr Mohamed envisages that it could be commercialised in about three years, with an expected retail price of R25 000 or less.

One of the students who worked on the hand in 2017, Irfaan Mohamed, is now doing his Master's degree on a self-adjusting prosthetic socket for lower-limb amputees. His personal website (https://irfaanmohamed.com/) showcases the media coverage for the 3D Prosthetic Hand project, as well as his own contributions. He and his classmate Nabeel Seedat were responsible for perfecting the hand's 'tripod pinch' – the grip used to hold a pen – after which sensors were added to the fingertips to enable the hand to sense force. The paper they co-authored with Mr Mohamed, titled 'Custom force sensor and sensory feedback system to enable grip control of a robotic prosthetic hand', was presented at the International Conference on Biomedical Robotics and Biomechatronics (BioRob2018) in the Netherlands in August 2018.

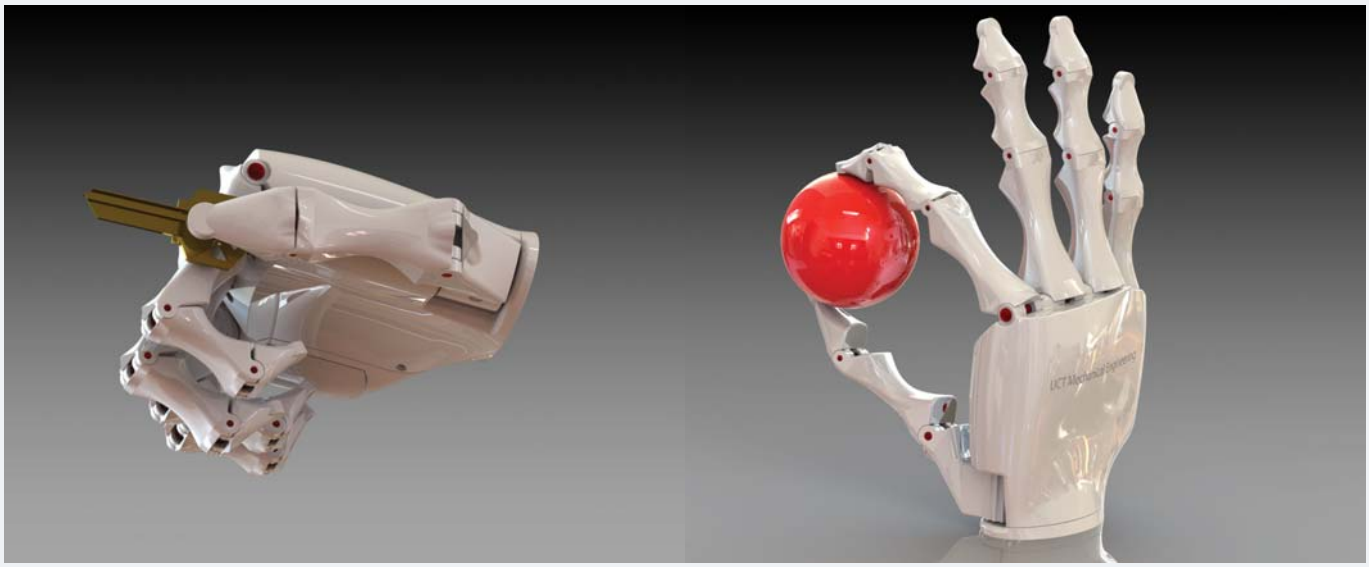
Most recently, the project team entered the 3D Prosthetic Hand in the Inventor's Garage competition at the SA Innovation Summit, held in Cape Town in September 2019. A total of 146 entries from across Africa were received, and the 3D Prosthetic Hand was selected as one of three finalists in the Healthcare category. As Abdul-Khaaliq Mohamed explained when interviewed on the Gareth Cliff Show on 16 September: "We didn't win, but the exposure was wonderful and we had the opportunity to meet lots of similar-minded entrepreneurs and potential funders and collaborators."

- Search YouTube for 'Wits 3D Prosthetic Hand' to view a number of videos featuring various team members demonstrating the hand, including one from SABC's Expresso Show in November 2017 and a more recent interview from the Innovation Summit in September 2019.

Tenim Hand

University of Cape Town mechanical engineering student Severin Tenim and his supervisor, Associate Professor George Vicatos, took a different approach for the Tenim Hand, developed as Severin's Master's project. Rather than making use of any electronics, this was a mechanically operated prosthesis relying on levers, pulleys, cables, bearings and springs. In common with many other mechanical prostheses, a conventional socket was used to attach the hand to the amputated arm, and the hand was operated via a metal cable linked to a shoulder harness, so that movement of the shoulder muscles changed the tension on the cable. The cable ran through the 'wrist', and pulling on it would make the fingers grip until the hand was closed. A knob adjacent to the little finger allowed the fingers to be locked in position, while the thumb was attached by a swivel so that it could rotate either towards or away from the fingers. The 'skin' was 3D printed by the Centre for Rapid Prototyping and Manufacturing at the Central University of Technology (CUT) in Bloemfontein, according to Severin's design plans.

A provisional patent for the Tenim Hand was registered in the United Kingdom, and Severin noted in his thesis, submitted in September 2014, that the prototype cost less than R12 000 to make and assemble. The following month he and Prof. Vicatos were given the Cutting Edge award for their invention at the *Popular Mechanics* FutureTech Conference.



The original Tenim Hand shown here was a mechanically operated prosthesis, controlled by a metal cable linked to a shoulder harness. It is now being updated to an electromechanical prosthesis, activated by electric motors.

After graduating, Severin relocated to Dubai, where he now holds the post of Strategic Project Manager at a large construction company. In 2017, however, Ameen Bardien – a biomedical engineering student under the supervision of Associate Professor Sudesh Sivarasu at UCT's Medical Devices Lab – began work on updating the design of the Tenim Hand. The goal is to convert it to an electromechanically actuated prosthesis, which would place the Tenim Hand in the large gap between myoelectric prostheses, costing as much as R500 000, and cable-driven prostheses, costing as little as R4 000.

Work on the new project began with addressing the issues that were found during the design validation Tenim had conducted as part of his thesis. Issues already resolved include redesigning the thumb so that larger objects can be held, and adjusting the closing trajectories of the fingers so that they grip around objects better, instead of pushing them away with the fingertips. The new parts were 3D printed at UCT's Medical Devices Lab.

"Current work on the Tenim Hand project includes the integration of a wrist adjustment mechanism and the electromechanical actuation system," explains Ameen.

"The wrist mechanism allows the hand to be manually pronated or supinated (rotated) so that the user can grasp objects more easily. The electromechanical actuation of the hand aims to help prosthesis users who struggle with the immense amount of strain on their shoulders when using cable-driven prostheses. These two systems are currently being manufactured and tested for integration into the Tenim Hand."

- A News24 video of the original prosthesis is available on YouTube. Search for 'Tenim Hand'.

A Lego prosthesis

David Aguilar, a young Spaniard who was born without a right forearm, built his own prosthetic arm using Lego pieces while still at school!

He is now a bioengineering student in Barcelona, and has made a number of different versions of the arm, each more advanced than the last.

Search YouTube, where he's profiled in a number of videos – most recently on the Lego Channel – or check out David's own video 'Mk-III, the ultimate Lego prosthetic arm' on his YouTube channel, Hand Solo. Watch and be inspired!

David Aguilar with the first three versions of his prosthetic arm, and with the Lego kit that he used to build 'Mk-III'.

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