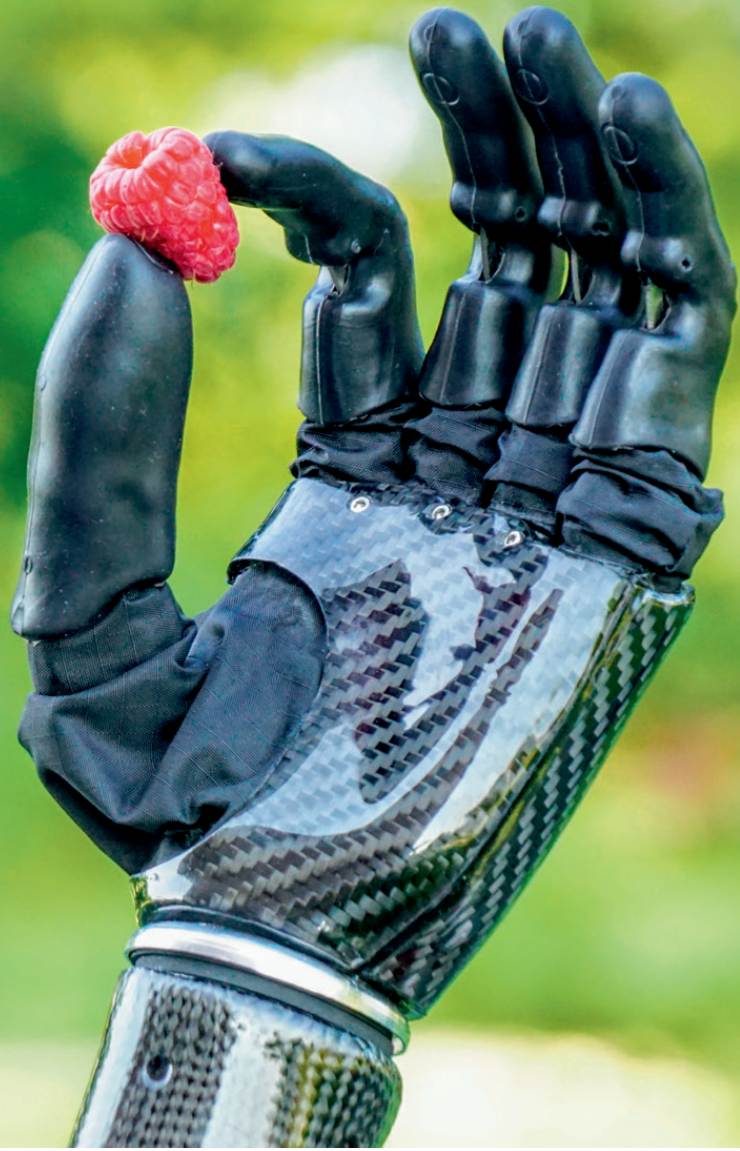
Non Material



A Feel for the Future of Bioengineering

感受生物工程的未來

Text by Steve Jarvis Photographs courtesy of PSYONIC

Smashing martial arts boards with your prosthetic hand is not in the user manual, but, if it is called the Ability Hand, and if it is capable of doing that, then why not? Impressively, the same hand is also able to pick up individual raspberries with ease. Once a staple of science fiction, the future of bionic prosthetics is already here.

說明書上並沒有講解怎樣義肢砸碎武術木板，但是如果這隻能力之手（Ability Hand）能夠做到這一點，那又有何不可？更厲害的是，這隻手還能輕鬆地拿起小如一粒紅莓。仿生義肢曾經是科幻小說中的主要內容，此刻，未來已然到來。

The maker of Ability Hand, PSYONIC, a start-up out of the University of Illinois Urbana-Champaign, has spent the last eight years refining their bionic hand, and the company now boasts one of the most affordable, robust, and useful prosthetic devices ever created. We speak to the founder of PSYONIC, Dr. Aadeel Akhtar, about his journey and what lies ahead at the frontier of bioengineering.

Clicking the hand into place on a nearby arm prosthetic socket, Akhtar, enthusiastically launches into the details of the Ability Hand. "There is a spring steel link connecting the joints through a 3D-printed bone made of rubber and nylon, making it flexible in the lateral direction, allowing movement side to side, but still rigid when something needs to be gripped. The palms are made of carbon fibre, which gives structure to the motors and other components, while allowing the hand to be very strong and durable. The hand itself is detachable, comes in different sizes, and weighs less than an average human hand. You can even charge your phone on its USB-C rechargeable battery."

As cool as it looks on the outside, it is on the inside where the magic happens. Akhtar continues, "Inside each of the fingers are six touch sensors, one on the fingertip, one on the finger pad, two on the lateral side and two on the medial side for a total of six sensors per digit. Then there is a vibration motor positioned appropriately on the residual limb so users can receive haptic feedback from the touch sensors.

The Ability Hand's sensory system is compatible with most major control systems, opening up the technology to a wide range of users. "A common way to control a hand is using two muscle sensors located on the forearm, where even without a hand you still have these muscles, but there are also three or four other ways to get motor control and sensory perception via different muscles and skin regions such as shoulders, etc.," said Akhtar.

While Akhtar enthuses over the technology, he is quick to point out that having an artificial hand that can replicate much of what a real hand can do is an incredibly empowering experience for people with limb differences. Moreover, having something that looks futuristic and cool is a real image change for prosthetics, inspiring interest and awe rather than pity for an appendage that has been lost.

A technical and personal journey

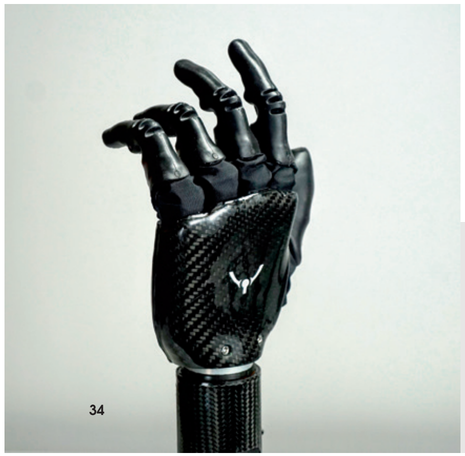
Prioritising the human element is an important part of the Ability Hand story. Actually, it is a very personal journey for Akhtar, one that has its roots in a childhood visit to Pakistan where he saw an amputee, a girl his age, hobbling along with only a stick for help. The comparison with his life was confronting, and he vowed to someday help people like her. It was no faint promise. With degrees in Biology and Computer Science, a Masters in Electrical and Computer Engineering, and a PhD in Neuroscience, he has been constantly moving toward this goal.

"When I was in graduate school we visited Ecuador and saw a patient who had lost his left hand. After fitting the prototype, the recipient Juan said it was as if a part of him had returned after 35 years. This was the real start of PSYONIC, and was a very motivating factor because I could not accept that this life-changing technology could be left on the shelf as an unused project, something we see so often with academic projects." Akhtar wanted every amputee to feel the way that Juan did when he tried on the hand for the first time.

Akhtar first started making bionic hands in 2014, and in the subsequent eight years they have gone through nine prototypes. "The first four hands were 3D-printed in plastic, but it was after the fourth prototype we started this process called "customer discovery" and talked to as many end-users as possible. This amounted to hundreds of patients and clinicians, and the number one thing they complained about, even with $50,000 injection moulded and custom machined steel bionic hands, was that they were brittle and fragile. It wasn't as if they were doing anything crazy. Something as mundane as hitting their hand on a table would break it because they were rigid and would just snap at the joints."

This crystallised the parameters for Ability Hand. Akhtar explains, "The goal became being able to use low-cost 3D printing, but make this hand more robust than anything out there. This led us to the soft robotics literature, where researchers were experimenting with low-cost silicone with properties similar to our own ligaments, skin and tendons. So we started 3D-printing a rubber bone reinforced with nylon and encased it in silicone. This made it stiff in the areas where we needed it to be stiff, but also flexible where needed. The result is a hand both flexible and tough."

The Ability Hand is a marvel of bioengineering, but it can only be a pale imitation of what nature and evolution have provided us. Akhtar elaborates, "The Ability Hand only has six motors and therefore six degrees of movement, but it is much less than an actual human hand that has closer to 23 degrees of movement. Given these limitations, to make the most of the hardware we needed to think what information was required to give the body in order to give the mind a complete representation of what is happening with the hand."



Highly responsive digits enable diverse grip patterns
反應靈敏的手指可實現多種抓握模式

Tough enough for load bearing and delicate enough to grip instruments, the Ablity Hand gives users a new lease on life
Ablity Hand 足夠堅強去承重，同時也足夠細膩去抓握物件，讓用家重獲新生。

Sense catching is a fine art

Akhtar gives insight into this complex sensory arrangement, "A short haptic buzz lets the user know when they have come into contact with an object, and also how hard they have grabbed the object via the strength of the vibration signal. This is combined with a contact reflex, where a sensor will detect pressure over a minimum threshold and then the hand physically slows down or stops automatically. It is an artificial version of a reflex so the user isn't directly controlling this, but it slows the process down enough for the user to define control over how they want to control or squeeze an object."

"The most sophisticated control comes with having the haptic feedback work in conjunction with the contact reflex function, allowing the delicate control necessary to touch fragile objects," said Akhtar. However, for him, the biggest challenge facing prosthetics' development is actually proprioception, which is the ability for us to know where our joints are located in space without us having to look at them.

"Your mind has a representation of where your hands or feet are, and this movement is synced with your mind, and this allows what is called embodiment. It is the thing that makes us feel like an object isn't just an object, but actually part of our own body. So, if you stimulate the proprioception sensory nerves when you move your finger, you can stimulate it appropriately to make it feel like your phantom hand or finger was actually moving. This is the point when you have created a bond between the mind and the machine, and it actually feels like an extension of your body."

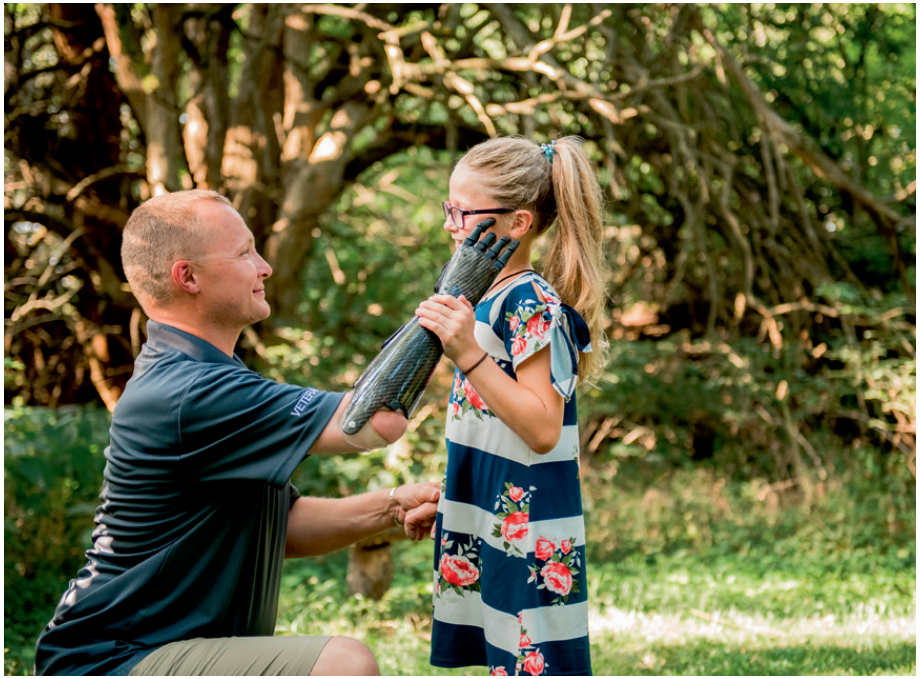
Akhtar thinks bionics will undergo ever-more biological integration, "We have been partnering with university research labs that are not only working in peripheral nerve sensing, but also in the brain, directly stimulating these neural networks. The goal is to be able to move the hand directly from the brain, and we are now exploring integrating sensors into the bones, residual muscles and nerves as the next level of integration," said Akhtar. Something that will be critical for their next project, the Ability Leg, "It is a leg that is directly integrated into the bone, but also able to directly read the nerve signals so you can bend your ankle with the fidelity that a person had prior to their amputation. That is the future we are looking at."

The robotics and AI industry are also taking a close interest in Ability Hand. Akhtar elaborates, "These companies are trying to build robots that are doing human tasks, and we built a hand that was optimised for humans to do human tasks, so the crossover is clear when you are trying to design robots to do human tasks. It just makes sense. Facebook, for example, has bought some of our hands and has installed them on robotic arms being developed for applications like remote medicine. Or more everyday things, like grabbing pill bottles and opening caps or bottles of water. This is an entirely additional application, one we considered in the past, but we didn't realise how synergistic the crossover is between robots and prosthetic limbs."

Bioengineers need good designers

Given his work's reliance on integration and seamless communication, we asked Akhtar his opinion on what role designers can play in bioengineering. "At the end of the day user experience is most important. How it feels and functions are critical to making a good product, but traditionally there has been less of a focus on aesthetic factors, the thing that makes you feel cool to be wearing a bionic limb. This is where designers can contribute by helping engineers to come up with something that is not only functional but also aesthetically appealing. More than just a tool, it should be an extension of their body."

A lot of the designers Akhtar has worked with in the past have been able to come up with great renders of really interesting ideas. Yet they are not applicable to real-world applications because of engineering limitations. He continues, "That is why it is so critical to have a dialogue at the earliest stages, because engineers don't have sophisticated design skills that make the technology user-friendly, but they do understand what is required to make it work. Having a dialogue helps synchronise both sides of the equation. Merging the engineering and the design side is so important when you are making something that is real."



The Ability Hand can give a new lease on life
Ability Hand 可以賦予用家新生命

Ability Hand的製造商PSYONIC是來自伊利諾伊大學厄巴納-香檳分校的一家初創公司，過去八年一直在完善他們的仿生手。現時他們的義肢設備是市場上最實惠、堅固和實用的產品之一。我們專訪了PSYONIC的創辦人Aadeel Akhtar博士，談談他的製作歷程以及生物工程的未來發展。

Akhtar將仿生手裝入身旁的手臂義肢插座上，便開始熱切地介紹Ability Hand：「這裏有一個彈簧鋼條，通過由橡膠和尼龍製成的3D打印骨骼連接各關節，使其具有橫向靈活性，可以向側移動，但在需要抓握東西時，它仍然可以非常穩定。手掌是由碳纖維製成，既為起動機和其他組件提供結構性的支持，同時使手掌非常堅固耐用。仿生手本身是可拆卸的，有不同的尺寸，重量比普通人的手要輕。你甚至可以用它的USB-C可充電電池為手機充電。」

它的外表看起來很酷，內部亦暗藏玄機。Akhtar繼續説道：「每隻手指裏面有六個觸覺感應器，一個在指尖，一個在指墊，兩個在外側，兩個在內側。在殘肢的適當位置裝上感應器，用家便可以透過感應器的振動起動機得到得觸覺。」

Ability Hand的感應系統與大多數控制系統兼容，因此可為廣泛用家提供這項技術。Akhtar表示：「控制手部的常見方法是使用位於前臂上的兩個肌肉感應器。即使沒有手，你仍然有這些肌肉。但也有另外三四種方法，通過不同的肌肉和肩膀等皮膚區域，讓用家得到活動控制和感官知覺。」

Akhtar對這項技術充滿熱情，他指出擁有可以模仿真手大部分功能的人造手，能給予有不同肢體障礙的人士帶來超乎想像的自主體驗。此外，這看起來充滿未來感和型格的義肢，為義肢帶來形象上的改變，它能夠激起人們的興趣，同時令人驚嘆不已，而不是對失去肢體的人士感到遺憾。

技術和個人之旅

優先考慮人類元素，是Ability Hand的一個重要部分。事實上，這對Akhtar來説是一個非常個人的歷程。他在童年時曾造訪巴基斯坦，在那裏遇見一個與他同齡的截肢女孩，只靠一根棍子的幫助蹣跚而行。 他感到很震驚，並發誓有一天要幫助像她一樣的人。這並不是一個輕淡的承諾。其後他獲得生物學和計算機科學學位，電子和計算機工程碩士學位，以及神經科學博士學位，一直在朝著這個目標前進。

「在研究生時期，我們到訪厄瓜多爾，看一個失去左手的病人，也是產品測試者Juan。為Juan裝上義肢後，他説自己的一部分彷彿在35年後回來了。這標誌著PSYONIC的真正開始，也是一個令我非常鼓舞性的因素。我不能接受這種改變生活的技術變成一個被束之高閣的閑置項目，這種情況在學術專題項目中可謂非常普遍。」Akhtar希望每個截肢者都能像Juan一樣，獲得第一次試用義肢時那種感覺。

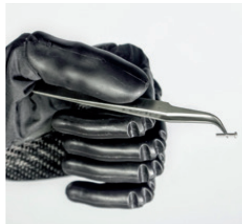
Akhtar在2014年首次開始製作仿生手，隨後八年先後開發了九個樣品。「前四隻仿生手是用塑膠3D打印的，但到第四個樣品之後，我們才開始了這個稱為『客戶發現』的過程，盡可能多與用家交流。我們和數百名病人以及臨床醫生討論，他們抱怨的第一件事就是，就算是價值五萬美元的注模客製鋼鐵仿生手，也是非常脆弱易壞的。用家並不是做了什麼瘋狂的操作，他們只是把手碰到桌子這樣平常的東西，仿生手便會受破損，因為它們都是硬的，往往在關節處斷裂。」

這促使了Ability Hand的各項參數變得更具體。Akhtar解釋説：「我們的目標是能夠使用低成本的3D打印技術，製造出比現有產品都要堅固的仿生手。順著這一思路，我們閱讀了有關軟體機器人的文獻，其中研究人員試驗低成本的矽膠，質感類似我們的韌帶、皮膚和肌腱。就是這樣，我們便開始以3D打印了一個橡膠骨頭，用尼龍加固並以矽膠包裹。這讓它在該堅硬的地方堅硬，該靈活的地方靈活，最後就得出一隻既靈活又堅韌的手。」

Ability Hand是生物工程的一個奇跡，但Akhtar表示它只是對自然和生物進化的粗略模仿。他解釋道：「Ability Hand只有六個感應器，因此只有六種移動方式，相比起實際人類手部近二十三個移動方式要少得多。因為這些限制，要最大程度運用到硬件，我們需要思考要給身體提供哪些信息，才能讓大腦充分反映手上正在進行的動作。」

感官捕捉是一門藝術

Akhtar深入分析這複雜的感官活動：「短促的觸覺提示可以讓用家知道他們接觸到一個物體，並通過振動信號的強度知道抓住物體力度的大小。這與接觸反射相結合，感應器檢測到超過最低閾值的壓力，接著手部動作就會自動慢下來或停止。這是一個人工的反射動作，所以用家並不是直接控制，但它令這個過程漸漸慢下來，然後慢到足以讓用家決定如何控制或擠壓一件物體。」



他表示：「最複雜的操作是讓觸覺反饋與接觸反射功能同時運作，容許觸摸脆弱物體時所需的精細控制。」不過對他而言，本體感覺才是義肢發展面臨的最大挑戰，也就是我們無需查看，就能知道關節所處的空間位置的能力。

「你的大腦中存在著四肢在哪的概念，它們的動作和大腦同步，這就實現了所謂的具身認知。它讓我們感覺到一個物體不僅僅是一個物體，而實際上是我們自己身體的一部分。因此，如果你在移動手指時刺激本體感覺神經，你可以通過適當的方式刺激，使它就如虛幻的手或手指在移動一般。這就是你在思想和機器之間建立聯繫的重點，實際上你會感覺它是你肢體的延伸。」

Akhtar認為仿生學將會經歷生物整合不斷推進的過程，他説：「我們一直在與大學研究實驗室合作，這些實驗室通過外圍神經感應或在大腦中直接刺激這些神經網絡。我們的目標是能夠直接通過大腦指揮手部動作，現在正在探索將感應器結合到骨骼、殘餘肌肉和神經中，作為下一個整合的階段。」Akhtar説這對他們的下一個項目 — 能力之腿（Ability Leg）是至關重要的一環。「這條腿可以直接和骨頭結合，也可以直接讀取神經信號。這樣，用家就可以有一種猶如截肢前彎曲腳踝那樣真實的感覺。這就是我們想要的未來。」

機器人和人工智能業界也對Ability Hand產生了濃厚的興趣。Akhtar 解釋道：「這些公司正在嘗試製造執行人工任務的機器人，而我們製造了一隻專為人類執行任務而優化的手，因此他們想要合作的想法自然很合理。例如Facebook購買了我們的一些仿生手，並安裝在應用於遠程醫療等方面的機械手臂，或者是更多日常的事項，例如拿藥瓶、打開瓶裝水的瓶蓋等。這是一個完全附加的應用，我們過去曾考慮過，但我們沒有意識到機器人和義肢之間的合作可以如此相輔相成。」

生物工程師需要優秀的設計師

由於Akhtar的工作依賴整合和無縫溝通，我們詢問了他對設計師在生物工程中可以扮演什麼角色的看法。「歸根究柢，用家體驗是最重要的。它的感覺和功能對於製作一款好的產品至關重要，但傳統上人們很少關注美學元素，即佩戴仿生義肢會讓你感覺很酷那樣。這就是設計師可以通過提出實用而美觀的東西，來幫助工程師。它應該是他們身體的延伸，而不僅僅是一個工具。」

許多Akhtar過往合作過的設計師都能夠提出非常有趣的意念。然而，基於工程上的限制，有些構想並不適用於實際應用上。他繼續説道：「這就是為什麼在最早階段進行對話是如此重要，因為工程師並沒有具備精緻的設計技巧去到技術能方便用家使用，但他們確實知道需要甚麼可行的條件。對話有助雙方同步。當你製作真實的東西時，將工程和設計結合便變得非常重要。」

Dr. Aadeel Akhtar
Dr. Aadeel Akhtar is the CEO and Founder of PSYONIC, a company developing advanced bionic limbs that are accessible to all people with limb differences. Dr. Akhtar received his PhD in Neuroscience and MS in Electrical & Computer Engineering from the University of Illinois at Urbana-Champaign in 2016. He received an MS in Computer Science in 2008 and BS in Biology in 2007 at Loyola University Chicago.

Dr. Aadeel Akhtar
Aadeel Akhtar 博士是 PSYONIC 的行政總裁和創辦人。該公司開發先進的仿生肢體，讓有不同肢體障礙的人士都可以使用。Akhtar 博士於 2016 年在伊利諾伊大學厄巴納 - 香檳分校獲得神經科學博士學位，於 2008 年在芝加哥洛約拉大學獲得電子和計算機工程碩士學位，並於 2007 年獲得生物學學士學位。