The Robot's Net

- Cable-based robot inspired by spiders' webs
- Positioning at ten times Earth's acceleration
- dSPACE prototyping system provides powerful control

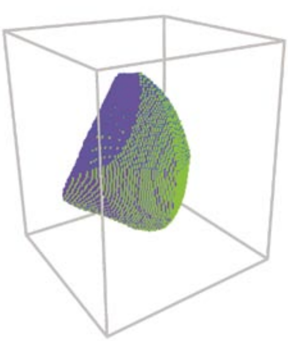
Engineers and mathematicians in the Mechatronics department at the University of Duisburg-Essen in Germany have for some years now been working on a new, innovative type of robot. With inspiration from spiders' webs and the enormous load-bearing capacity of modern high-tech cables, future robots will use cables to get things moving in numerous application areas. A dSPACE system based on a DS1005 PPC Board provides powerful, reliable control.

In many industrial applications, a robot's payload is all but negligible in comparison with its own mass. This means that when the payload is transported, by far the greatest proportion of energy is needed for accelerating the robot itself. High energy consumption and low acceleration power are the result.

▲ *Working on the prototype: The mechanical structure is simple, the control system complex.*

Ten Times the Earth's Gravitational Acceleration

Our team of researchers at the University of Duisburg-Essen is working on a new kind of robot that will avoid this disadvantage. The idea is to use cables to move and position a payload such as a platform with a gripper. The lengths of the cables determine the position of the platform. To change each cable length quickly, the cables are wound on winches that are each driven directly. Because the cable winches are mounted in fixed positions on a supporting framework, only the inertia of the platform with payload and the moment of inertia of the cable winches have to be overcome. The cables themselves have a negligibly low mass, and being made of modern, high-tech fiber, also enormous tensile strength. The prototype, SEGESTA, reveals the potential of cable-based parallel robots, as they are called. SEGESTA reaches accelerations up to ten times that of the Earth, and speeds of up to 10 m/s. Thus, even as only a prototype, the system already exceeds that of most off-the-shelf industrial robots.



▲ *SEGESTA's usable workspace as determined by simulation.*

Motor Winches Take the Load

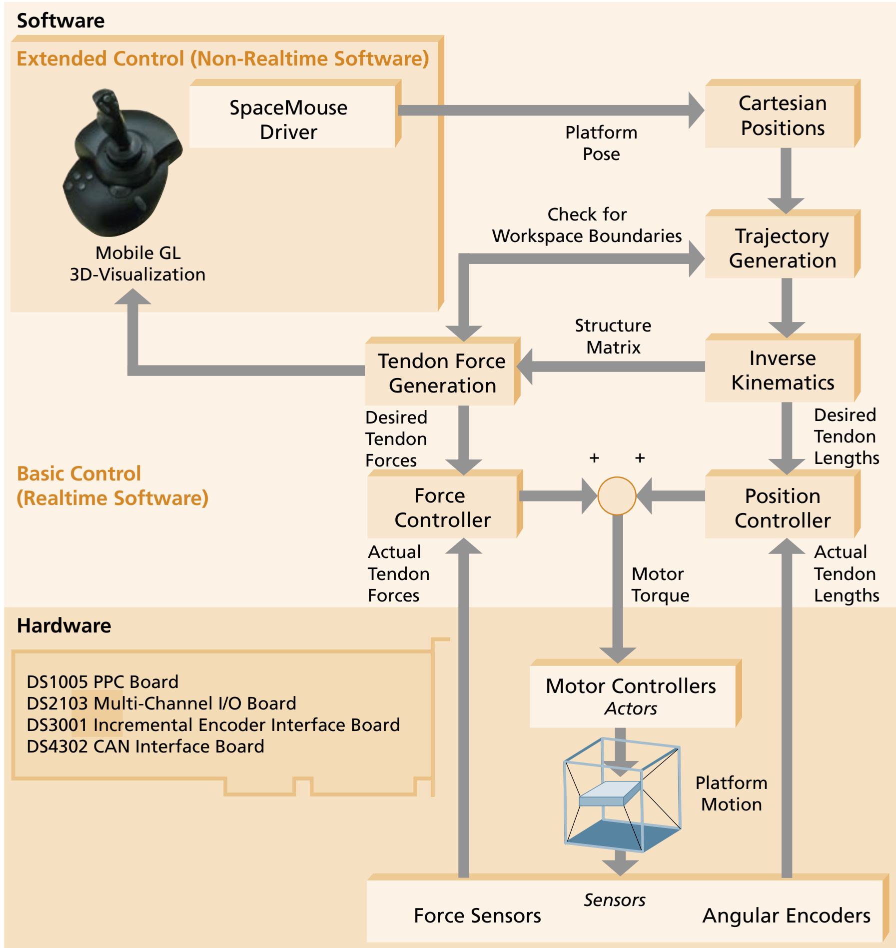
One interesting point is that because the platform has six degrees of freedom (translation, rotation), it has to be held by at least seven cables to fix its position in space. This is because cables can only pull, but not push. The parallel structure produces relatively complex workspaces for the cable-based systems being studied. The forces that arise can be distributed across any required number of motor winches, so the machine can transport very heavy loads, like the ones handled by cranes, at comparatively high accelerations and speeds. If heavier payloads have to be carried, extra winches can simply be added to increase safety and the maximum bearing capacity. The conceivable magnitudes can vary from very large, heavy-load robots right down to the micro range.

Reliable Control System with dSPACE

We have very tough requirements regarding the control system, since the achievable speeds necessitate a high controller frequency of at least 1 kHz. Moreover, a powerful processor is needed to calculate the cable lengths and cable forces. Thus, we were looking for a control system with industrial reliability for our test setup, and we chose a dSPACE system. We put together a powerful control system based on a DS1005 PPC Board supplemented by numerous I/O boards (DS2103 Multi-Channel D/A Board, DS3001 Incremental Encoder Interface Boards, DS4302 CAN Interface Board), which can also be conveniently programmed via MATLAB®/Simulink®. The system is also ideal for giving students an insight into a modern control system.

The control system has the following structure:

- The system interpolates the position and speed along the desired trajectory to provide the reference variables.
- The inverse kinematics compute the cable lengths and speeds to fit the desired position and speed.
- The actual lengths of the cables (and the actual speed, using numeric differentiation) are determined via the I/O of the dSPACE system.
- A PD controller calculates the reference currents and sends them to the prototype's digital motor controller.



▲ *The control schema for force and positioning control on the SEGESTA test bench.*

In manual mode, the test setup benefits greatly from the flexible integration of Windows® input devices via ControlDesk's experiment environment.

The Silken Thread in Practice

The possible application areas of cable-based parallel robots are many and varied. Any kind of application requiring a large workspace is conceivable, for example, transportation in large factories or storehouses, and also applications that would benefit from high speeds, such as industrial handling and pick-and-place. The system could also conceivably run in direct contact with people, for example, as a fairground ride, or giving valuable support in the sphere of medical rehabilitation technology. In the latter field particularly, we are hoping to cooperate with other German and European partners to develop an orthopedic aid that uses the "silken thread" to help patients practice walking movements, for example, after accidents or operations. The cables would be attached to a corset worn by the patient, either with a small degree of slack to provide extra safety, or pulled taut to hold the patient's entire weight. The idea is that because the mechanism is so inconspicuous, the patient would not have the feeling of being hooked up to a machine. The cables are simply there to give support.

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Glossary

Cartesian positions – Positions expressed in terms of height, width, and depth.

Inverse kinematics – Compute the rope lengths from the position of the platform.

Parallel systems – A group of robots.

Workspace – The area in which the robot can move (translation in all 3 spatial directions, rotation around all three axes).