Search and Rescue Platforms and Capabilities. NCCR-Robotics

Disaster scenarios present complex unpredictable structures hardly accessible by man portable tools and other conventional machines. Risks like secondary collapses, toxic/harmful environments and extra damage to infrastructure or the victims due to lack of previous situation assessment, often keep rescuers away from zones that require imminent intervention. Robots arise as assets to fulfill these gaps providing an innovative approach to the problem, while keeping human rescuers safe.

NCCR Robotics is working on developing robots that are capable of address such accessibility challenges in a reliable way. We are focus on the development of multi-modal aerial and ground (legged) platforms and their state of the art technology for perception, control and coordination.

Through the development of a communication/control framework for our robots, we foresee an interplay of an heterogeneous team of robots and humans acting in different fronts and performing several tasks in search and rescue, including reconnaissance and mapping, structural inspection and forensics, estimation of size/volume of debris, serving as communication repeaters, providing logistic support, and certainly, in the medical assessment, intervention and recovery of victims.

The purpose of this document is to briefly present the robotic platforms developed by NCCR - Robotics highlighting their current capabilities according to the operation scenario.

Operation scenarios:

Aerial:
which type of platforms/technology we have? (names, labs involved, descriptive characteristics)
what real capabilities have been proved (hopefully in the field) with these robots?

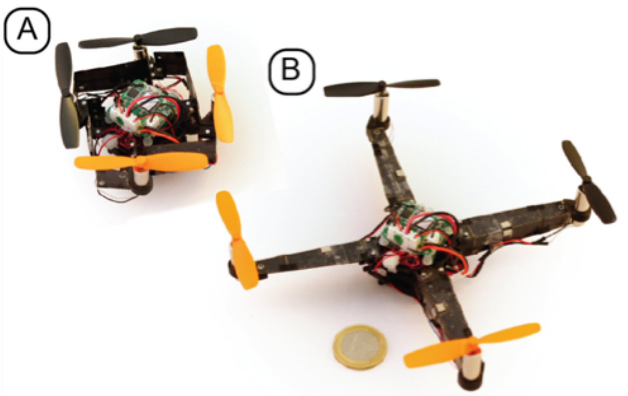
<u>Quadrotors (Robotics and Perception Group, UZH):</u>

- Autonomous, vision-based navigation in GPS-denied environments
- Live, dense 3D reconstruction of the environment

Our quadrotors can navigate autonomously without any external infrastructure: all sensing and computation is done onboard. We use vision as main sensing modality and process the images on a smartphone computer. This allows the quadrotor to navigate in GPS-denied environments, with lacky communication links, and without any human intervention. Our 3D reconstruction software allows to build a map of the environment while the quadrotor is exploring the area. Our technology was tested with experts from the Zurich firefighters on their training facilities and showcased at a variety of trade fairs, including CeBIT and AUTOMATICA.

Foldable quadrotor (Laboratory of Intelligent Systems, EPFL)

- Ease storage and transportation
- Autonomous self-deployment



Aerial robots provide valuable support in several high-risk scenarios thanks to their capability to quickly fly to locations dangerous or even inaccessible to humans. In order to fully benefit from these features, aerial robots should be easy to transport and rapid to deploy. With this aim, we have developed a novel pocket sized quadrotor with foldable arms. The quadrotor can be packaged for transportation by folding its arms around the main frame. Before flight, the quadrotor's arms self-deploy in 0.3 seconds thanks to the torque generated by the propellers. Next versions will embark HD and thermal cameras for video streaming and detection of heat sources.

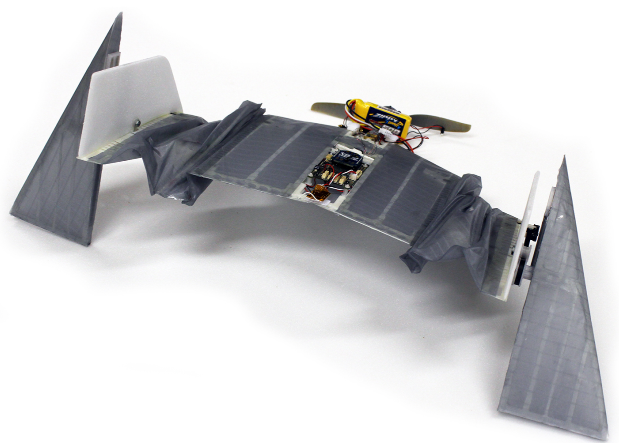
GimBall (Laboratory of Intelligent Systems, EPFL)

- Exploring very cluttered environments
- Providing video signal to rescuers

Flying robots that can locomote efficiently in GPS-denied cluttered environments have a strong impact in search and rescue scenarios. However, dealing with the high amount of obstacles inherent to such environments is a major challenge for flying vehicles. Conventional flying platforms cannot afford to collide with obstacles, as the disturbance from the impact may provoke a crash to the ground. In the GimBall, a spherical protective cage is decoupled from the inner frame by a gimbal system which allows a new type of resilient flying robots to collide with obstacles while remaining stable. Additionally thanks to its spherical shape the GimBall can roll on walls and ceiling to find its way or floor to save energy.

Multi-modal flying and walking robot (Laboratory of Intelligent Systems, EPFL)

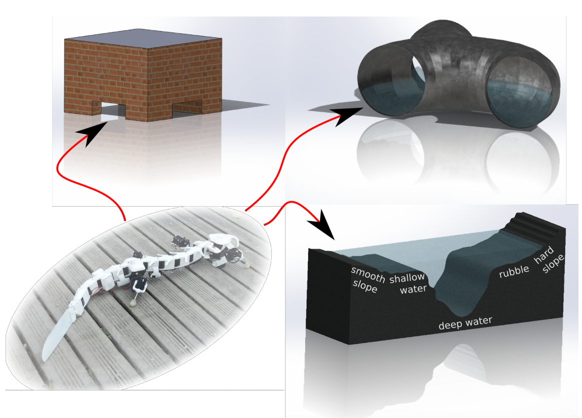
- Forward flight for covering long distances and ground locomotion for local exploration
- Integrated design approach for weight minimization
- Adaptive morphology for optimized performances



With the aim to extend the versatility and adaptability of robots in complex environments, a novel multi-modal flying and walking robot has been designed. The robot consists of a flying wing with adaptive morphology that can perform both long distance flight and walking in cluttered environments for local exploration. The robot's design is inspired by the common vampire bat Desmodus rotundus, which can perform aerial and terrestrial locomotion with limited trade-offs. Wings' adaptive morphology allows the robot to modify the shape of its body in order to increase its efficiency during terrestrial locomotion. Furthermore, aerial and terrestrial capabilities are powered by a single locomotor apparatus; therefore it reduces the total complexity and weight of this multi-modal robot.

Ground:
which type of platforms/technology we have? (names, labs involved, descriptive characteristics)
what real capabilities have been proved (hopefully in the field) with these robots?

Amphibious:



We focus our efforts in a novel niche for amphibious robots.

Amphibot (Biorobotics Lab., EPFL):
- Fully waterproofed.
- Radio controlled (current versions equipped with sensors and GPS).

- Approximately 15 minutes of swimming autonomy.

Amphibot is a robot inspired by Lampreys in form and locomotion. It can swimm on the surface of water and also perform some underwater operations (in new versions). It is equipped with sensors for pollution detection and a GPS. Their autonomy and range may vary according to the task performed. Its slender shape makes this robot a very versatile tool for access underwater debris and collapsed submerged structures.

Salamander-Like robots (Biorobotics Lab., EPFL):

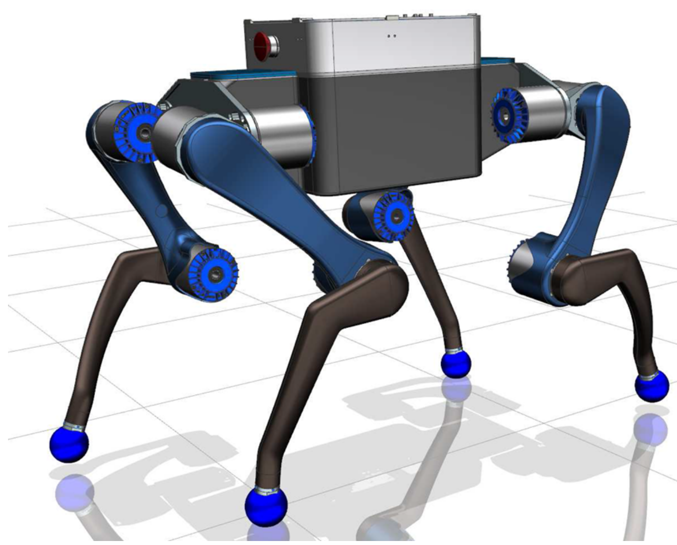
- Partially waterproofed.
- Controlled using a tether for increasing reliability.
- Multi-modal (walking/swimming) gaits.
- Motor skills for obstacle avoidance/overpass (leg reflexes, posture control)

The salamander robots add extra locomotion and control capabilities to Amphibot, provided a set of limbs. The salamander robots can swim, walk and perform transitions between aquatic and terrestrial media. An interesting niche of work for these robots in disaster scenarios are the shallow waters, which present difficult access for other type of robots. By using a tether, better information gathering and control can be provided to the users, while keeping its autonomy high. Some semi-autonomous capabilities to avoid or tackle obstacles are being proved to increase the locomotion output of this robotic platforms. New versions attempt to be fully waterproofed and compliant for better adaptation to the exigent disaster scenarios.

Mammal/Dog

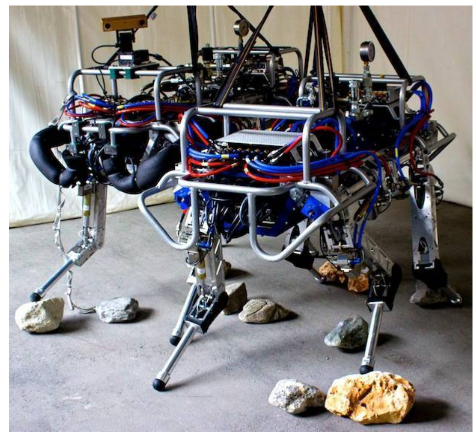
StarlETH and Anymal (ETH, ASL)

- Autonomous, laser and camera based navigation in rough terrain
- Ruggedized design with about 2 hours autonomous operation



Anymal, our quadrupedal robot and ruggedized successor of StarlETH, is built for autonomous ground operation in challenging environments. It is designed to reach a large mobility for overcoming substantial obstacles, yet it is kept compact and lightweight such that it can be handled by a single operator. Equipped with multiple cameras, laser sensors, and an optional pan-tilt-zoom and thermal camera head, the machine can autonomously navigate and deliver useful information about the environment or potential victims. The robot is equipped with three onboard PCs, a wireless access point, and a long distance remote control unit that ensures reliable operation in search and rescue missions. The users can give high level input such as waypoints in an online created 3D map, while path optimization, foothold selection and locomotion control is autonomously executed by the robot.

Hydraulic Quadruped (ETH, ADRL)
HyQ is a fully torque-controlled Hydraulically actuated Quadruped robot (1.0m x 0.5m x 0.98m), designed to move over rough terrain and perform highly dynamic tasks such as jumping and running with different gaits (up to 3-4m/s). To achieve the required high joint speeds and torques, hydraulic actuators are powering the robot's 12 active joints.



Capabilities :

- Walk, trot and run up to 2m/s
- Rear and jump up to 0.5m from squat
- Animal-like step reflex
- Torque and position-controlled joints
- Indoor and outdoor operation
- Real-time control system with dynamics simulator

Inter - robot - human coordination and collaboration ?

Wrapping up with capabilities of inter-robot collaboration:

Air-ground collaboration (Robotics and Perception Group, UZH):

- Flying robot explores area and detects obstacles for ground robot
- Fastest mission includes removal of obstacles by ground robot
- Flying robot guides ground robot step by step

We face a scenario where a ground robot must deliver an emergency kit to a victim, which is too heavy for a flying robot. To find the victim and spot obstacles on the way, the flying robot can exploit its bird's-eye view. A mission plan is computed that includes the removal of small obstacle. Then, the flying robot guides to ground robot to the victim and monitors the mission. All steps are executed without any human intervention. This demo was showcased at the AUTOMATICA trade fair in Munich and won the KUKA Innovation Award 2014.