UFABC wheelchair with three wheels on each axle climbs stairs

Solutions for wheelchair users

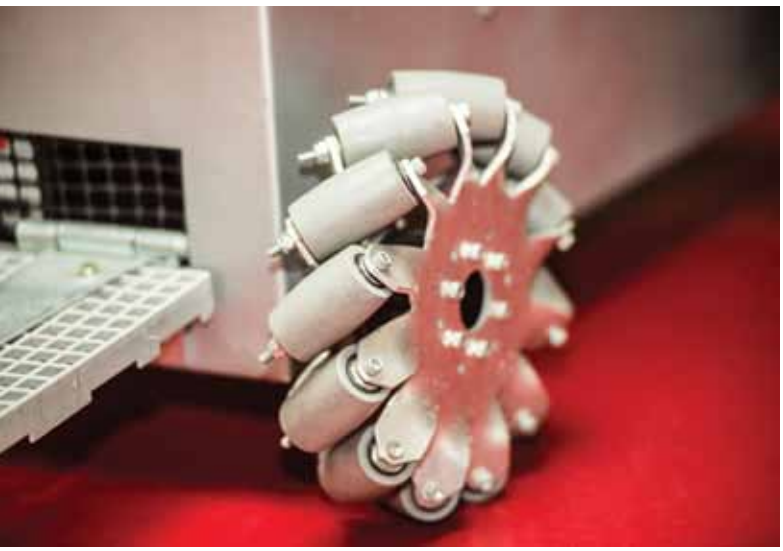
New wheelchair designs promise to make life easier for those who depend on these vehicles

TEXT **Evanildo da Silveira**

PHOTOS **Eduardo Cesar**

The collapsible manual wheelchair was invented in 1933 by Harry Jennings, a mechanical engineer from the United States. Today, there is a vast number of models, for those powered by arm strength as well as by motor. While very helpful in increasing the mobility of their users, they present some difficulties in situations such as sharp inclines, irregular sidewalks and curbs with no ramps, for example. To overcome these obstacles, researchers and companies are looking for solutions to make wheelchairs more efficient and easier to control. Several research studies are currently underway in Brazil, ranging from the design of motorization kits, to systems that use facial expressions to control motorized wheelchairs.

One of the most advanced, which is already on the market, was designed by mechanical engineer Júlio Oliveto Alves while pursuing his master's in the Guaratinguetá School of Engineering (FEG), at São Paulo State University (Unesp). It consists of an electric traction system for manual wheelchairs. Christened Kit Livre, it is a portable, collapsible device made up of a wheel and a rechargeable electric motor. "When attached to a conventional wheelchair, it turns it into a motor-



Easy maneuverability using a wheelchair that moves in every direction (*above*). With four uniform omnidirectional wheels, the device has small rollers that allow movement in any direction (*left*)

ized tricycle that can achieve speeds of up to 20 kilometers per hour (km/h) with average autonomy of 25 km," Alves explains. "With Kit Livre, someone with a disability can go up and down sidewalk curbs and travel on uneven or sandy surfaces and grass, in addition to climbing hills with angles of up to 40%."

The idea for converting a wheelchair into a tricycle came about in 2009, while Alves was working towards his master's degree, with Victor Orlando Gamarra Rosado as his advisor. In 2012, the patent for the invention was filed with the Brazilian Industrial Property Institute (INPI) and Alves started thinking about a commercial project. "In 2013 and 2014, my brother Lúcio and I worked on developing a business model that could allow us to market Kit Livre all over the country," he says. "In 2014, we established the company Livre – Soluções em Mobilidade in São José dos Campos [SP]."

At the end of that same year, they won the Santander Entrepreneurship Award, which granted them the sum of R$100,000. They used their winnings to manufacture the first commercial batch and start operations at the company in April 2015. "Since then, we've distributed our devices in 19 Brazilian states, through sales in our online and brick-and-mortar stores as well as in large retail networks," Alves reports. "As of now, we've sold nearly 250 of them, at R$4,990 apiece." In addition to the Santander, the company earned other awards such as that given out by Acelera Startup, organized by the Federation of Industries of the State of São Paulo (Fiesp), and the FedEx Small Business Grant awarded by FedEx Brasil. "Ours is a product that ensures more independence and autonomy to those who are disabled, thus increasing their ability to integrate with society while using an innovative and comfortable design," says Victor Rosado.

Two other prototypes under evaluation for attachment to simple manual and flexible wheelchairs were developed under the scope of the Mobility Project by a group of professors and students in the School of Mechanical Engineering at the University of Campinas (FEM-Unicamp), led by Professor Franco Giuseppe Dedini. One of them, called Módulo Líbero, consists of a rechargeable electric motor and two wheels. It was designed to be attached to the bottom of the chair, so the chair ends up having six wheels. "It's these two extra wheels, attached to the electric motor, that will bear most of the unit's weight, facilitating the transit of the original wheels over irregularities and obstacles in the terrain," Dedini explains.

Another kit is called Mochila. Lighter and less powerful, the device is attached to the back of a wheelchair and through the use of small wheels connected to a motor, propels the vehicle. These kits offer some advantages over traditional motorized wheelchairs, such as weighing less and being easier to maneuver and fold for transport in automobiles. "Another advantage offered by the two models is the ease with which wheelchair users can connect or remove the kit whenever they want," says mechanical engineer Flávia Bonilha Alvarenga, who earned her PhD under the supervision of Dedini, one of those responsible for the Módelo Líbero project.

The motorization kits offer another important advantage: lower price. "Today in Brazil, motorized wheelchairs cost from R$5,000 to R$40,000, depending on their features and uses, while manual wheelchairs run from R$400 to R$6,000," Dedini says. "Our Mochila prototype cost R$1,000 and the Módulo Libero cost R$1,500. The target sales price for these products is somewhere between R$1,200 and R$1,800. But that's just an estimate."

Fausto Orsi Medola, a bioengineering researcher and professor in the School of Architecture, Arts and Communications at Unesp's Bauru campus, is developing a motorized system that is a little

different. He is part of a group that also includes University of São Paulo (USP) Professor Carlos Alberto Fortulan of the São Carlos School of Engineering (EESC) and Professor Valéria Elui of USP's Ribeirão Preto School of Medicine. "What we've made is a manual wheelchair with motorized assistance," he explains. "It is manual, but has an electric motor with a rechargeable battery that can be connected when needed to increase user mobility on ramps, ascents and long distances, reducing upper arm muscle strain." To carry out the project, the group received R$27,000 in funding from the National Council for Scientific and Technological Development (CNPq).

Medola says that the manual wheelchair with motorized assistance that he developed is similar to models already available in the international market. "They are known as push-rim activated power assist wheelchairs," he says. "However, they have two motors, one on each back wheel, that work independently, increasing the power the user can apply to the wheels. Our proposal is different because it has only a single motor attached to the back wheels, which guarantees maneuverability closer to that of conventional manual wheelchairs." The prototype still needs some perfecting before it can be put on the market.

Kit Livre: accessory that consists of a wheel, handlebars and rechargeable electric motor that can be attached to a manual wheelchair

IN ANY DIRECTION

At the Federal University of the ABC (UFABC) in Santo André (SP), researcher Luís Alberto Martinez Riascos is working on two ambitious projects: an omnidirectional wheelchair (with wheels that go in any direction) and a wheelchair that climbs stairs. "Conventional wheelchairs are hard to move and maneuver in tight or crowded spaces," he says. "Simple maneuvers require a lot of clearance. With omnidirectional wheels, the chair can be moved in any direction, including diagonally and sideways. It's easier to move in small spaces." In this type of chair, all four wheels are the same size, unlike conventional wheelchairs whose back wheels are larger. Riascos explains that the chair uses omnidirectional wheels known as 45° Mecanum or 45° Swedish wheels. "They have rollers around the wheel that have an axis of rotation at 45° in relation to that of the chair, but with traction in the transverse direction. Appropriate combinations of the motions of the four wheels allow for any movement or rotation," he explains.

In addition to tight spaces, wheelchair users face other problems on a daily basis, such as stairs, curbs, and irregular or bumpy terrain. "We've created a wheelchair that's able to climb stairs as well as overcome other obstacles," Riascos says. The project began in 2011, and in 2012 he received funding from FAPESP. This chair is based on the principle of delta or star wheels. They are composed of three small wheels that spin on a single axle, enabling them to climb and descend stairs. "There is already a patent for a drive-less tri-star wheel, like those used in hand trolleys," he says. "But the motorized drive system is patent protected, so we've had to design our own model." Each delta wheel has an electric motor that is activated independently. On flat surfaces, it has the same autonomy as conventional [motorized] wheelchairs, close to three or four hours. "It also has another, slightly smaller motor that controls inclination of the seat-back to ensure user comfort and safety," Riascos says.

For now, there are no projections for when the prototypes will become commercially available, or what their estimated price will be. "There are still some issues that need to be resolved, such as control and the ability to handle certain maneuvers," Riascos says. He notes that there are wheelchair models that go up and down stairs already available in the international market, the best in his opinion being the French-made Top Chair. The problem is its price: it costs R$75,000.

There is also China's Observer model and the iBOT from the United States, which was taken off the market due to safety issues. "The prototype we developed allows for instant transition from flat surface to stairs and vice-versa, while the Top Chair has wheels for flat surfaces and a system much like a conveyor

Two prototypes in development at Unicamp: the *Mochila* (*left*), which is a device that can be attached to a conventional wheelchair to propel the vehicle, and the *Líbero*, with electric motor and two additional wheels

The software uses a 3D camera to capture facial expressions that are then translated into wheelchair movement, such as moving forwards and backwards

PHOTO PAULO PINHEIRO

belt for stairs," he explains. "Another advantage that we offer is the weight. The one we built weighs 78 kg, nearly half the weight of our competitors' models – Top Chair weighs140 kg, the Observer weighs 197 kg and the iBOT weighs 131 kg."

THE MATH BEHIND THE SMILE

In order to meet the demands of a public that has more severe physical disabilities, such as quadriplegics who are only able to move their facial muscles, computer scientist Paulo Gurgel Pinheiro has developed a computer program that can translate facial expressions, such as a kiss, smile or raised eyebrow, into wheelchair commands such as forwards, backwards and spin. "This is how people who have lost the ability to move their arms and legs can control a motorized wheelchair," he says.

Known as Wheelie, the software can be installed on any computer. It uses a small 3D camera to capture points on one's face, around the eyes, mouth and nose. "The program uses nearly 80 of these points," Pinheiro says. "Then the app analyzes them to try to extract the facial expression that the user may be making." It's possible to configure a command for each expression. For example, a kiss moves the wheelchair forwards, a raised eyebrow makes it turn left. "The user chooses which expressions he is able to make more comfortably and the relationship it will have in operating the wheelchair," he explains. Pinheiro says that similar models on the international market do not have the same efficiency. "All the solutions currently available for hands-free control of wheelchairs require people to use some sort of wearable sensor," he says.

The Wheelie program was designed to understand the face of any user. "Like humans, it recognizes someone's smile in real time, precisely because the mathematics behind all smiles is the same," he explains. He says that the project began in August 2015. "Even before setting up the company we developed a simple functional prototype to demonstrate the program's potential. Now, less than six months after the PIPE [Innovative Research in Small Businesses Program] investment, our algorithm is classifying twice the number of expressions in half the time," he asserts. "In addition to FAPESP funding, we've obtained funding from Intel through its Intel Innovator Program that supports innovative ideas all over the world," he says. "The company helps us with infrastructure, advertising and networking." The goal is to have the product on the market by late 2018. The startup Hoobox Robotics was founded for this purpose. "The idea is to sell the software to large wheelchair manufacturers who would then equip their products with it," he says. ■

Projects

1. *Design and construction of more accessible wheelchairs* (No. 2012/04915-0); **Grant Mechanism**: Regular Research Grant; Principal **Investigator**: Luis Alberto Martinez Riascos (UFABC); **Investment**: R$ 95,161.77.
2. *Wheelie and Gimme, innovative technology to drive motorized wheelchairs* (No. 2015/22624-1); **Grant Mechanism**: Innovative Research in Small Businesses Program (PIPE); **Principal Investigator**: Paulo Gurgel Pinheiro (Hoobox Robotics); **Investment**: R$26,700.00.
3. *Wheelchair mobility: implications of the design on the kinetic, biomechanical and perceptive aspects* (No. 2016/05026-6); **Grant Mechanism**: Regular Research Grant; **Principal Investigator**: Fausto Orsi Medola (Unesp); **Investment**: R$90,567.00.