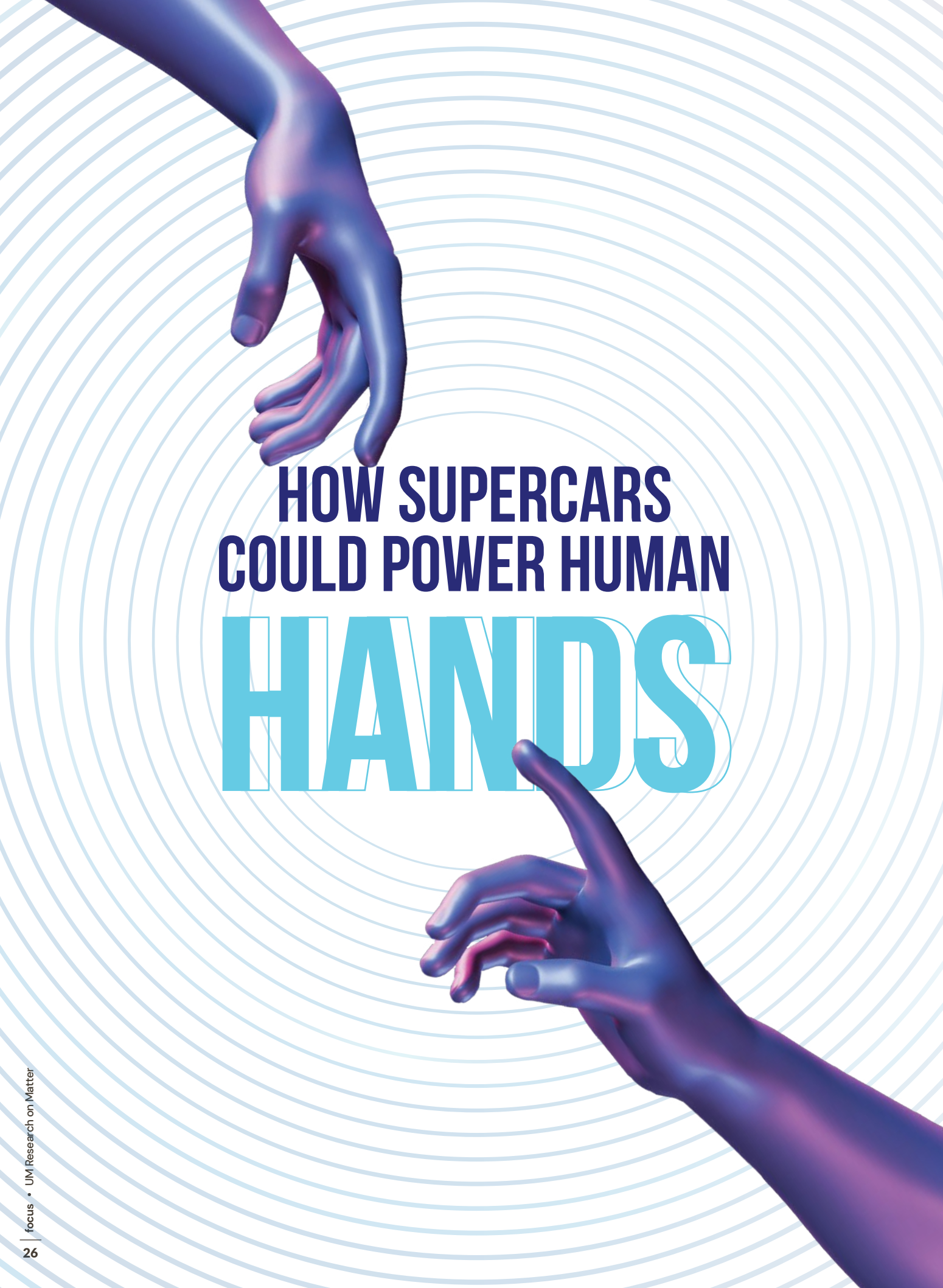


The image features two stylized, metallic-looking hands in shades of blue and purple. One hand is positioned at the top left, reaching downwards, while the other is at the bottom right, reaching upwards. They are set against a background of numerous concentric, light blue circles that create a sense of depth and focus. The hands are positioned as if they are about to grasp each other, framing the central text.

HOW SUPERCARS COULD POWER HUMAN HANDS

Author: **David Mizzi**

*Could the same motors that push electric supercars drive innovation in the world of prosthetics? **The PROJOI project** aims to adapt these high-performance designs to rethink artificial limbs.*

With prosthetics, the goal is to create something that can adequately mimic an organic limb. Prosthetic limbs are typically powered by small electric motors, but creating a motor that can match the performance of a human limb is a notoriously difficult task. However, Prof. Ing. Reiko Raute, Associate Professor at the Department of Electrical Engineering, and Prof. Ing. Michael Saliba, Professor at the Department of Mechanical Engineering, have drawn inspiration from the world of electric supercars to develop a small but powerful motor that could tip the balance.

THE STRONG BUT SILENT TYPE

Forget science fiction; ultimately, prosthetics are nowhere near close enough to match the performance of their original human counterparts. Organic human limbs are

feats of bone and muscle; strong enough to climb, push and pull, yet sensitive enough to pick a flower. Even something as simple as holding an egg requires an extraordinary amount of coordination between your brain and finger muscles. Essentially, your fingers 'sense' the right amount of force needed to pick the egg up without cracking it. This is known as proprioception, and it is crucial for spatial awareness and for gauging the force required for certain tasks. It is also one of the many challenges engineers face when building prosthetics.

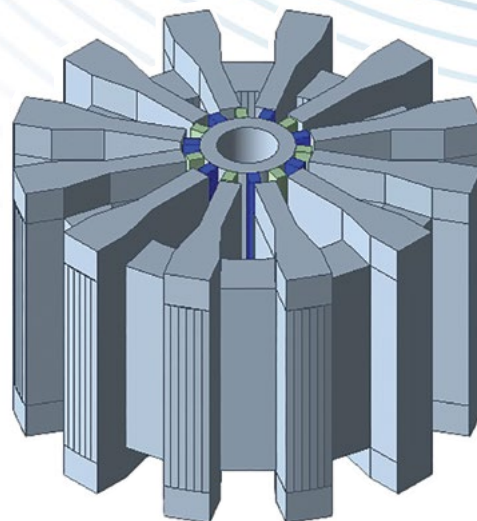
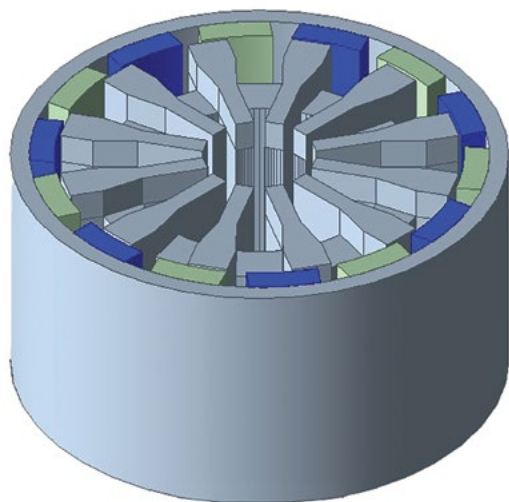
'Our fingers are backdrivable, so we can push them back and forth,' explains Raute. Secondly, we also get some feedback from the outside world. 'A typical prosthetic would have a high-ratio gearbox, so the finger would move with a gearbox, but then you cannot push it back. There would be no feedback,' he explains.

There is also the question of torque. Torque is the amount of force needed to rotate an object around a point. It is

a twisting force. Think of a door; trying to open it close to the hinges is harder than opening it from the handle. With a hand, your finger is the hinge, and without enough torque, you would not even be able to lift a mug of coffee.

To generate this torque in a prosthetic, you need a small motor; however, small high-speed motors, like dentist drills, make high-pitched sounds. Hearing the high-pitched whirring of a dentist's drill every time you use your hand is something most sane people would prefer to avoid. 'My colleague, Michael Saliba, is working on the mechanics of the prosthetic hand to generate the right torque. We need slow movement but high torque,' explains Raute.

Creating a prosthetic that is lightweight, strong, and silent, while also being proprioceptive (flexible), requires a special type of motor. To build such a motor, Raute and his team drew inspiration from an unlikely source: Koenigsegg's high-performance sports cars. ➤



Outer rotor with radial magnets (left) and inner rotor with radial magnets (right)

Images courtesy of the PROJOL team

WHAT DO SPORTS CARS HAVE TO DO WITH PROSTHETICS?

It comes down to motors and magnets. Many modern electric cars typically use permanent magnet synchronous motors (PMSM), whereas high-end electric sports cars have recently started using radial-axial motors and YASA axial motors. Before we go further, let's break these down.

When an electric current passes through a magnetic field, it generates a force. That is the underlying principle of all electric motors. In electric motors, interactions between magnetic fields generate torque that makes the rotor spin. You can have an inner radial motor, where the rotor is inside the stator, or an outer radial motor, where the rotor is outside the stator. We will

return to these shortly. Note that the rotor is the part that rotates, while the stator remains stationary.

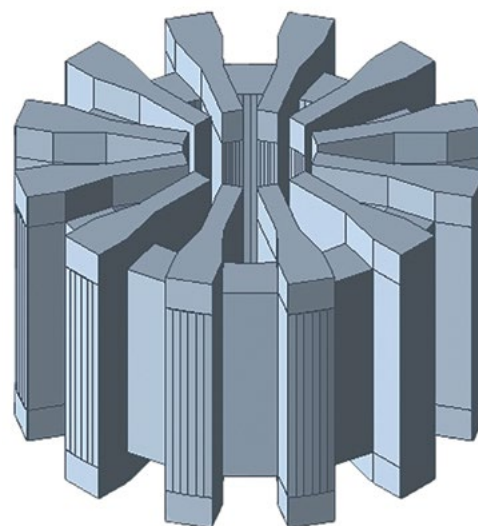
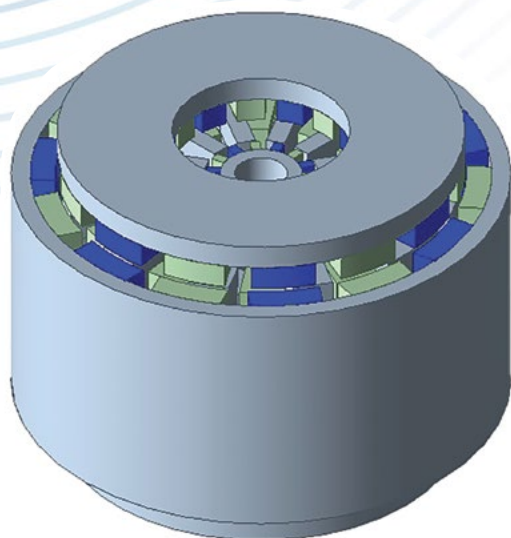
Let us have a look at a PMSM inner radial motor to illustrate this. Copper windings sit outside the rotor, facing inwards. In this configuration, the permanent magnets are on the inside with the rotor, facing outwards. Because the rotor is inside, it has a smaller diameter.

Conversely, a PMSM outer radial motor has the rotor located outside the stator. The magnets are on the external rotor, facing inwards, while the copper windings are on the inside, facing outwards. In this case, the rotor has a larger diameter, which generally generates more torque.

Axial flux motors, also known as 'pancake motors', use a different geometric layout. Instead of the

longer radial motors, axial flux motors are flat. The magnets are on the circumference of the rotor, inside and out. Interestingly, this results in the magnetic field being perpendicular to the shaft. While this means you need more magnets, it also means you get more torque with the same diameter when compared to an inner radial motor. Furthermore, axial flux motors weigh less and, as a result, have a higher power-to-weight ratio. Thanks to their high performance, YASA uses these types of motors for the Mercedes-AMG models.

'Koenigsegg took this a step further and combined both the radial flux and axial flux machines into a single structure – a configuration known as a radial-flux motor. While this uses three sides to place the magnets, ours uses four. We combine



Fully assembled motor, with radial and axial magnets (left) and stator core of motor (right)

magnets on the top and bottom sides, inside and outside. The stator is almost completely surrounded by the magnets,' explains Raute.

While these supercar motors can generate an immense amount of torque, ultimately, the motor for a prosthetic needs to be much smaller. For PROJOI, the motor needs to be 25 x 25 x 40mm and weigh less than 60 grams. A radial-flux motor design allows for maximum torque generation within a small space, making it the optimal choice. The question is, how did this motor perform?

CHASING THE HUMAN HAND

The overarching goal is to create a motor that can equal or exceed the performance of a human hand. 'We are still only at about 25% of the desired performance, so we would still need

to implement a gearbox. However, while typical prosthetics use a gearbox with a 1:100 ratio, we would need a 1:4 gearbox, which would allow for some proprioceptive feel,' says Raute.

Another challenge lies with the materials, specifically magnetic saturation. While engineers can increase the current or use stronger magnets, the steel inside the motor can only carry a limited amount of magnetic flux. Once the steel saturates, extra current or magnetic field strength no longer increases torque. 'For example, we had one design with several magnets, but then the steel saturates and the flux is not there. So we made the stator steel a bit thicker and the magnets a bit thinner, which allowed more room for the flux,' Raute explains. That being said, Raute is optimistic. 'We have computer

simulations and a 3D CAD model to simulate the forces in the electric motor during operation. The next step is to develop the prototype,' he says.

Trying to design a motor for a prosthetic is no easy task. However, the same engineering that drives electric supercars could also help accelerate the development of better prosthetic limbs.

Of course, none of this would have been possible without adequate funding. 'I am really happy with Xjenza Malta and the new funding opportunities. Things have come a long way from 10 years ago. Xjenza provides the means for us to excel further,' Raute adds. **T**

The project 'Proprioceptive Prosthetic Joint Actuator (PROJOI)' is financed by Xjenza Malta through the FUSION: R&I Research Excellence Programme 2025.