Automatic Control in Agriculture

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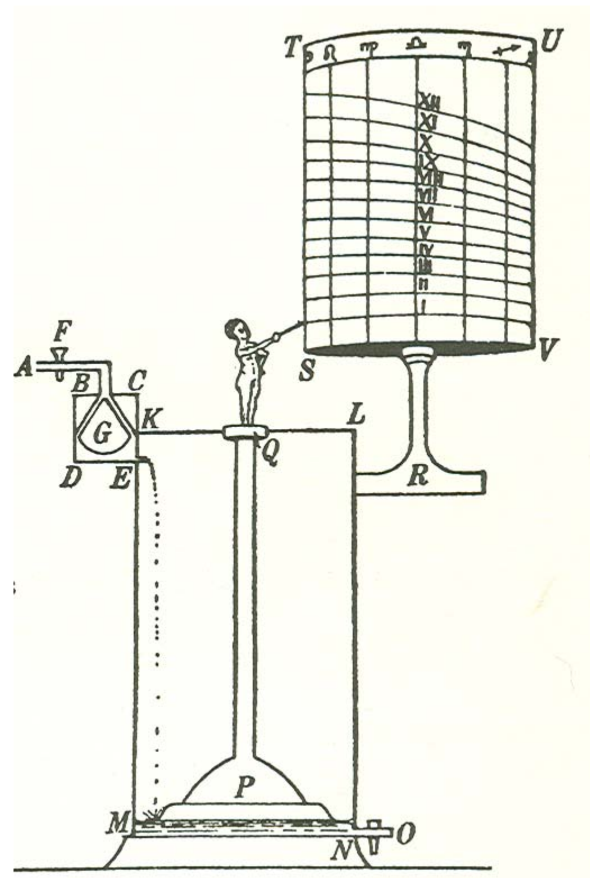
Bologna, 10 November 2012

Feedback Systems

The core of any automatic control system is the idea of feedback, a simple principle governing any regulation process occurring in nature.
Humans have always copied nature in the design of their inventions: feedback is no exception.
The introduction of feedback in the design of man-made automation processes occurred as early as in the golden century of Hellenistic civilization, the third century b.C.
The scholar Ktesibios, who lived in Alexandria circa 240-280 b.C. and whose work has been handed to us only by the later roman architect Vitruvius, is credited for the invention of the first feedback device. He used feedback in the design of a water clock.



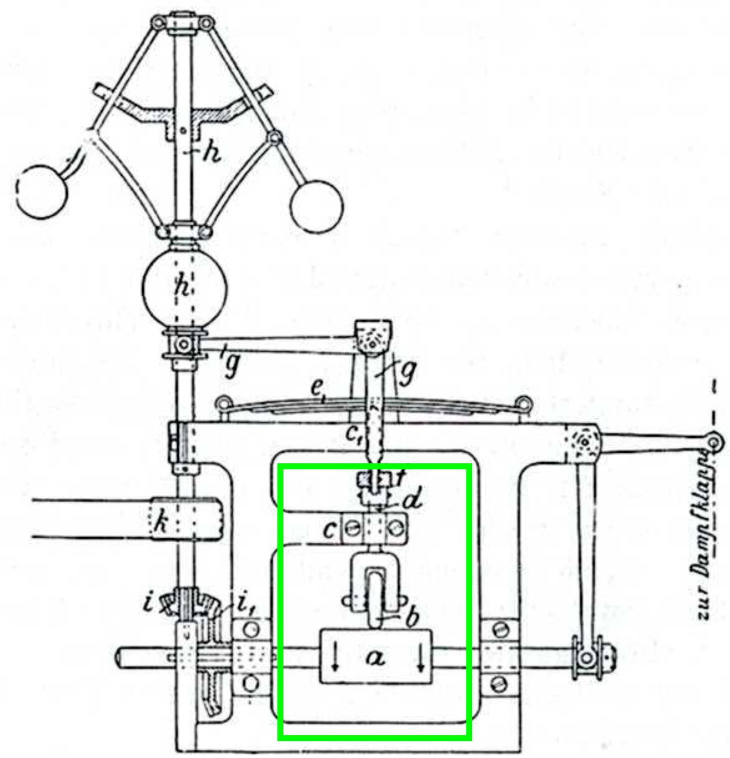
Feedback Systems

The idea of using feedback to moderate the velocity of rotating devices led to the design of the centrifugal governor in the 18th century.

In 1787, T. Mead patented such a device for the regulation of the rotary motion of a wind mill. The same principle was applied two years later, by M. Boulton and J. Watt, to control the steam inlet valve of a steam engine.

Stability of the governor was analyzed by G.C.Maxwell in 1968.

The governor was refined in the late 19th century, with the introduction of integral control to compensate for constant disturbances. W. von Siemens, in the 1880s (a wheel-and-cylinder mechanical integrator).



Feedback Systems

At the beginning of the 20th century, feedback was used in the design of automatic steering systems. In 1922 Nicholas Minorsky introduced PID control in the design of autopilots.

Minorsky's controller was successfully venne experimented on the USS *New Mexico*. However, the device was soon removed because "*the ship crew was strenously opposed to automatic steering*".

In 1947, the first fully unmanned flight of a C-53 over the Atlantic, including takeoff and landing.

280 AUTOMATICALLY STEERED BODIES.

DIRECTIONAL STABILITY OF AUTOMATICALLY STEERED BODIES.

By N. Minorsky.

I. INTRODUCTION.

The problem of directional stability of automatically steered ships is gradually becoming of increasingly greater importance for various reasons.

The possibility of obtaining more accurate steering by automatic means than can be accomplished by manual control with its inherent limitations due to the low sensitiveness of the human eye in detecting slow angular motions, fatigue, etc., becomes of greater importance with the increase in size of ships and cost of fuel.

For merchant ships an accurate and reliable automatic steering device becomes a real money saving proposition, largely justifying its use.

On battleships, by its use the absence or reduction of yawing in action means a better efficiency in gunfire, increased maneuvering speed and also a greater cruising radius.

In the case of airships, especially for long distance trips, directional stability is also of importance because the behavior of direction indicating instruments is then more satisfactory which leads to a still better stabilization, so that the certainty and safety of aeronavigation is thereby increased to an additionally greater degree.

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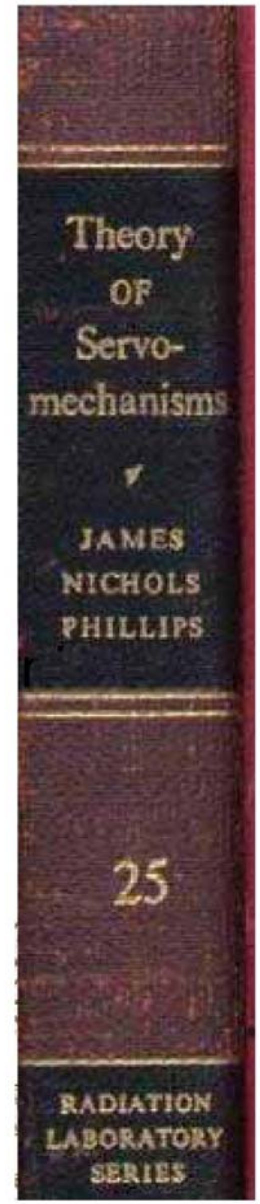
A new discipline emerged …

IFAC

The perception that feedback control and, in a wider domain, automation were taking the shape of an autonomous discipline, occurred right after the second world war, where the application to radar and artillery had a dramatic impact.
By the early 1950s, the principles of this newborn discipline quickly became a core ingredient of most industrial engineering curricula, professional and academic societies were established, textbooks and handbooks become available.
At the beginning of the 1960's, two new driving forces provoked an enormous leap ahead: the rush to the space and the advent of digital computers in the implementation of control systems.



An International Federation

The late 1950's saw the birth of an International Federation of Automatic Control (IFAC), as a multinational federation of scientific and/or engineering societies each of which represents, it its own nation, values and interests of scientists and professionals active in the field of automation and in related scientific disciplines.

The purpose of such Federation, established in Heidelberg in 1956, is to facilitate growth and dissemination of knowledge useful to the development of automation and to its application to engineering and science.

Created at a time of acute international tensions, IFAC was a precursor of the spirit of the so-called Helsinki agreements of scientific and technical cooperation between east and west signed in 1973.

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An International Federation

IFAC

It was the first opportunity, after the second world war, that scientists and engineers had of sharing complementary scientific and technological backgrounds, notably the early successes in the space race in the Soviet Union and the advent of electronic computers in the United States.
The first President of IFAC was an engineer from the Unites States, while the first World Congress of the Federation was held in Moscow in 1960.

IFAC

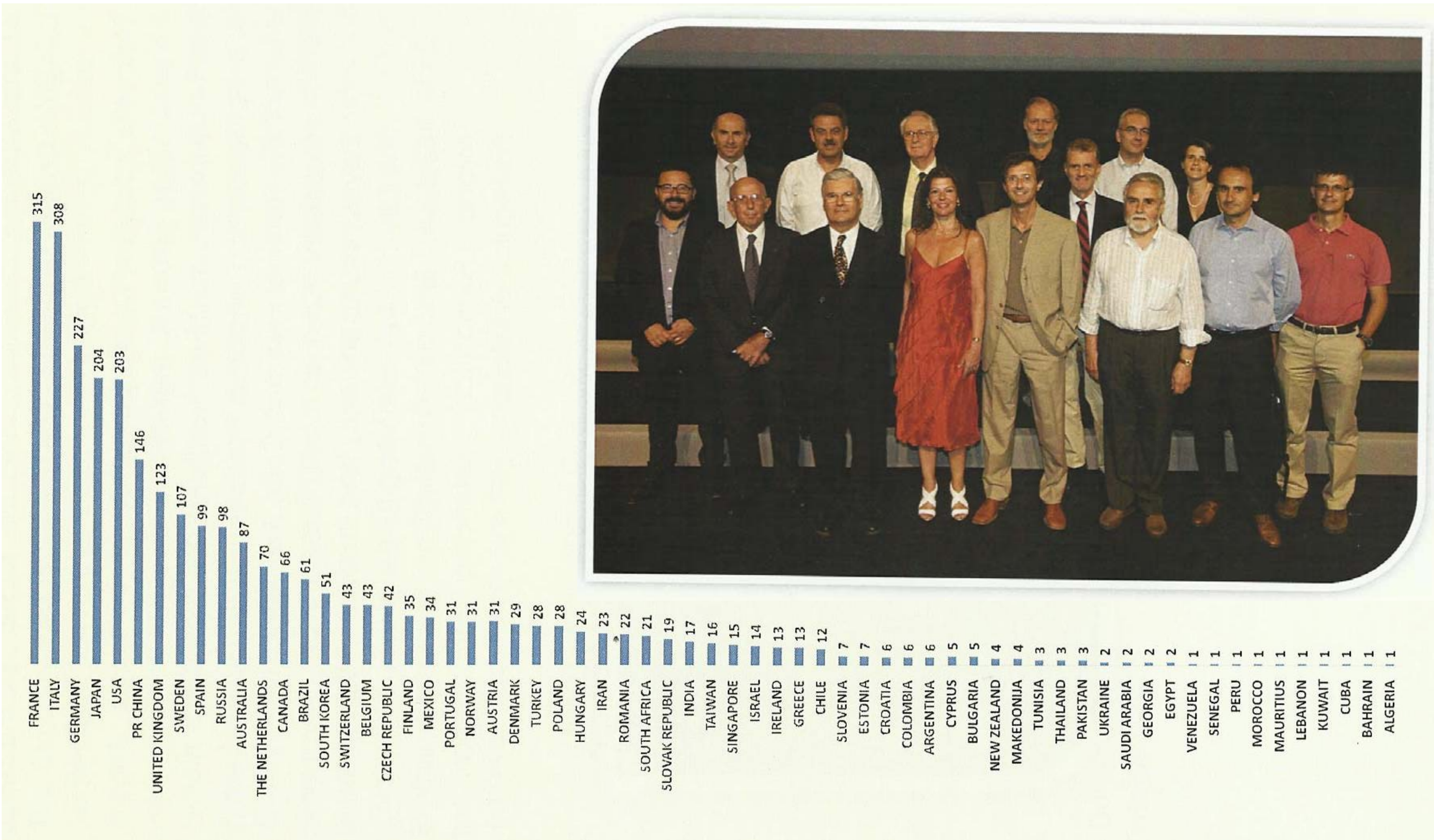
The Federation currently includes 52 national member organizations, runs more than 60 scientific Conferences with a three-year periodicity, including a World Congress of Automatic Control, and publishes some of the leading Journals in the field.

An International Federation

The 18th World Congress of Automatic Control, was held in Milano:
29 August – 2 September 2011, attended by a record-high number of about 2900 delegates

An International Federation

Research in Automatic Control in the worls is in constant growth and the quality of academic researh in Automatic Control in Italy is of a very high level.



IFAC' technical activities

The technical areas covered by IFAC are taken care of by 40 Technical Committees. These are responsible for the planning and monitoring of the technical events, such as symposia, conferences and workshops, with the NMOs acting as hosts. The technical TCs are organized into nine groups (Coordinating Committees)

1. Systems and Signals
2. Design Methods
3. Computers, Cognition and Communication
4. Mechatronics, Robotics and Components
5. Manufacturing and Logistics
6. Process and Power Systems
7. Transportation and Vehicle Systems
8. Bio- and Ecological Systems
9. Social Systems

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The IFAC TC on Agriculture

IFAC

The focus of one of the 40 Technical Committees of IFAC is on Control in Agriculture.

Main current challenges in agriculture:

- *Effects of Population increase*: it is forecasted that the world's population will increase by 1.3 times from the present level of 6.7 billion to 9.1 billion in year 2050.
- *Sustainable Agriculture*: in Asia, the US and the EU, interest has been shown in "sustainable agriculture" for reducing the environmental impact of agricultural production.
- *Labor shortage*: aging workforce, declining skilled workforce, increases in agricultural production costs.

One way to solve address these challenges is to adopt key technologies of information and automation such as robotics.

The IFAC TC on Agriculture

- Modeling, identification and control methodologies for agricultural production lines and processes, both on the process level (e.g. photosynthesis of crops, soil-water-plant-atmosphere cycle and metabolism of farm animals), as well as on the systems level (e.g. control of greenhouses, warehouses, animal houses, plant factories and controlled ecological life support systems)
- Energy issues such as heating, cooling, lighting, and energy saving in agriculture
- Robotics and mechatronics for agricultural automation
- Process and equipment design and identification
- Post-harvest operations such as grading, drying, storage of crops of fruits and vegetables, also food processing (quality and safety)
- Precision farming, cultivation processes and harvesting. It includes computer networks, image analysis and sensors and artificial intelligence applications.
- Ergonomics, including man-machine systems and man-machine interfaces in agriculture for human and animal comfort and welfare.

The IFAC TC on Agriculture

Chair: Noboru Noguchi (Hokkaido University, Japan)
e-mail: noguchi(at)bpe.agr.hokudai.ac.jp

Vice-Chair (incoming chair): Arto Visala (Aalto University, Finland)
e-mail: arto.visala(at)tkk.fi

The IFAC TC on Agriculture periodically organizes

- a triennial Conference: AGRICONTROL
- a triennial Workshop: BIOROBOTICS

The IFAC TC on Agriculture

International Workshop

DYNAMICS AND CONTROL
IN AGRICULTURE AND FOOD PROCESSING

PROGRAM

13-16 June 2012, Plovdiv, Bulgaria

Highlights of DYCAF '12

A Japan five year project (2010-2014) to develop robot farming system using multiple robots for rice, wheat and soybean (Hokkaido University and 10 industries). Emphasis on

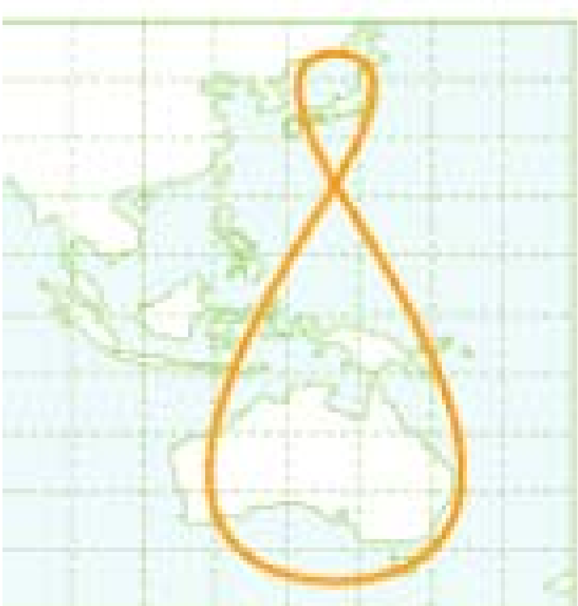
- ❑ Development of robot platforms
- ❑ Navigation systems
- ❑ Safety issues
- ❑ System Integration

Robot Platforms

- ❖ *Robot vehicle for real-time autonomous data acquisition and crop monitoring*
- ❖ *Robot tractrors for rotary tillage, weeder, seed broadcaster, fertilizer and seed–planter*
- ❖ *Wheel-type and crawler type*
- ❖ *Rice transplanter and combine harverster*

Highlights of DYCAF '12

Navigation Systems



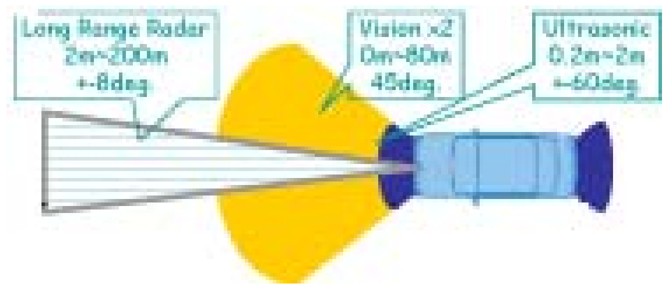
Source: Noboru Noguchi, Robot Farming Systems Using Multiple Robots, 18th IFAC World Congress, 2011 (invited)

- ❑ Sensors used: RTK-GPS (real-time kinematics GPS) to obtain position, accuracy 2 cm) and IMU (inertial meas unit) to obtain posture (pry angl), accuracy 0.5 deg/hr. *Problems: expensive*
- ❑ New Low-cost sensors under development and experimented. *Problems: algorithm to do sensor fusion*
- ❑ Development of Software to create navigation maps in UTM (Universal Transverse Mercator) maps.
- ❑ Plans to exploit the Quasi-Zenith Satellite System (QZSS) managed by Japan Aerospace Exploration Agency (JAXA) for robot navigation.

Highlights of DYCAF '12

Safety issues

- Obstacle detection: 2 dim laser scanner in front (angle 10 and 180 deg, range 8, 16, 32, 80 m)
- Force sensors in the vehicle bumper
- Long range radar, vision, ultrasonic sensors (Bosch)



Source: Noboru Noguchi, Robot Farming Systems Using Multiple Robots, 18th IFAC World Congress, 2011 (invited)

Highlights of DYCAF '12

System Integration

- ❑ Automate the farming from planting to harvesting
- ❑ Robot tractors receive commands and send information, from/to control center, via wireless LAN
- ❑ Crop information includes crop status and soil quality (to be used for fertilization)
- ❑ Mission plan has multiple layers
- ❑ Crop status, yield, quality such as protein content

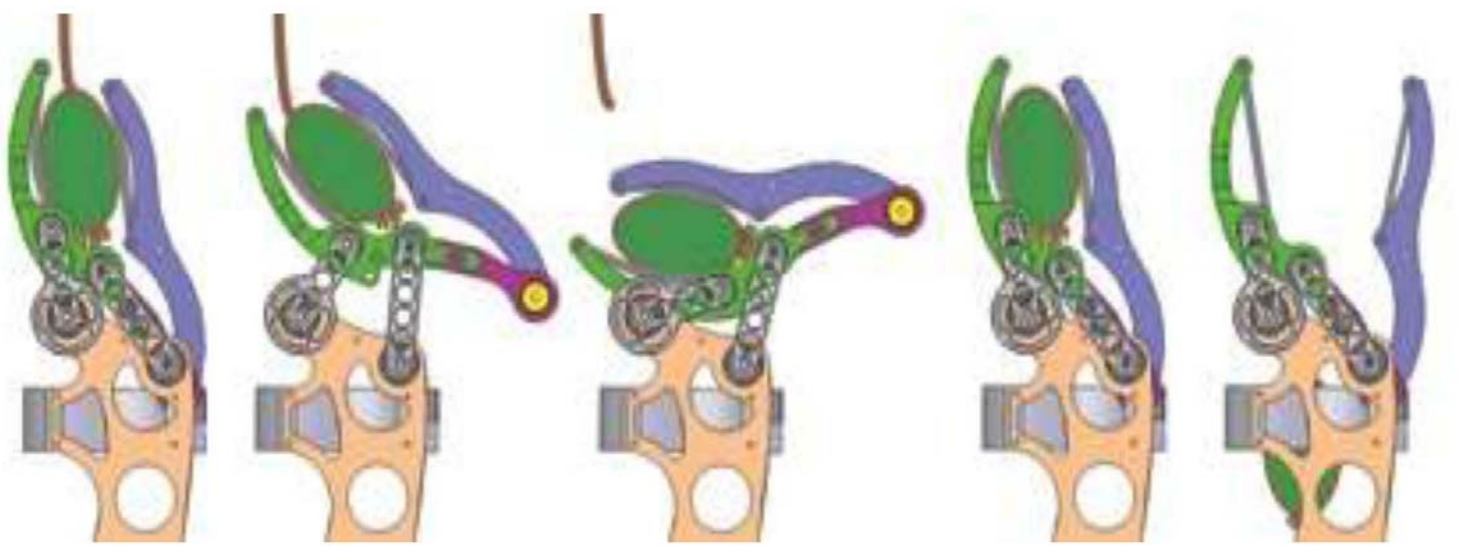
Highlights of DYCAF '12

Fully integrated automated fruit picking:

- Flexibility: all terrain, all weather, all task
- Multiple tasks include: pick, prune, pollinate, fruit count
- Navigation, to and within the orchard
- Appropriate design of robot arm and end effector
- Computer vision: target detction and recognition
- Only pick fruit of the correct size and shape (8 *colour webcams, auto-iris and auto-focus lenses, to get the coordinates of the fruit*)
- Inspect and discard defective fruit
- Autonomus re-fueling, loading/unloading bins, etc.
- Intelligent produce handling

Highlights of DYCAF '12

A picking hand
developed at Massey University/Southern Cross Robotics



Source: Claire Flemmers et al., Mechanization on the Horizon - Orchards of the Future, Proceedings of the National Cherry and National Apple & Pear Conference, Hobart, Tasmania, August 2009

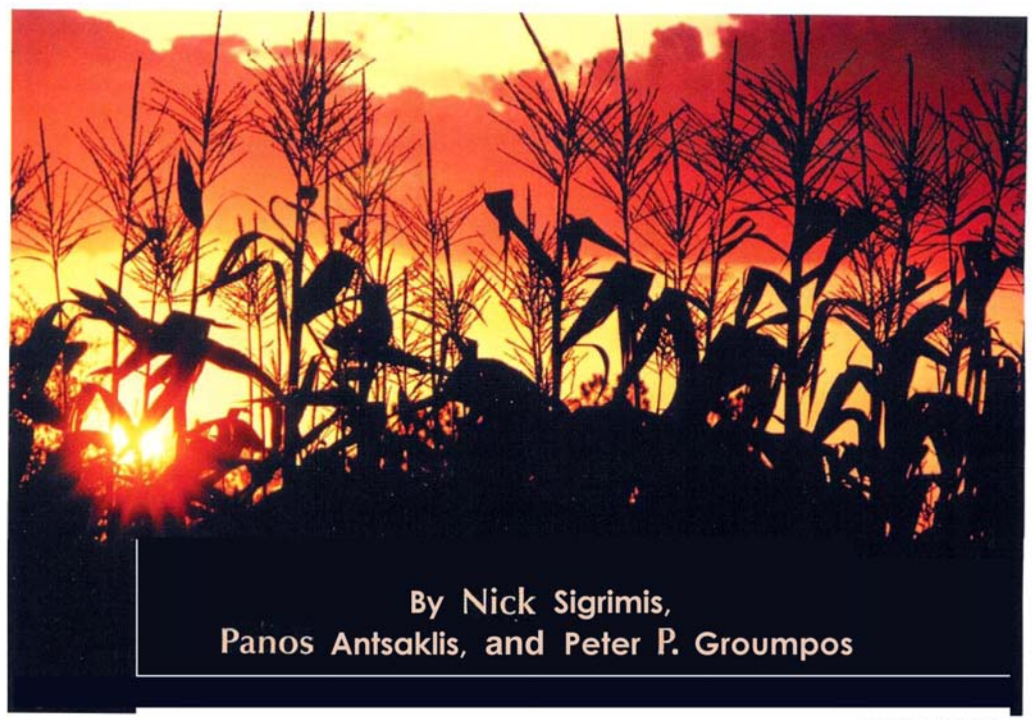
A sister organization

The Control Systems Society (CSS)
of the International Institute of Electrical and Electronic Engineers (IEEE)

A sister organization

A special issue of the Control Systems Magazine

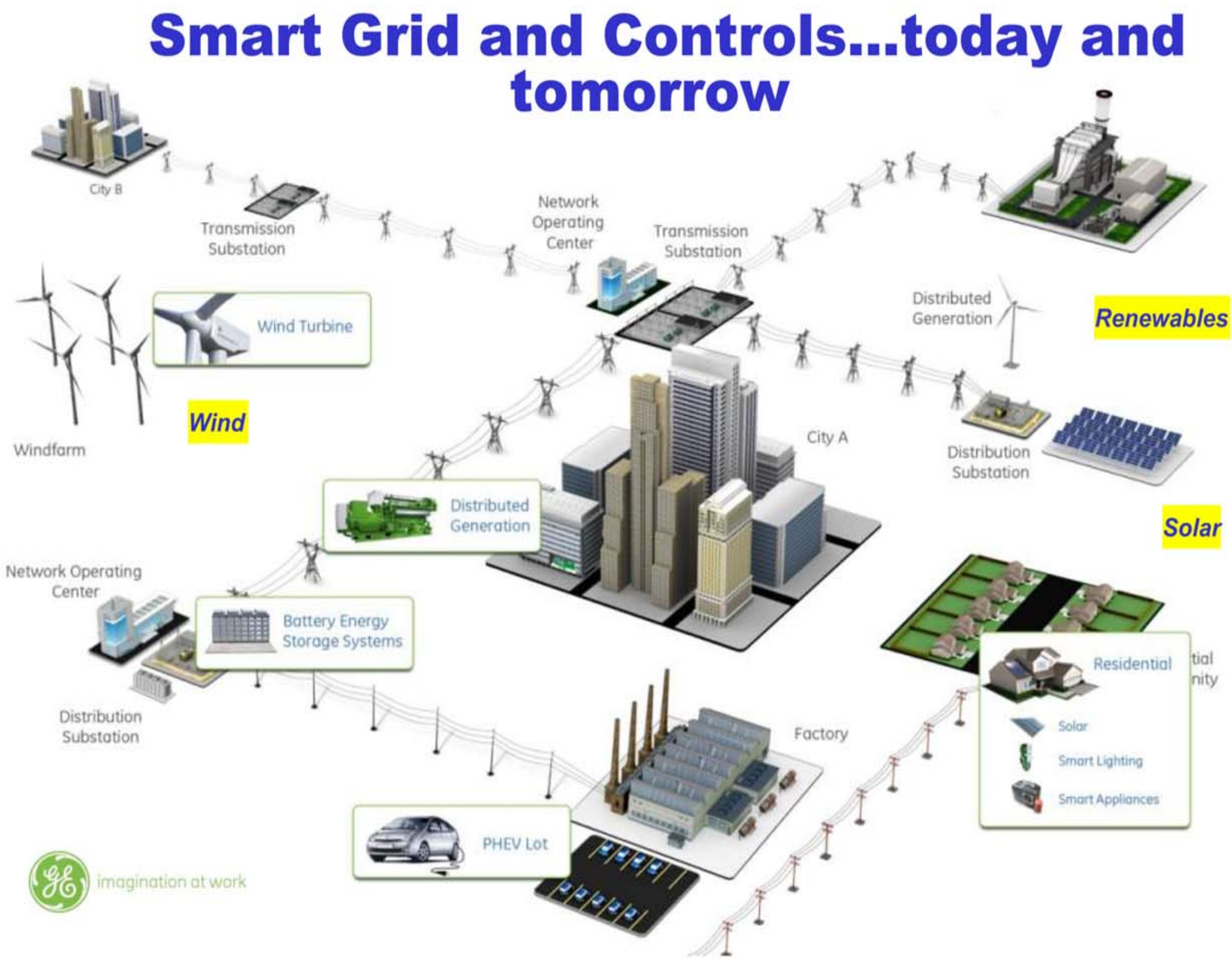
Advances in Control of Agriculture and the Environment



A window on the future

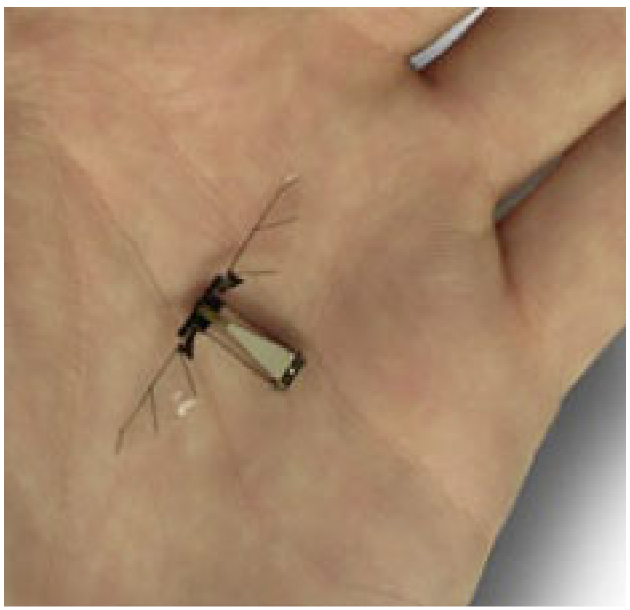
- A Smart Farm ?
- The robofly
- Systems biology
- Consensus and coordination

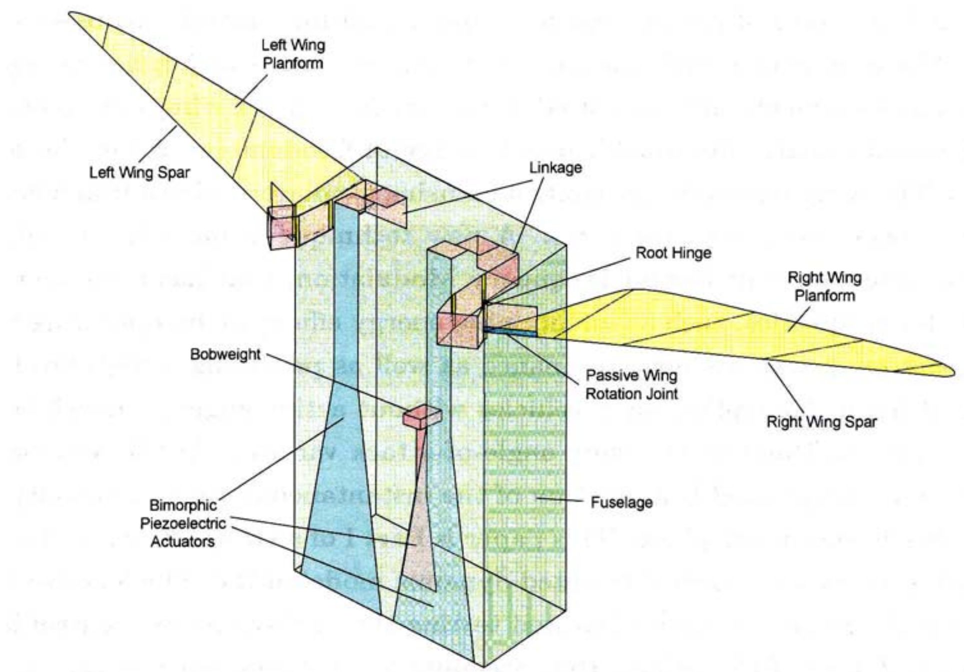
Towards a Smart Farm



The Robofly

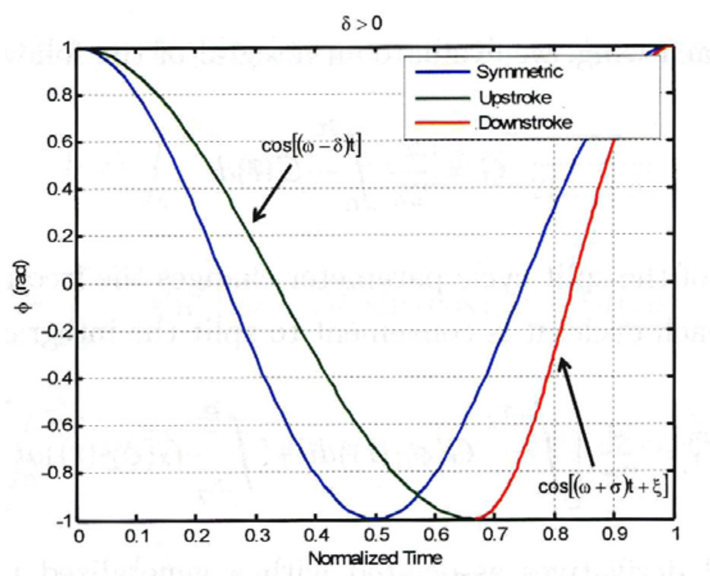
In 2006, the first takeoff of an insect-size micro-robot, actuated by a flapping wing, device developed at Harvard University, control system developed at Wright-Patterson Air Force Base.
The dream of Leonardo comes true.





The Robofly

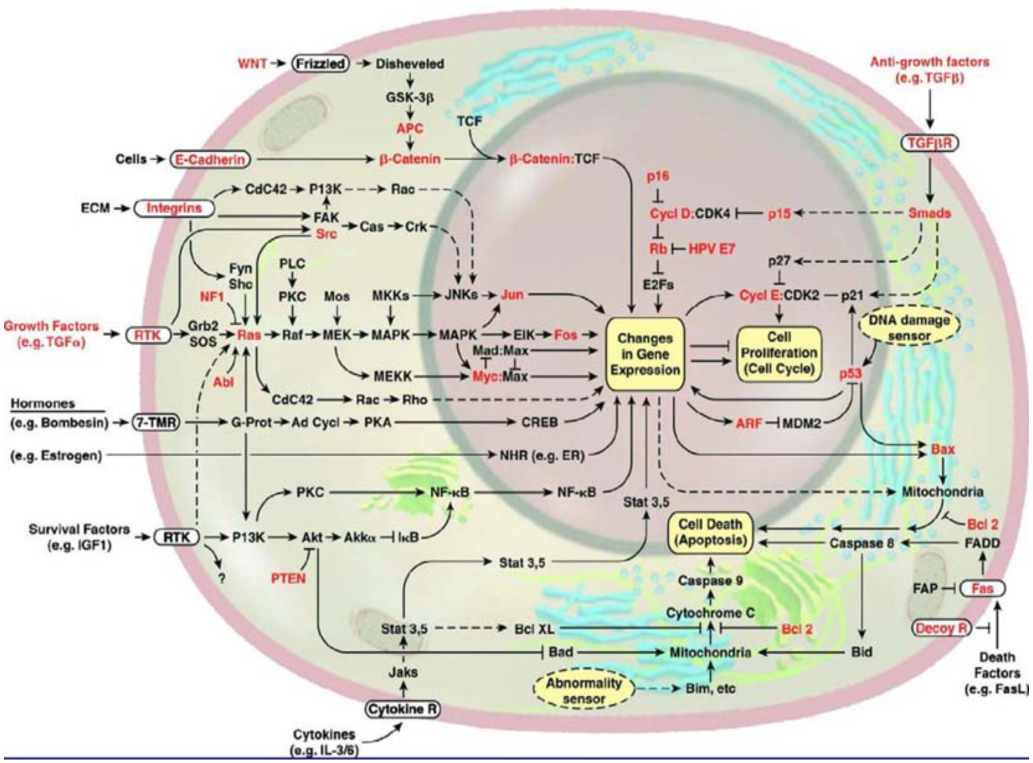
Robofly is powered by a pair of independent piezoelectric actuators controlling the rotation of the support of the flapping wing with respect to the robot body.
The wing passively rotates with respect to the support and hence the angle of attack is a function of the angular velocity of the support



The challenge for control:
To shape the input to the actuators, so as to obtain six degrees of freedom, as in a helicopter.

Systems biology

Modeling and control of biological processes is a quickly growing field of research

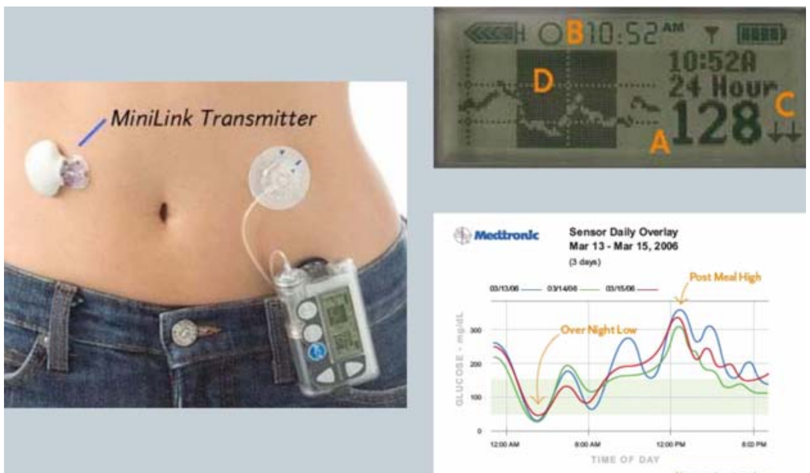


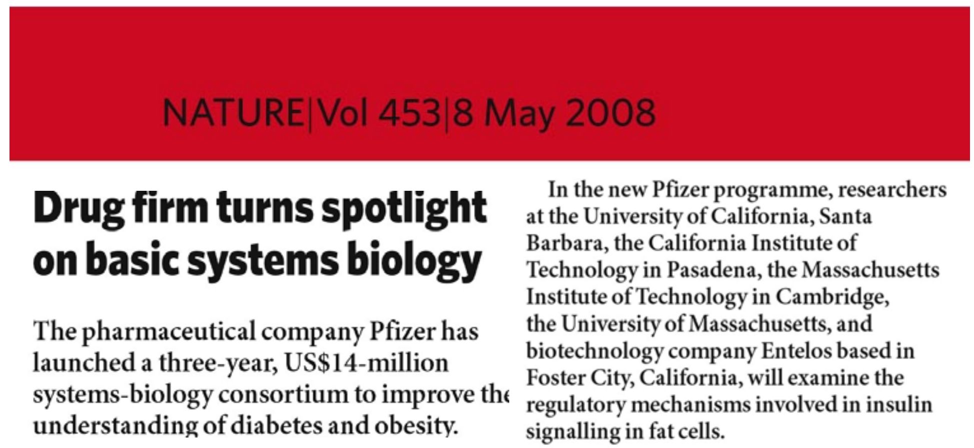
Example: modeling, in cancer cells, of information flow (Hananan-Weinber) responsible of growth, differentiation ans apoptosis. Receptors, enzyme proteins and their role in catalytic reactions.

Similar developments in agriculture can be useful to improve quality of crops and soil quality, to increase yield, pest control, etc.

Systems biology

Researchers at UCSB have recently demonstrated that an automatic artificial pancreas (APS) can efficiently keep constant the level of glucose in a patient affected by diabetes.
The automatic (feedback system) continuously monitors the level of glucose and automatically releases insuline





NATURE|Vol 453|8 May 2008

Drug firm turns spotlight on basic systems biology

The pharmaceutical company Pfizer has launched a three-year, US$14-million systems-biology consortium to improve the understanding of diabetes and obesity.

In the new Pfizer programme, researchers at the University of California, Santa Barbara, the California Institute of Technology in Pasadena, the Massachusetts Institute of Technology in Cambridge, the University of Massachusetts, and biotechnology company Entelos based in Foster City, California, will examine the regulatory mechanisms involved in insulin signalling in fat cells.

It is not difficult to imagine how similar feedback systems could be effectively introduced in various agricultural processes

Consensus and coordination

An area of increasing interest in Control Theory is the analysis and control of systems composed by a large number of individual agents (multi-agent systems).

Typical control tasks consist in reaching coordination, synchronization, and - in general – consensus on a common goal.

The information available to each agent is limited (e.g. only about its neighbors).

A corpus of theoretical results is quickly growing

There are fascinating examples of inter-organism consensus reaching in nature: flocking, swarming, fireflies flashing in synchrony, etc.

In the engineering world, one of the most commonly cited examples for consensus and synchronization is the problem of coordinated motion of individual mobile agents.

Coordination of a large number of agricultural robots is an appealing application.

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Conclusions

- *The spectrum of interests of IFAC's Technical Committee on Agriculture spans from design of individual robot platform design to full integrated automation of the farm.*
- *Potentials, in automated agriculture, of new devices such as the Robofly*
- *Relevance, in automated agriculture, of recent developments in System Biology*
- *Impact of recent advances in Control Theory for Multi-Agent (mobile) Systems on coordination and consensus of Agricultural Robots*