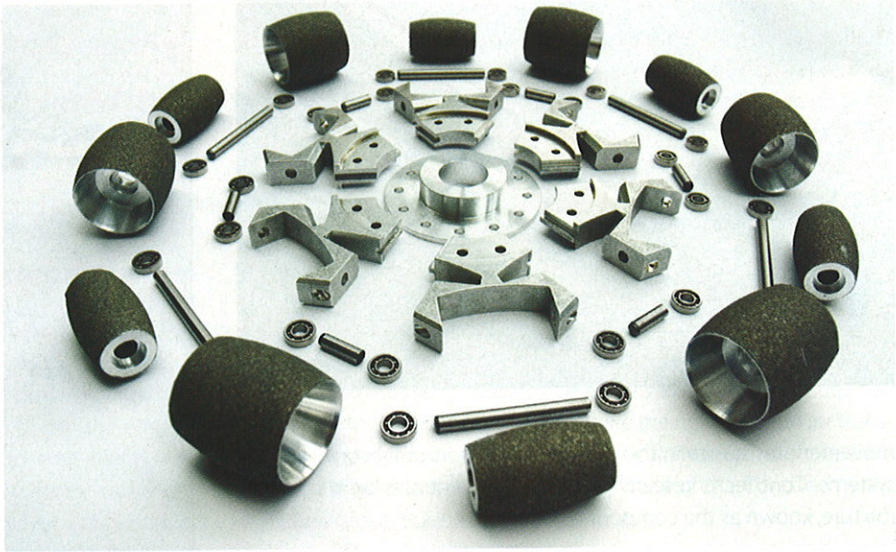
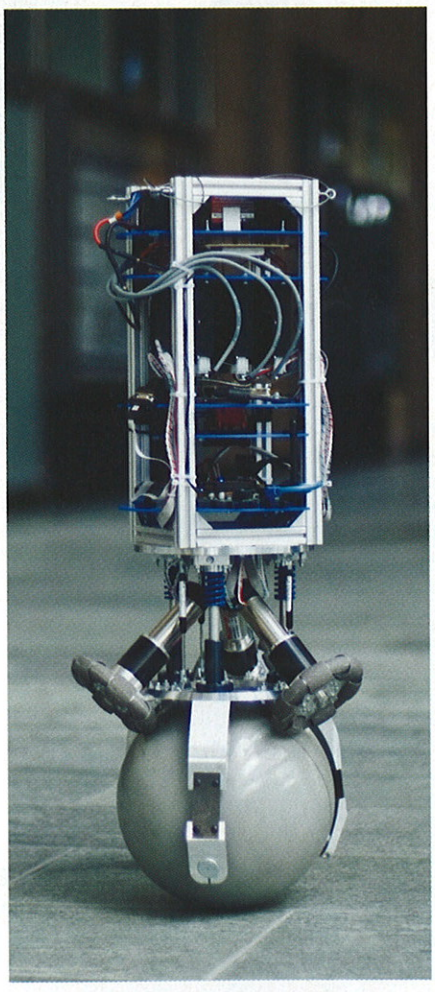
Motor/gearhead combination drives innovative ballbot

The Ballbot Rezero developed by an interdisciplinary team of students accomplishes not only a balancing act on the ball, but equally impresses by its convincing technical solutions, unprecedented agility and appealing design.





As a focus project of the Swiss Federal Institute of Technology Zurich (ETHZ), students of the Autonomous System Lab (ASL) along with their fellow colleagues at the Zurich University of Applied Sciences (ZHAW) and the Zurich University of the Arts (ZHdK) have formed a cooperation of a special kind. The result of this collaboration is named Rezero, the first Ballbot that not only perfectly masters balancing on a ball. It also exploits its movement potential and shows that a robot can look appealing without bystanders needing to overcome their inhibition threshold. As tour guide, servant, assistant or as toy, Rezero feels comfortable when space is limited or in crowded places.

One obvious attribute of a Ballbot is the ball on which it stands. Its contact area to level ground is actually a single point, making the robot generally instable by design and highly at risk to keel over. On the other hand, this fact enables free movement in any direction as well as the rotation around its own axis.

Another aspect: Rolling in a particular direction produces counter torque – the tilt of the robot in opposition to the direction of motion – in turn, would actually make it tumble. A Ballbot makes use of this fact as it slightly leans in the opposite direction to, quasi, chase behind its center of gravity. But even when appearing standing erect, it equilibrates by continuously slightly revolving the ball underneath its center of gravity.

An obstacle to be overcome is the actuation of the ball itself: A normal wheel rotates radially around its own axis, either forward or backward. Yet, a movement in the wheel's axial direction can only be achieved by overcoming the friction. Applied to the drive of a ball it means that, when moving in one direction, at least one of the drive wheels would radially jam. This requires the employment of a multi-directional drive system. Thereby, so called omniwheels take care of load transmission in one direction, while simultaneously providing free-wheeling in the other direction.

The Rezero solution: The ball

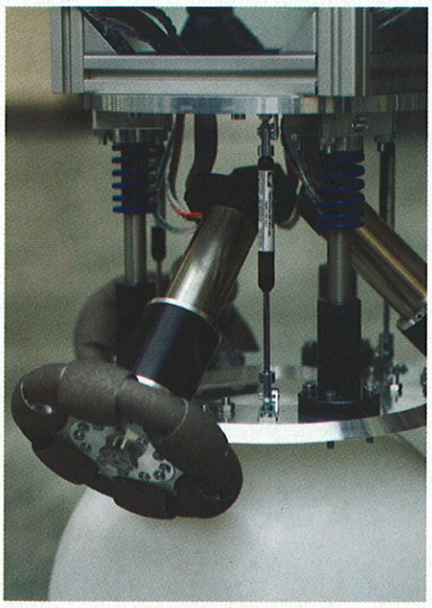
The ball is a project-own design that distinctly differentiates from other approaches. Its structure and the consequently required manufacturing process have been made-up in collaboration with an industrial partner. It is based on a geometrically highly accurate aluminum hollow sphere covered by a 4mm thick rubberized, low-wear surface providing a very high coefficient of static friction. Both factors, result in quite running, dynamic acceleration capability, and high velocity of up to 3.5 m/s (almost 13 km/h).

The Rezero solution: Drive system

Another in-house development are the three omniwheels which are arranged in 120° angles around the ball's circumference. This in particular, since available standard solutions could not satisfy the requirement of an entirely encapsulated outer shape .Their complex geometry, low-loss design of the individual components and load transmission-optimized surface all contribute to the high-grade construction design.

The wheels are driven by a motor/gearhead combination made by maxon motor. They compose of a EC-4pole 30, a planetary gearhead GP 42 C and an angular encoder HEDL 5540. The drives' suspension is designed that the ball remains ideally positioned underneath the three omniwheels to provide continuous traction. The drives are regulated by EPOS 70/10 positioning controllers in current control mode, being addressed as slaves within the CAN network. The three drives are being coordinated by the real time low-level computer.

The drive system impresses by its remarkable maximum dynamics during acceleration and deceleration, high velocities and, at the same time, high-precision positioning and quite running.



Control, position monitoring and sensor technology

In control are two data processors; a real time low-level computer for fast, accurate equilibration and position monitoring, and a high-level processor in Linux running the Robot Operating System (ROS) which takes care of interaction with the surroundings. Rezero can be controlled by various input methods, such as joystick or trajectory planning via MATLAB.

The Inertial Measurement Unit (IMU) represents one of the robot's core components. The system measures translative and rotatory accelerations, as well as spatial tilt angles and features a compass. Data are being smoothened by an internal Kalman filter and transmitted to the low-level computer. The unit oper-ates at a frequency of 160 Hz and represents the clocking link within the regulation chain.

To perceive its surrounding, Rezero is equipped with various laser and ultrasonic detectors. Their arrangement allows full 360° detection of objects within a range of approximately 6.5m. Depending on the selected mode, detected objects are assessed as obstacles, or they can be incorporated in the robot's behavior. Thus, for example, allowing Rezero "to take chase". The sensory capabilities are being enhanced by surround microphones, whereby their signals can also be integrated into the robot's actions.

The result

Rezero it the first Ballbot that not only perfectly commands the act of balance, but also outbids the moving capabilities of a Ballbot in an incomparable manner. The project team's well-elaborated concept impresses: The successful in-house development of the mechatronic elements, the high grade design and the interdisciplinary total package solution make Rezero an outstanding eye catcher.

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