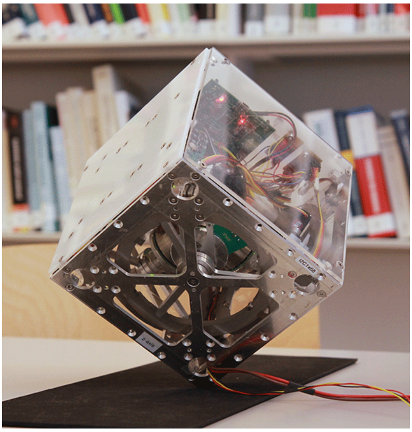
ETH Academic Exhibits

Exhibit: The Cubli
Lead researchers: Mohanarajah Gajamohan, Prof. Raffaello D'Andrea
Institute: Institute for Dynamic Systems and Control (IDSC), ETH Zurich
Project webpage: http://www.idsc.ethz.ch/Research_DAndrea/Cubli

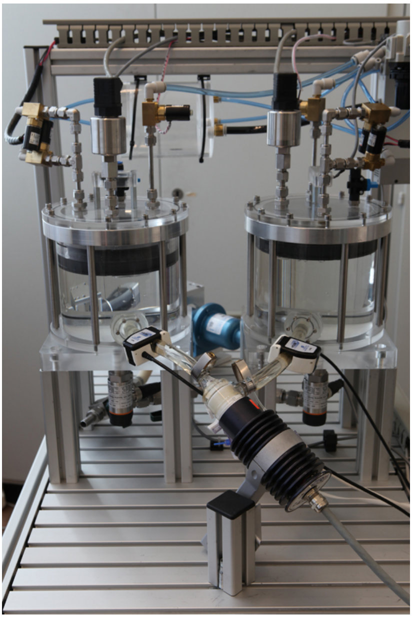
Description:
The Cubli is a 15 x 15 x 15 cm cube that can jump up and balance on its corner. Reaction wheels mounted on three faces of the cube rotate at high angular velocities and then brake suddenly, causing the Cubli to jump up. Once the Cubli has almost reached the corner stand up position, controlled motor torques are applied to make it balance on its corner. In addition to balancing, the motor torques can also be used to achieve a controlled fall such that the Cubli can be commanded to fall in any arbitrary direction. Combining these three abilities -- jumping up, balancing, and controlled falling -- the Cubli should be able to 'walk'.



* Note that this is an ongoing project and only the balancing aspect will be shown during the exhibition.

Exhibit: Physiological Blood Pump Test Bench
Lead researchers: Gregor Ochsner, Raffael Amacher, Marianne Schmid Daners, Prof. Lino Guzzella
Institute: Institute for Dynamic Systems and Control (IDSC), ETH Zurich
Project webpage: http://www.idsc.ethz.ch/Research_Guzzella/Biomedical_Systems/circulatory_assist_project

Description:



The physiological blood pump test bench is used to evaluate blood pumps and implantable Ventricular Assist Devices (VADs) that interact with the human blood circulation. This test bench is designed to emulate the blood circulation, which allows using it as a substitute for acute animal experiments. The test bench is based on a hardware-in-the-loop (HIL) concept, i.e., the blood circulation is completely simulated in software, while the blood pump is a real, hydraulic device. The HIL concept requires an interface between software and hardware, which is implemented by flow sensors in one direction (hardware to software) and by a pressure control system in the other direction (software to hardware). The test bench thus consists of two pressure-controlled reservoirs, where physiological pressures are applied up- and downstream of the blood pump and a flow probe, which feeds the measured flow rate back to the blood circulation model.

On the exhibition, we will give live demonstrations of the test bench and explain the fast pressure control system, which allows for the real-time interaction between the blood pump and the blood circulation model, in both physiological and pathological conditions.

Exhibit: Balancing Cube
Lead researchers: Sebastian Trimpe, Prof. Raffaello D'Andrea
Institute: Institute for Dynamic Systems and Control (IDSC), ETH Zurich
Project webpage: http://www.cube.ethz.ch

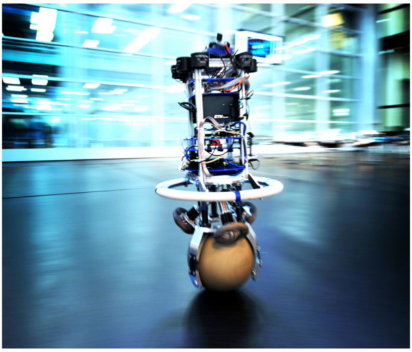
Description:

The Balancing Cube is a two-meter-tall dynamic sculpture that can balance autonomously on one of its edges or corners. The cube owes this ability to six rotating arms on its inner faces. The arms constitute the agents in the distributed and networked control system: each one is equipped with sensors, an actuator, and a controller; and the agents exchange data with each other over a communication network. The system combines the challenges of unstable dynamics with distributed control and networked communication, making it a rich platform for research in estimation and control.

The exhibition will feature the live demonstration of distributed and event-based state estimation algorithms recently developed at IDSC. When combined with state feedback controllers, these algorithms can stabilize the cube, while data is exchanged between the agents only when required to meet a certain estimation performance. With this approach, the communication rates automatically adapt to the need for feedback, and the average communication load in the network can be reduced compared to periodic data transmission.

Exhibit: Rezero
Lead researchers: Michael Neunert, Péter Fankhauser, Prof. Roland Siegwart
Institute: Autonomous Systems Lab (ASL), ETH Zurich
Project webpage: http://rezero.ethz.ch

Description:



Rezero is the name of a unique ballbot, able to balance and drive on a single ball. The robot has been built to demonstrate the unique driving capabilities of a ballbot and has put an emphasis on highly agile, robust and fast locomotion on a single spherical wheel. Rezero uses three omniwheels to actuate the ball in combination with an arrester to increase the contact force between the wheels and the ball. Dynamic stability is achieved with a state-feedback controller based on the measurements from an IMU and the motor encoders. The controller is derived from a three-dimensional model of the system and enables complex and fluid movements around all axes. Rezero can tilt up to 17 degrees, reaches a maximal speed of 3.5 m/s and is able to counteract strong external disturbances.

We will demonstrate Rezero in the regular conference breaks and visitors can experience the robot's capabilities in different interaction modes such as laser-range sensor based person following and compliant physical human-machine interaction.

Rezero was developed within an education project (Focus Project) by a team of 8 undergraduate students at the Autonomous Systems Lab at ETH Zurich.

Exhibit: Formula Student racecar “Umbrail”
Lead researchers: Academic Motorsportsclub Zurich, Prof. Pavel Hora
Institute: Institute for Virtual Manufacturing (IVP), ETH Zurich
Project webpage: http://www.amzracing.ch

Description:

The Formula Student Project consists of 18 Mechanical Engineering Students from ETH Zurich and 4 Electrical Engineering Students from Lucerne University of Applied Sciences and Arts. The goal of the project is to develop and build an electrically propelled and open-wheeled racecar to participate in the international Formula Student competition.

The exhibited car called “Umbrail” is last year’s model with which we were able to set a new benchmark in performance. The self-developed electrical motors power each rear wheel individually and thus offer a big opportunity for sophisticated yaw rate control via torque vectoring. Combined with the throughout lightweight construction, the car reaches a power to weight ratio of about 0.5 Hp/kg and 350 Nm torque at each rear wheel. Thus intelligent current limiting is necessary to prevent excessive wheel slip and loss of traction. Limited test time, grave nonlinearities and limited onboard computational power combined with the need for robustness against noise and disturbances provide the main challenges for a sophisticated controller design. Overcoming these challenges, “Umbrail” was the first electrical car ever in Formula Student to outperform not only the other electrical cars but also all combustion type cars.

Exhibit: The Blind Juggler
Lead researchers: Philipp Reist, Prof. Raffaello D'Andrea
Institute: Institute for Dynamic Systems and Control (IDSC), ETH Zurich
Project webpage: www.blindjuggler.org

Description:

The Blind Juggler (left in picture) is a robot that is able to juggle a ball on a linearly actuated paddle without any sensing; there are no cameras, no microphones, or any other sensors to detect the ball. The two key parameters that provide local stability to the ball trajectory are: 1) the parabolic, concave shape of the paddle; and 2) the acceleration of the paddle at nominal ball impact time.

The Swinging Blind Juggler (right in picture) takes sensorless robotic juggling one step further: it is the Blind Juggler strapped to a pendulum. The ball is struck at the peak angles of the pendulum, resulting in a side-to-side juggling of the ball. For sustained juggling, it is crucial to synchronize the swinging motion of the pendulum to the ball motion. Here at ECC **(Talk ThB9.5**), we present an optimal control based synchronization strategy that exploits the dynamic coupling between the motion of the paddle and the pendulum. Children on a swing exploit similar dynamics to control their amplitude. In previous work, synchronization was achieved by electric motors mounted to the pivots of the pendulum. With the new control strategy, sustained juggling is possible without these electric motors.

Exhibit: Autonomous RC Race Cars
Lead researchers: Alexander Domahidi, Alexander Liniger, Prof. Manfred Morari
Institute: Automatic Control Laboratory (IfA), ETH Zurich
Project webpage: http://orcaracer.ethz.ch

Description:

Mini 1:43 scale RC cars have come into their own with the release of the Kyosho dNano in 2008, which can drive on a desktop but moves at extreme pace. The exhibit displays an autonomous RC-car racetrack that serves as an educational platform for undergraduate students to study high-speed, real-time control in practice. The entire system has been designed and developed by students in a series of projects ranging from a low-cost high-precision infrared, networked vision system to an embedded platform that replaces the original Kyosho hardware and offers Bluetooth communication and accelerometer measurements.

Come see our cars race automatically using advanced real-time optimization based controllers – on a chip that could be in your smartphone. Can you beat them?

Exhibit: Two ARMin Exoskeletons with Virtual Air Hockey/Tennis Game
Lead researchers: Domen Novak, Prof. Robert Riener
Institute: Sensory-Motor Systems Lab, ETH Zurich
Project webpage: www.sms.hest.ethz.ch/research/arm_rehab

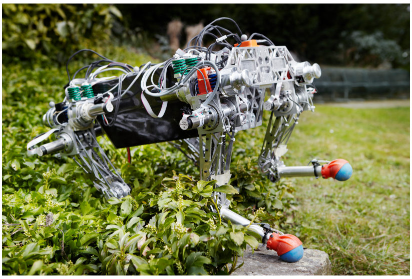
Description:

The ARMin is an arm rehabilitation robot that helps patients with neurological disabilities retrain their muscle strength and motor coordination. It boasts an exoskeletal structure with seven degrees of freedom and cooperative, patient-oriented control strategies. A multimodal display based on visual, acoustic and haptic cues allows task-oriented functional training. Virtual tasks performed on this display are designed to increase patient motivation through elements such as interactivity, automated difficulty adaptation and context-oriented music. Our latest scenarios investigate the effect of competition and shared experiences on patient motivation.

The exhibition will feature the live demonstration of one such virtual scenario. Two ARMin exoskeletons will be set up in the same area. Visitors will be able to place their arm in an ARMin and play a lawn tennis or air hockey game against another visitor by moving the ARMin. Though there is currently little physical interaction between the two players, the setup serves as a testbed for more complex robot control scenarios where patients will need to work together and adapt to each other's actions.

Exhibit: StarlETH – a Quadruped Robot
Lead researchers: Marco Hutter, Christian Gehring, Michael Blösch, Mark H. Höpflinger, Péter Fankhauser, Roland Siegwart
Institute: Autonomous Systems Lab (ASL), ETH Zurich
Project webpage: www.leggedrobotics.ethz.ch

Description:

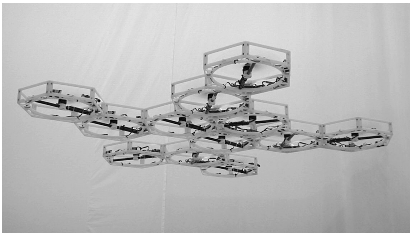


StarlETH is a quadrupedal robot driven by twelve highly compliant series elastic actuators. With linear dimensions of about half a meter and a total weight of 25kg, this autonomous machine resembles a medium size dog. StarlETH was built to for static maneuvers like climbing over obstacles as well as for fast and efficient dynamic locomotion. With full joint torque controllability, onboard state estimation and whole-body control techniques, this robot can autonomously locomote even under substantial external disturbances.

At the ECC exhibition, we will present our newest achievements. There will be live demonstrations in the regular conference breaks where people can watch and interact with the machine.

Exhibit: Distributed Flight Array
Lead researchers: Raymond Oung, Maximilian Kriegleder, Prof. Raffaello D'Andrea
Institute: Institute for Dynamic Systems and Control (IDSC), ETH Zurich
Project webpage: http://www.idsc.ethz.ch/Research_DAndrea/DFA

Description:



The Distributed Flight Array (DFA) is a modular, reconfigurable flying platform that is capable of flying in a limitless number of ad-hoc configurations. Each hexagonal shaped module of the DFA is equipped with its own suite of computational unit, sensors, actuators, and communication interfaces, and constitutes an autonomous agent of the system. The ability of agents to share information with their peers enables them to jointly complete tasks, which a single agent cannot do alone. One such task is flying in a coordinated fashion, which illustrates the motivation for research on distributed, cooperative estimation and control.

The exhibition will demonstrate two key aspects of the DFA – agents clustering in ad-hoc configurations and agents flying in a coordinated fashion. In the first part, agent will drive on the ground heading in a direction where they are most likely to find the rest of their peers. A recently developed algorithm guarantees that agents, which initially span a connected graph, will cluster in one single, yet random, configuration. In the second part, each agent will determine the topology of this ad-hoc configuration. This forms the basis for a scalable, decentralized controller and enables the agents to take flight in a coordinated fashion.

Exhibit: Autonomous Crosswind Flight of Tethered Wings
Lead researchers: Lorenzo Fagiano, Aldo Zgraggen, Prof. Manfred Morari
Institute: Automatic Control Laboratory (IfA), ETH Zurich, and Department of Mechanical Engineering, UC Santa Barbara
Project webpage: http://www.swisskitepower.ch/

Description:

The exhibit displays a tethered flexible wing flying autonomously in "crosswind" conditions, i.e. along trajectories that are roughly perpendicular to the wind flow. These flight paths are relevant to airborne wind energy systems, which aim to convert wind energy into electricity by exploiting the forces exerted by the wing on its lines.

The wing is equipped with an inertial measurement unit and a radio transmitter to send real-time measurements to the ground unit. Load cells and a line angle sensor on the ground complete the set of available measurements. The control input is the difference of length of the back ("steering") lines of the wing, which influences its turning rate.

Nonlinear estimation algorithms are used to fuse the information coming from the onboard and ground sensors to reconstruct the wing's position and velocity vectors at 50Hz sampling rate. The latter are used as feedback variables by a nonlinear, hierarchical control system that achieves the desired "figure-eight" trajectories. The control system has been successfully tested in multiple-hours flights with time-varying and unmeasured wind conditions and with different wings.

Two of the wings employed in the experiments are shown at the exhibit: a 12-m^2 power kite, and a 6-m^2 one. The former weighs 2.9 kg and it can develop, in a light 4 m/s wind, about 2500 N of traction force on the lines, while the latter weighs 1.7 kg and can develop about 1500 N of traction force.

Finally, an adaptive control strategy, able to track the wind direction using only line force measurements, has been also developed and tested experimentally and is displayed in the exhibit, too.