Intelligent Technical Systems

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My research field

Active methods and systems for:

- Mechanical vibration damping and stabilization
  - – magnetic bearings,
  - – piezoelectrics
- Motion control
  - – navigation of aircraft, unmaned arial vehicles,
  - – navigation of mobile robots,
  - – autonomous systems
- Intelligent Technical Systems

Short history of machine design

- Simple hand machines
- Machines powered by water, wind, stream engines
- Machines with gas, electric drives
- Automation of machines
- Mechatronics structures
- Intelligent technical systems

MOBILE ROBOTS –present

Flying, walking, swimming, driving robots with autonomy features.
Many different structures.

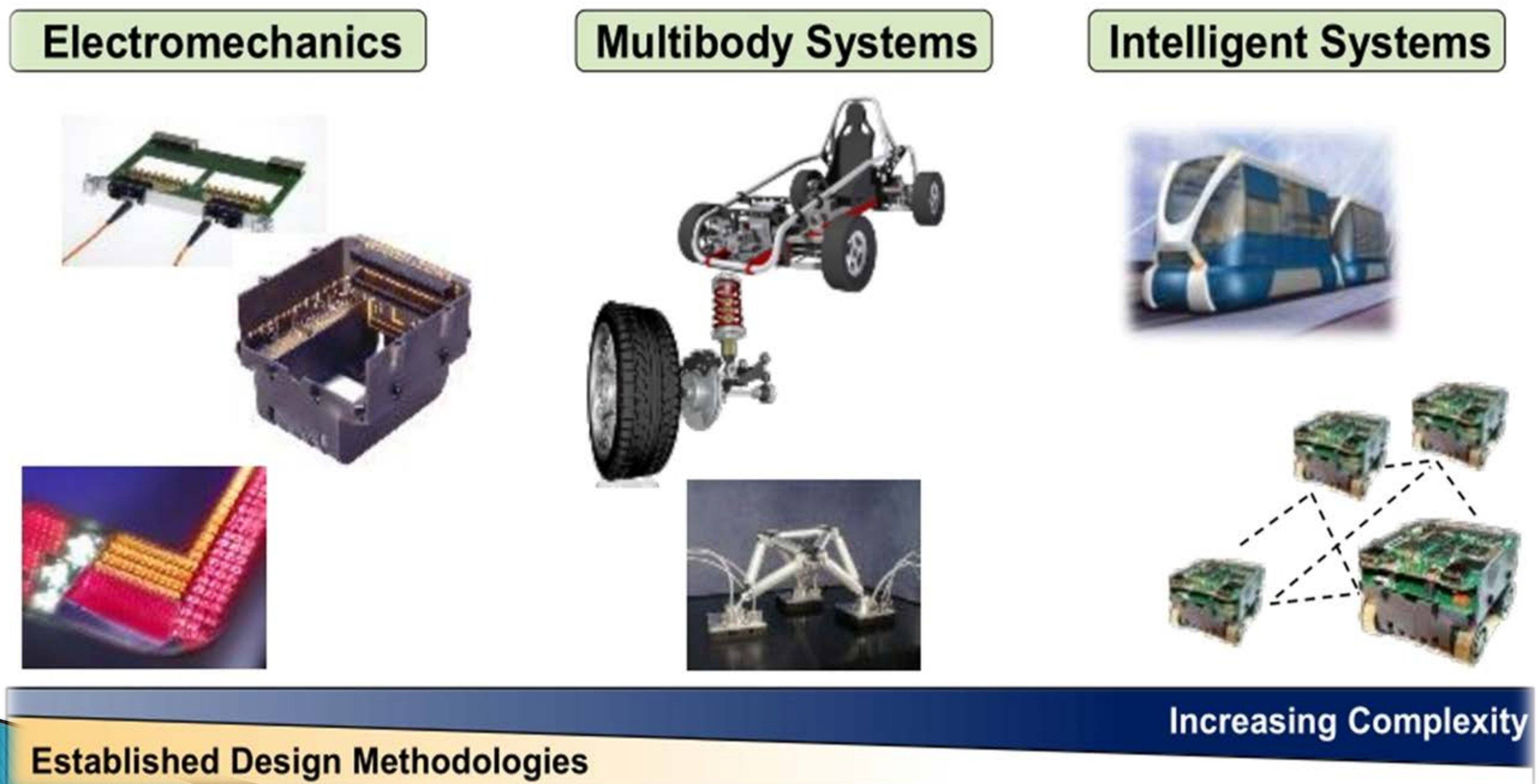
Machine„Intelligence”

- Mechatronics – synergy of mechanics, new materials, electronics, control loops, and informatics.
- Dispersion of structure– computer net, many local drivers – leads to the system.
- **Self-optimization** of the system to be:

- more flexible to new unpredicted tasks,
- robust to the internal and external disturbances,
- more friendly to the users.

VDI-guideline 2206 „Design methodology for mechatronic systems”, 2004

Present stages of machine developmens acc. Fraunhofer Institute/University of Paderborn



Consortium „Intelligent Technical Systems"

Machine autonomy and intelligence

Autonomy means the operators relegate of some decisions to the machines, directly. **Intelligent** machines can:

-share knowedge,

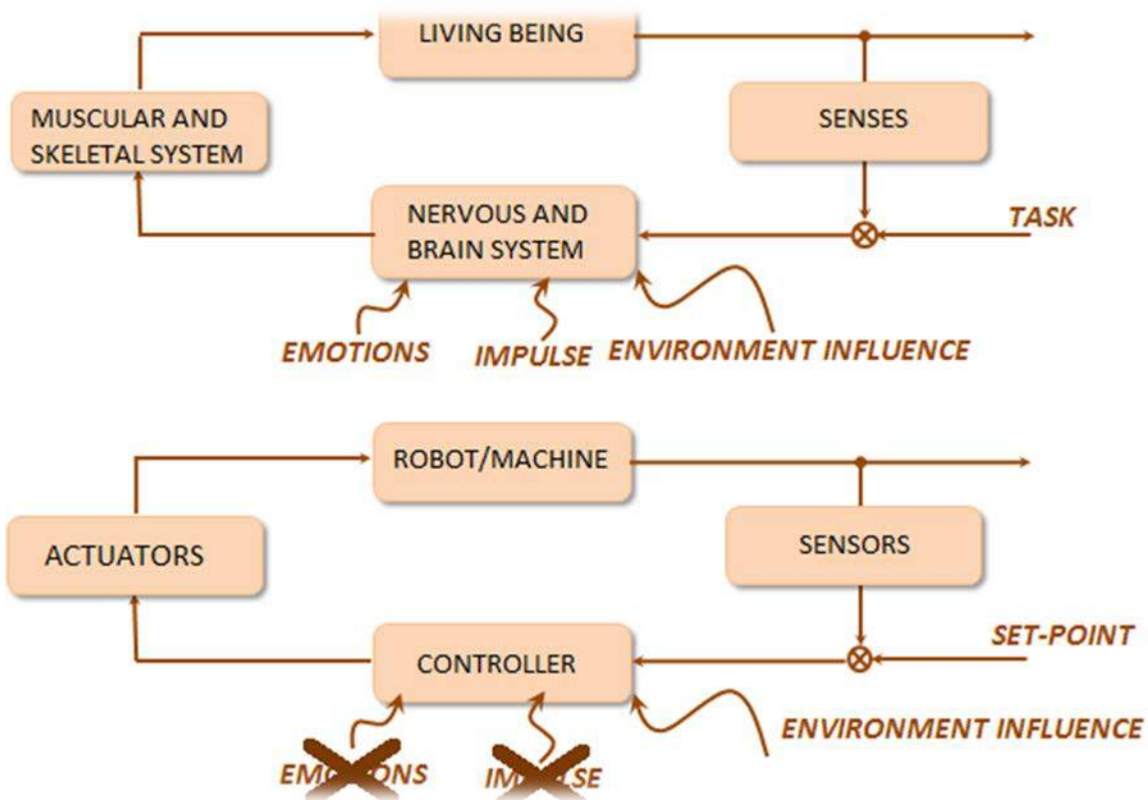
-coordinate behaviour,

-learn from experience

In case of mobile robots they, for example, can:

- Realise motion in w new unknown envirement with recognition of the objects,
- choose aims,
- Collaborate with other mobile robots - agents,
- Communicate with persons and machines by natural means (vision, acoustics, artificial speach in different languages, haptics) besides radio, phone, and video communications.

Living things as a pattern for „intelligent” machines



Man as a worker

- Can be tired (physically, physiologically, psychologically), must rest and sleep,
- Reacts to stimuli with delay
- Can not work in harmful and dengerous environment (atmospheric, chemical, radiatiation)
- Susceptible to surrounding influences (society, habits, emotions, localisation changes)
- And so on.

Man as an „intelligent” worker

Cognitive functions

observation,
recognition,
encoding,
registration,
memorization,
thinking,
problems solving,
motorics control,
language using.

MACHINES–Drives/Actuators

In modern machines is necessary to take advantage of abilities of modern and future mechanics, automatics, information technology and metrology.

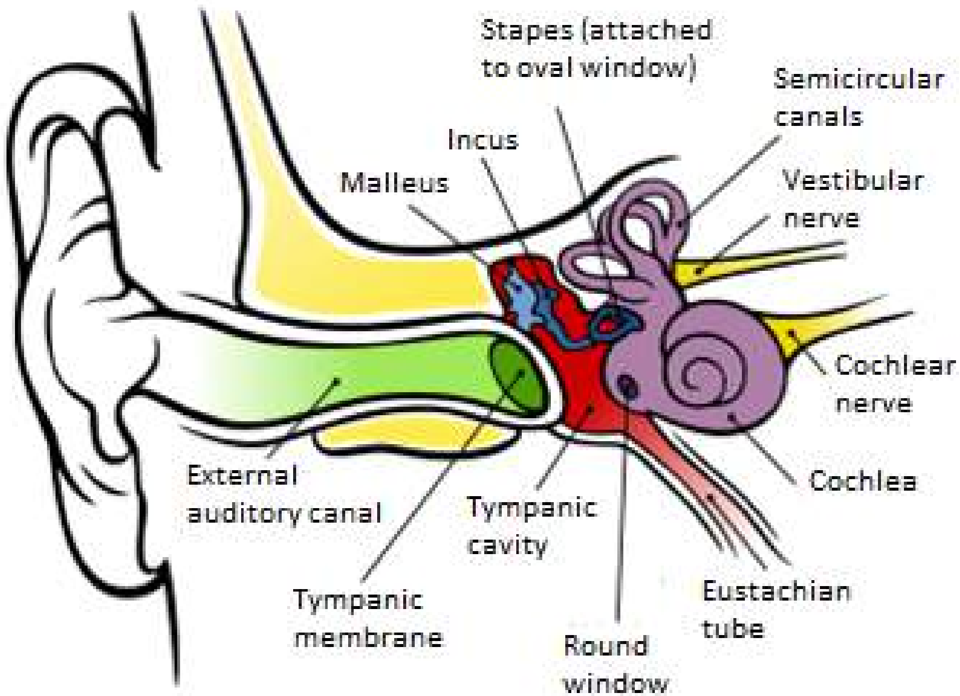
A one of the ways is a replacing main drive and automatics elements with distributed drives and local automatics elements.

The best example are hybrid vehicles with separated drives of the individual wheels and multicopters.

Sensors/measuring elements

- Human senses
- Point sensors
- Array sensors

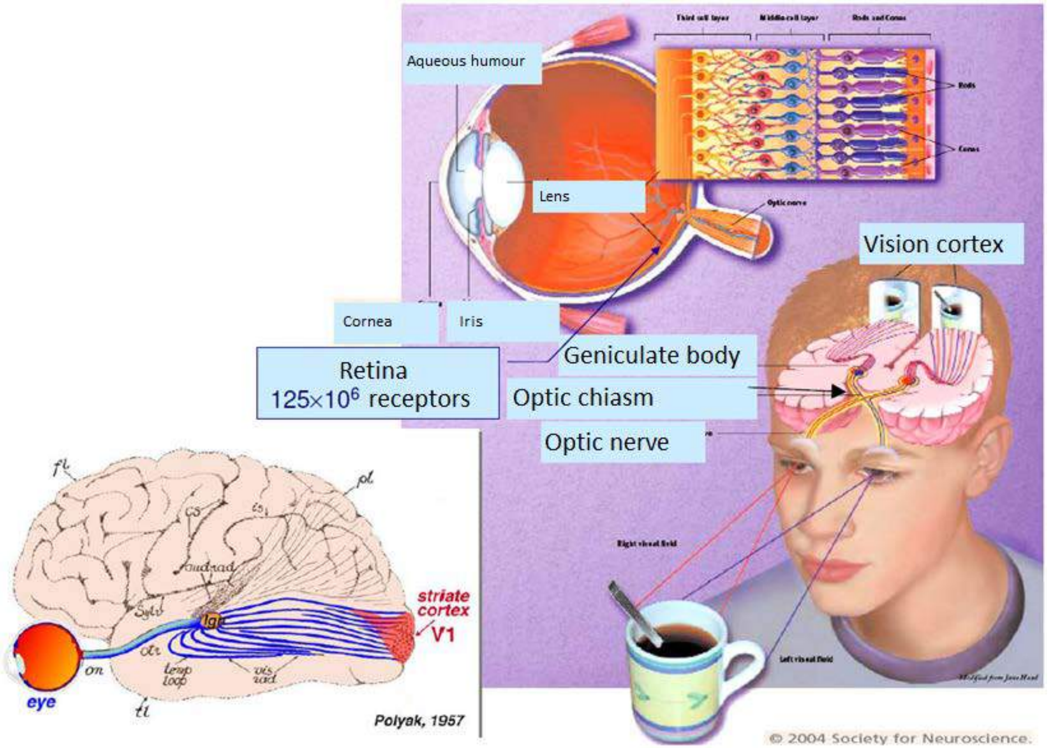
Hearing



Stapes (attached to oval window)
Semicircular canals
Incus
Malleus
Vestibular nerve
Cochlear nerve
Cochlea
External auditory canal
Tympanic cavity
Tympanic membrane
Eustachian tube
Round window

Eyesight

An organ of the sight is an eye, which receives stimulus by the retina based receptors; then they are transferred from eyes by optic nerves to sight responsible cerebral cortex parts.



Differences between ear and eye

1. Ear – point measurement
   - -continuous in time
   - -amplitude-frequency analysis
   - -time-frequency analysis
   - -frequency domain filtration
2. Eye – array measurement
   - - high inertia
   - - shape, distance, movement and colour analysis
   - - stereo vision and mapping
   - - greyscale and colour filtration
   - - 2D and 3D map generation

Decision element

- Brain and central nervous system
- Analog regulators
- Digital regulators – processors
- Controllers
- Computer network – processors cloud

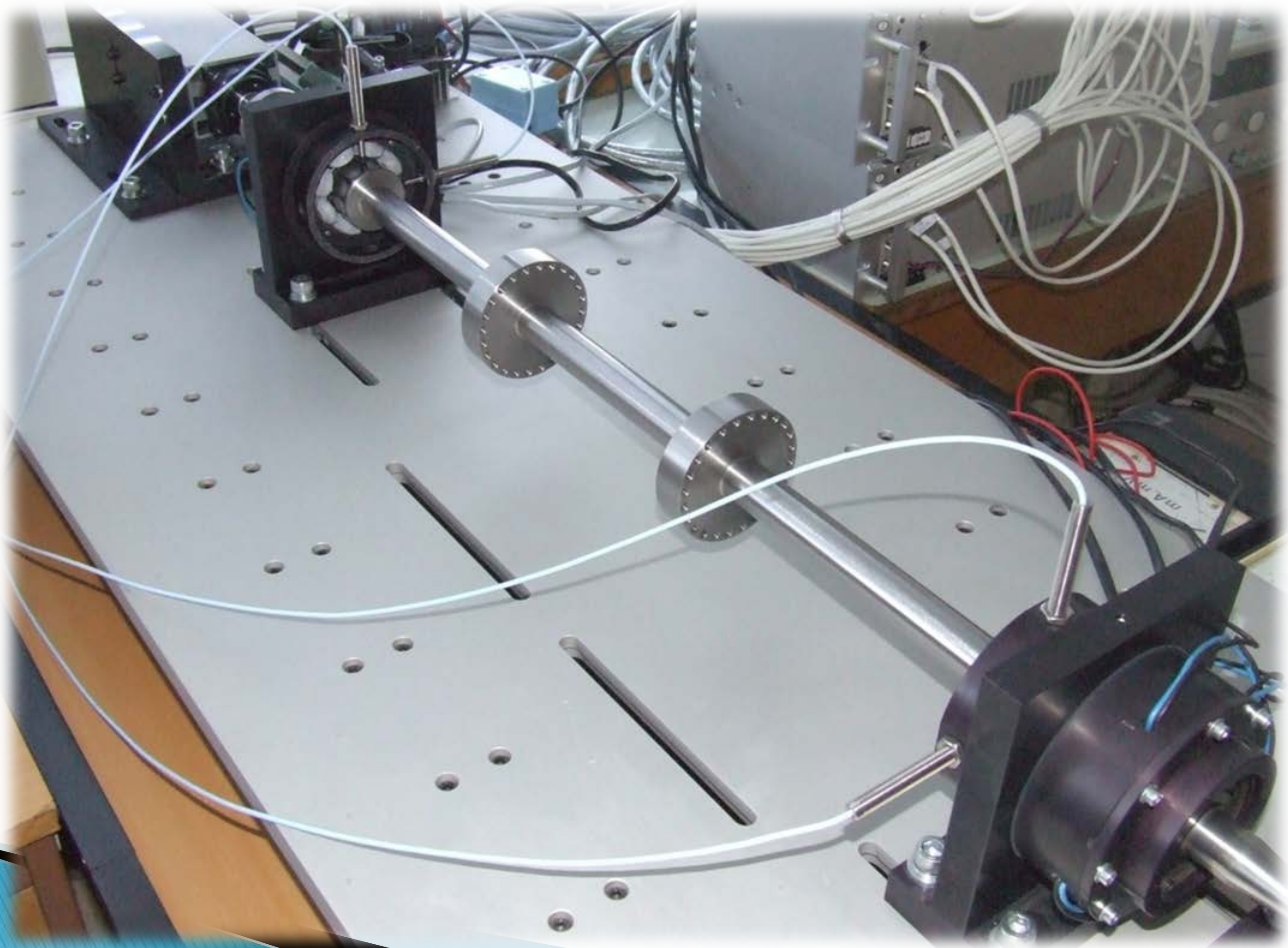
‘Intelligent’ systems examples

- **Rotating machine** with rigid rotor and magnetic bearings. Using of a measurement system for additional functions realization
- Hydraulic steering system redundancy for **attack aircraft** (tilt channel)
- **Unmanned aerial vehicle** navigation system. Vision systems utilization to avoid obstacles, group flights, landing with high angle of attack
- Autonomous **car** parking on the verge or pavement
- Cooperation of **unmanned aerial vehicle** and **unmanned ground vehicle** in moving in the unknown area ("mars rover")
- Communication between machines and between **machines and humans**

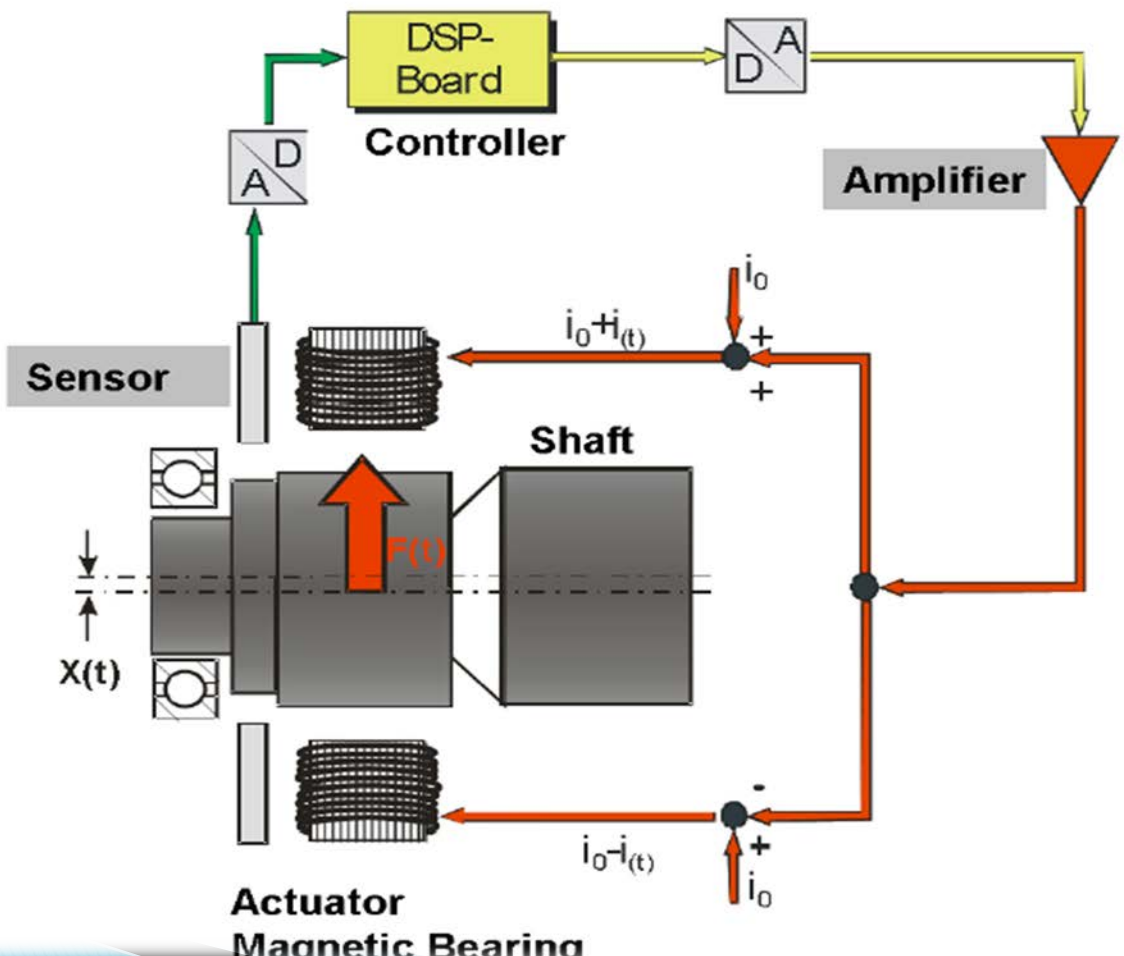
Features of ITS

- Multi-sensors, -actators
- Redundancy
- Reconfiguration
- Hierarchic control
- Computer aidded decisions

Rotor with magnetic bearings



Magnetic bearing - one axis control



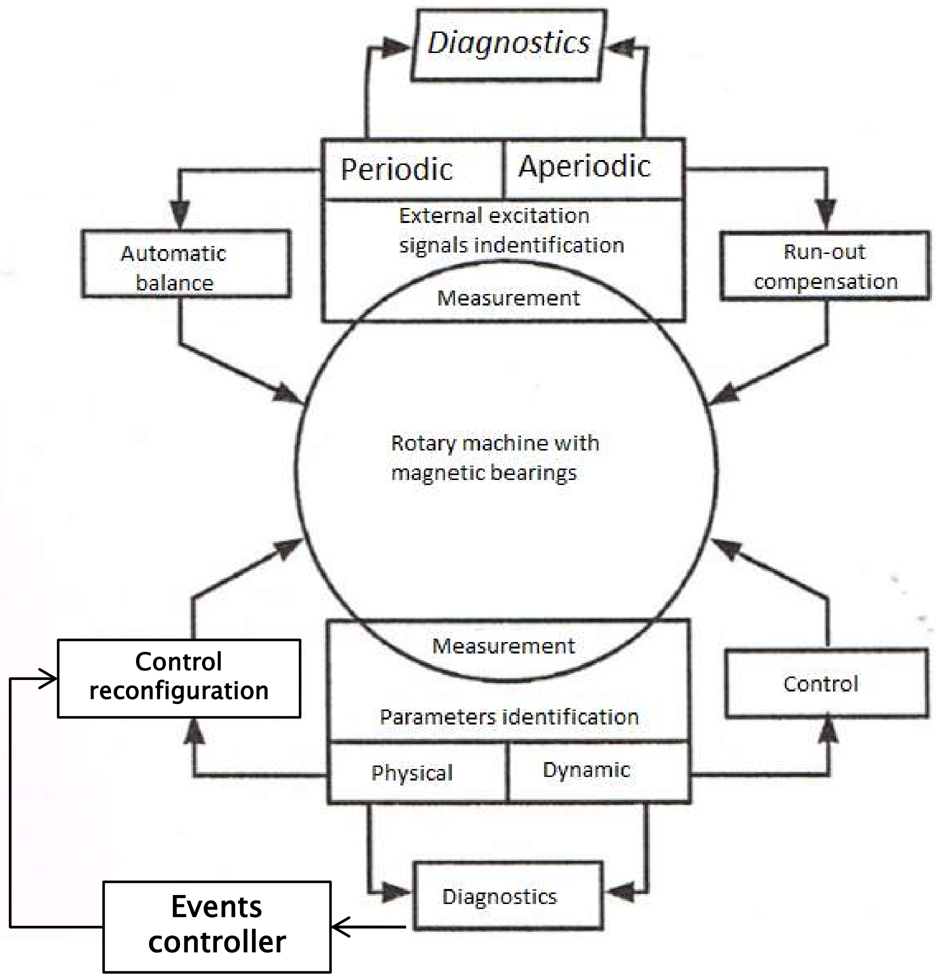
Tasks of ‘inteliigent’ rotating machine

- Stabilization at low and high rotation speeds
- In electrospindle a tool moving along the demand curves
- Counteracting external excitation signals (unbalance, runout)
- Minimization of energy used in bearings
- Rotation machine diagnostics
- Reaction to damages – system reconfiguration

Intelligent magnetic bearings design stages

- System dynamics modeling
- Selection of measure and executive elements
- Physical and dynamic parameters identification
- External excitation signals identification
- Control laws
- Damage diagnostics
- Reconfiguration mechanism

Intelligent magnetic bearings



Unmanned aerial vehicles

- Autopilots for aircrafts and multicopters
- Launchers: coilguns, railguns
- Vision systems for obstacle avoidance
- Group flights
- Landing on the target
- Indoor flights
- Powered-lift aircraft
- Airfields

Features of UAV as a control and navigation object

- Small Reynolds number of flow
- Small time constants
- Model nonlinearity
- Non-minimum phase plant
- Strong environment influence

UAVs






Coilgun

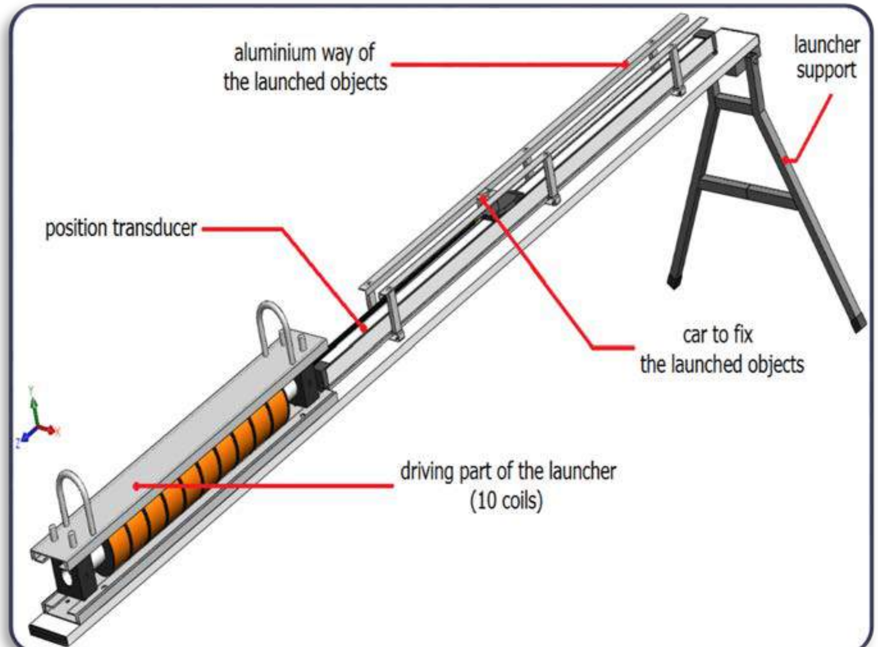
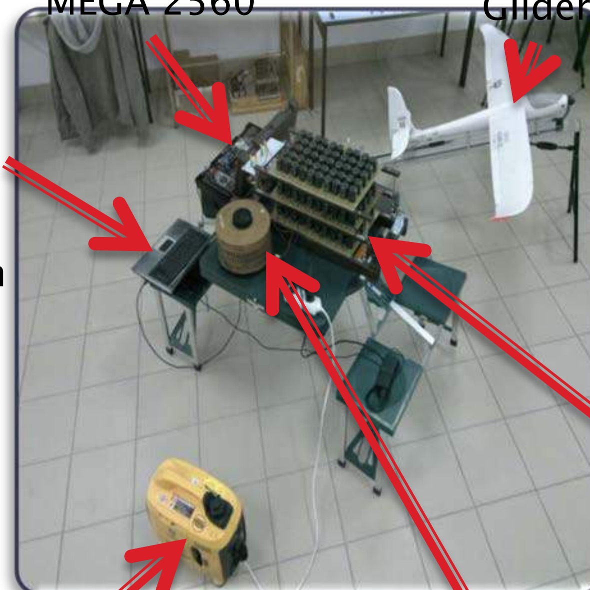
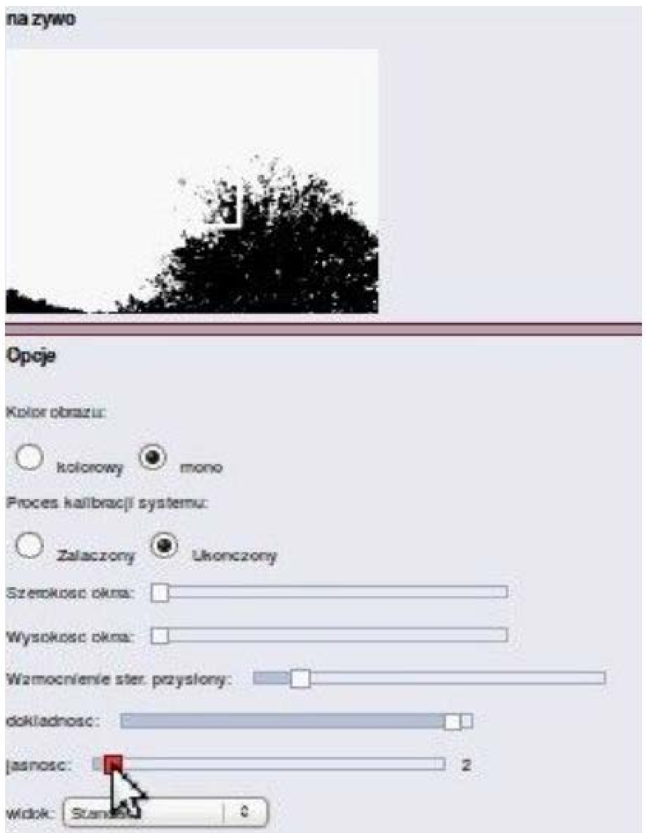


Fig. 1. CAD project of the EML for MAVs of a mass up to 2.5kg



Navigation with obstacle avoidance

In the case of mobile robots an important task is the evaluation of the environment in which robot moves, and reacting to appearing stationary and mobile obstructions.



Skyline detection method

In UAVs, fast reacting is particularly important because in the air there is no verge where UAV can stop. To avoid obstacles we used a vision systems and skyline detection method was precisely analyzed.


a)

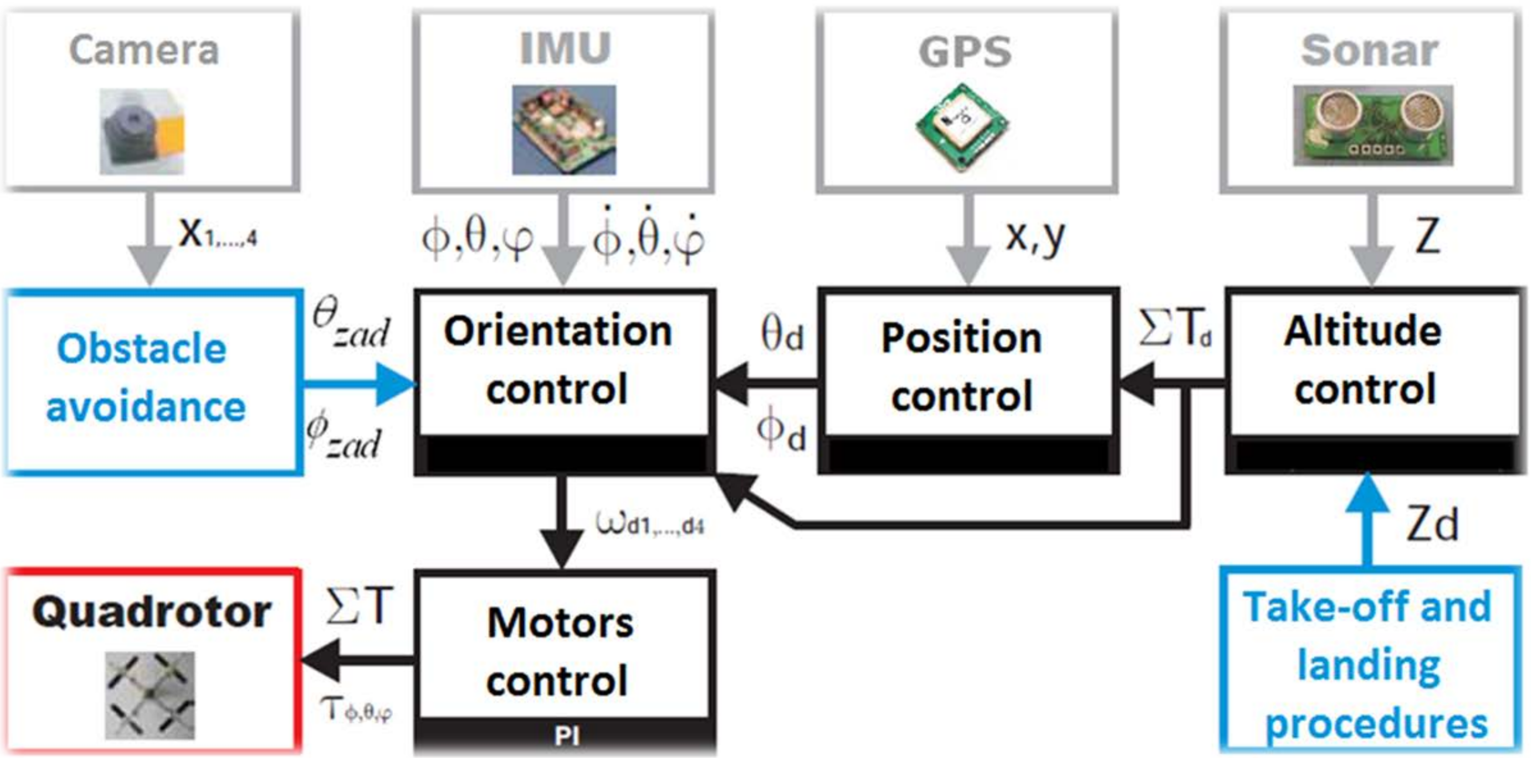

b)


c)

Skyline localization final effect for different UAV orientations

a) landward camera (UAV inclination increase case)
b) forward flight
c) change flight direction example (tilt angle change)

Control system with obstacle avoidance



Obstacle avoidance system tests

UAVs group flying

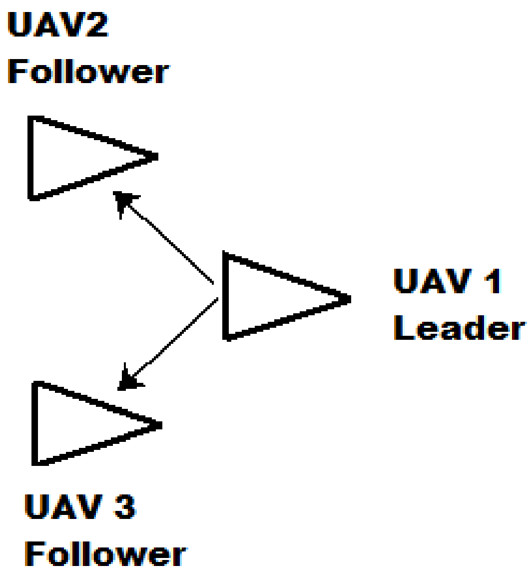
Group flying – an intended movement of one or more flying objects connected by common control law

Formation flying – a special case, emphasis is placed on reaching and keeping the specific formation

Implementation of the concept

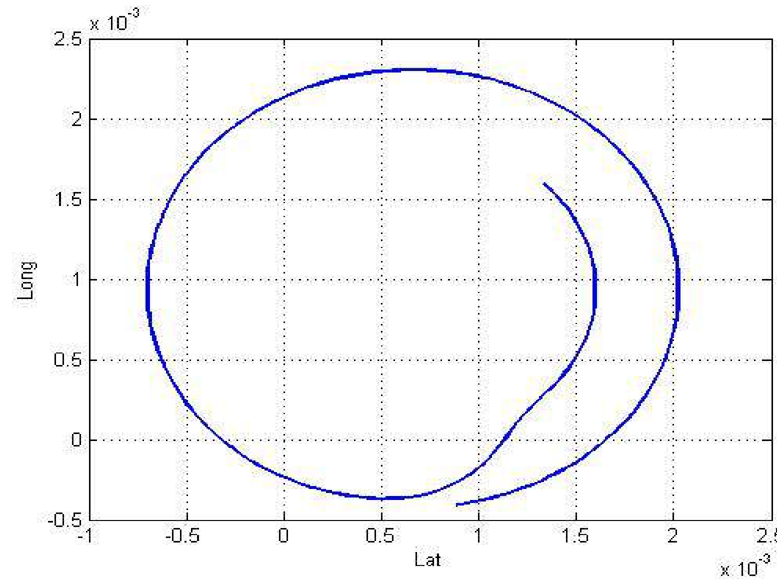
<u>Assumptions:</u>

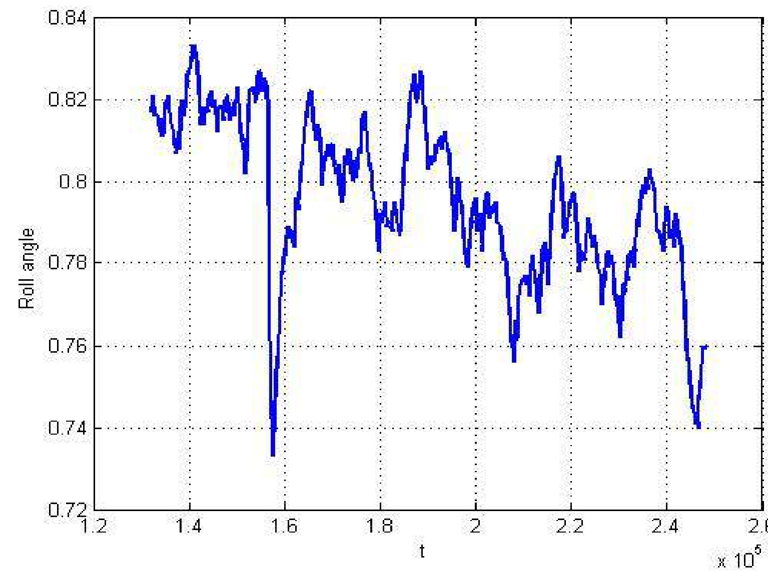
- Leader – Follower structure,
- Decentralized architecture ,
- Two main control loops,



HIL simulations

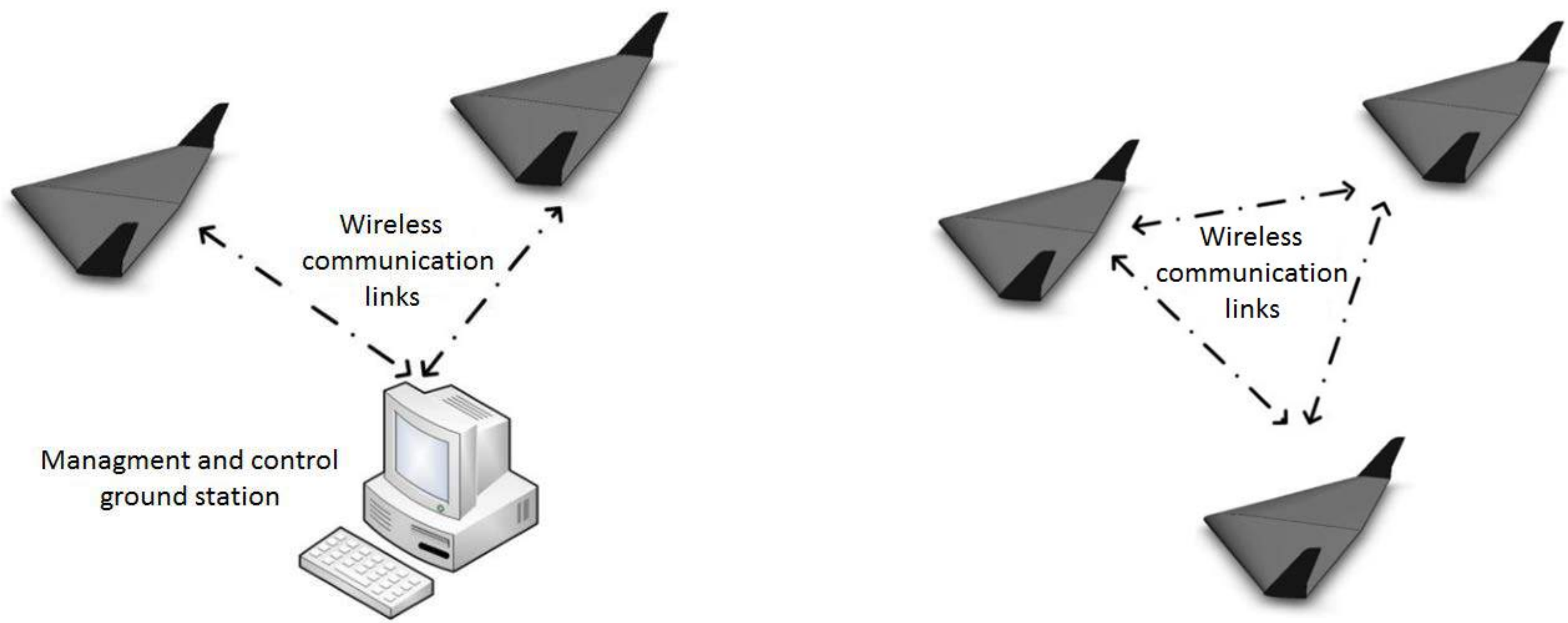
Group flying test stand





Mutual communication- radio

To provide communication between machines and humans, a human speech with environment noise analysis method was used, and for communication between UAVs flying in formation or swarm was used radio and vision systems.

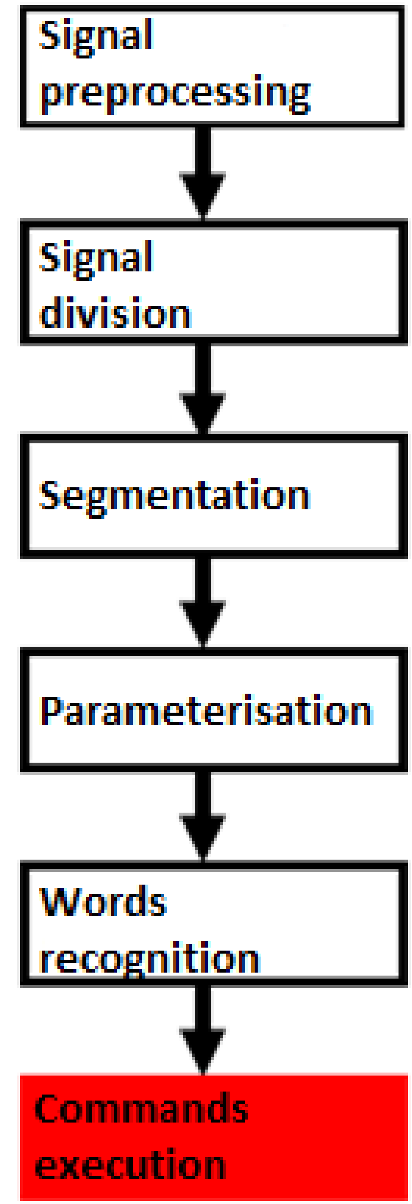


Mutual communication – voice

Command set I (fig.)

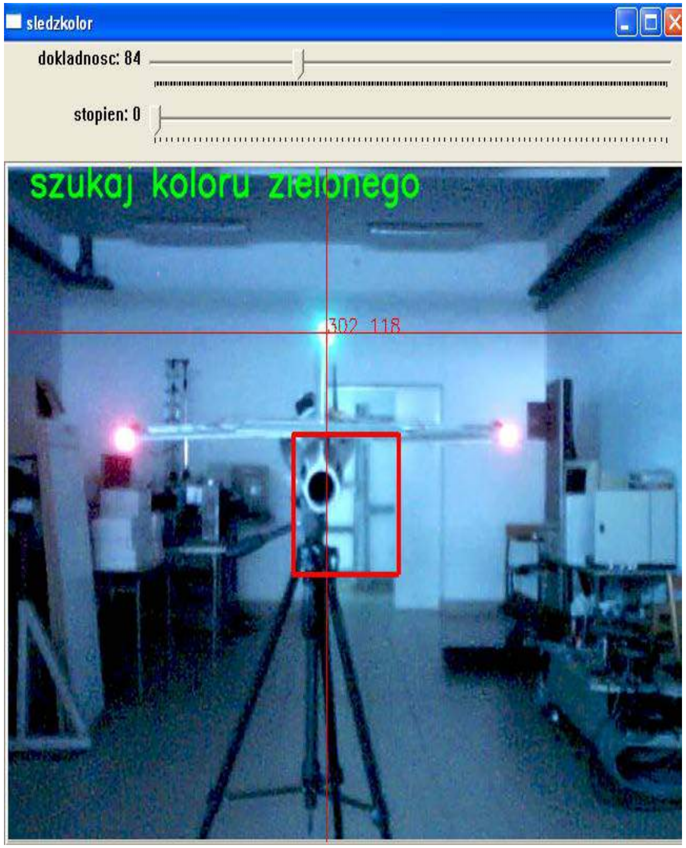
Command set II (months)

Control object



Mutual communication - vision

Laboratory stand

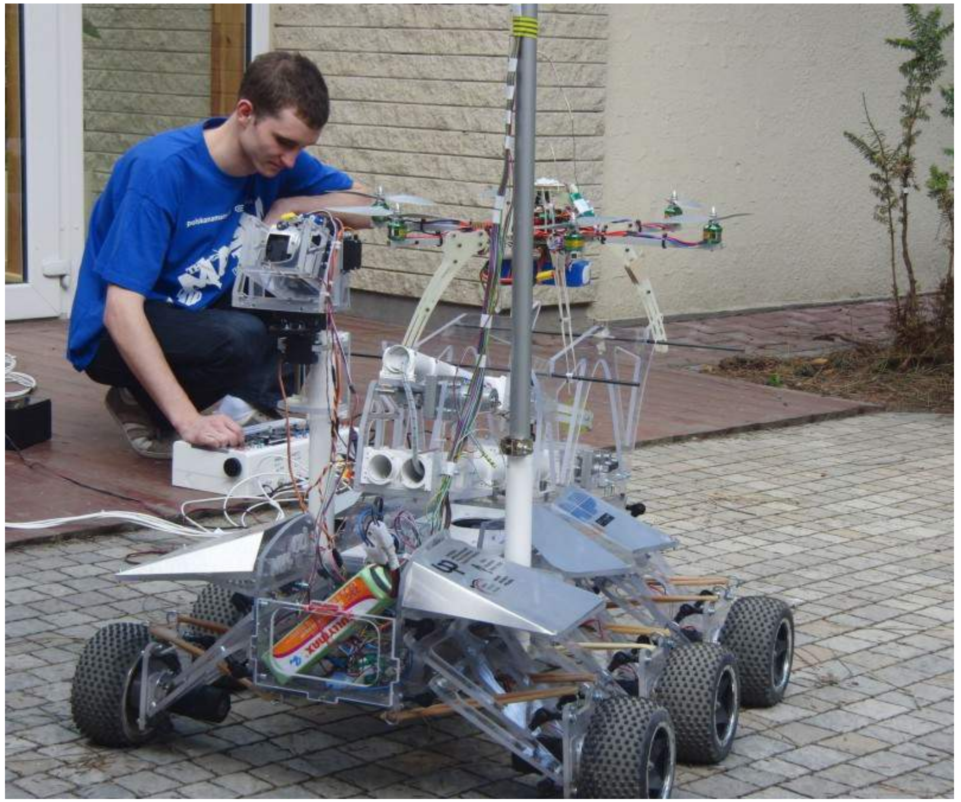


Group flying simulation

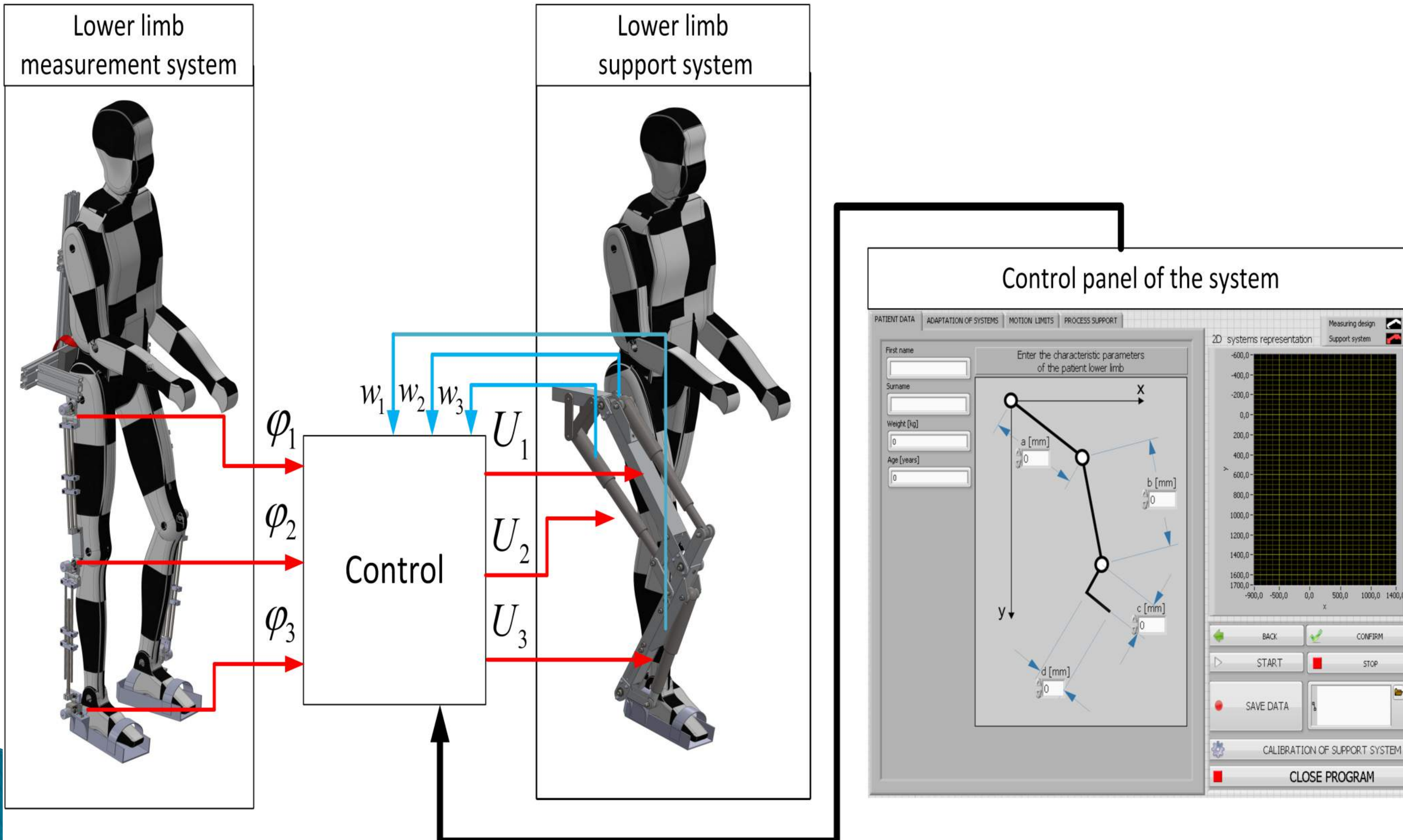
Rover – multicopter

Besides UAV group flights we carry out research on various mobile robots types cooperation abilities. For example, one of students team made use of cooperation between "Martian rover" and multicopter.

This allowed to gain a great advantage over the other competitors and the victory in University Rover Challenge in Utah (USA).

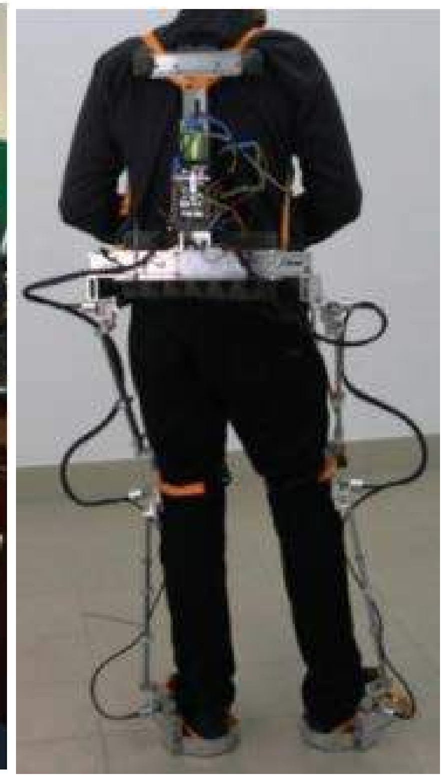


Rehabilitation system

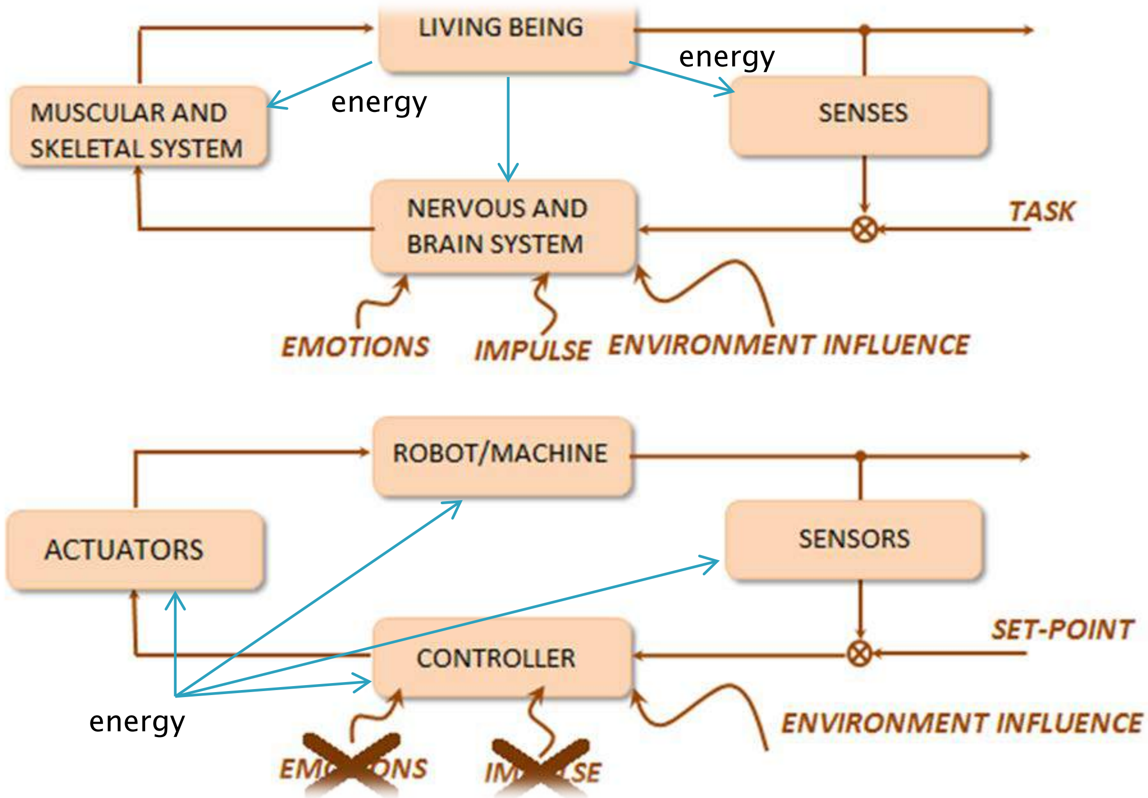


Powered exoskeletons

In the case of legged robot, the so-called exoskeletons are constructed. Their task is to support a human in moving heavy loads or repeating instructor/commander movements in execution various tasks.

Living beings as an example for „intelligent” machines



Conclusions

1. Intelligent technical systems need cooperation of different specialists in common projects
2. Deck equipment is the most important part of mobile robots
3. Drivers redundancy and control systems decentralization
4. Mutual communication between humans and machines

Thank you for your attention

Rehabilitation system