FARM TECHNOLOGY GROUP

ANNUAL REPORT 2011

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Wageningen University
Farm Technology Group
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Contents

Preface

Dear reader,

We are pleased and proud to present the annual report of the Farm Technology Group of 2011.The report contains contact information, mission and vision of the group, cv-'s of the staff, a short description of on-going PhD projects, finished MSc projects, a list of publications as well as a list of courses we teach in the BSc and MSc programmes Biosystems Engineering.

In short, our work focusses on the following three societal issues:

- limited availability and quality of labour in agricultural production systems,
- the health of men, plant and animals in production systems, and
- integral sustainability of production systems and chains.

We address these issues using the following four scientific focus fields:

- knowledge and technology of sensing, and methods for data processing and interpretation,
- modelling of biosystems,
- technology & control systems for automation and robotics,
- development of design methodology for complex socio-technical biosystems.

The Farm Technology Group is a lively and growing group. With a growing number of PhD students we are addressing the above topics yielding results that can be applied in agricultural practice as well as yielding a growing number of scientific publications in peer reviewed journals.

Also, the Farm Technology group is one of the main suppliers of the BSc and MSc programmes Biosystems Engineering. We are proud to mention that in 2011, again, the BSc programme Biosystems Engineering has been selected by students as the number 1 academic BSc programme in the Netherlands!

We hope you will enjoy reading this annual report. Feel free to contact us for more information on research and education or check our website: www.fte.wur.nl.

With best regards,


Prof. Eldert van Henten


Prof. Peter Groot Koerkamp

General information

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Farm Technology Group

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Mission of the Farm Technology Group

Our mission

The members of the Farm Technology Group see it as their mission “To enhance, exploit and disseminate the potential of technology in primary agricultural production processes to fulfill the needs of mankind and nature in a sustainable way”.

Our vision of agricultural production

When it comes to needs of mankind and nature, the perspective has rapidly changed the past decades. With a growing global population, the demand for food will increase continuously and food production is and will be the key issue of agricultural production. However, the past decades have also shown a gradual diversification of the product portfolio in Western Europe. Besides food, flowers, feed, fuel and fibers are gaining importance and production of functional foods, pharmaceuticals, renewable resources from plants etc. will appear on the agenda. Also the character of farm enterprises is changing. Besides being a part of a world wide production chain, nowadays farms in the Netherlands no longer only contribute to agricultural production but, as part of the society and the environment they operate in, contribute to recreation, nature conservation and health care. Meeting the growing and diverse demands of the global society puts strong pressure on nature with its limited available resources.

In the coming years key issues in this field will be: 1) efficient use of natural resources like energy, water, and chemicals, 2) welfare of animals and health of animals, plants and human beings (food safety), 3) reduction of the environmental impact of agricultural production, and 4) supporting, alleviating or replacing human labor. Enhancing and exploiting the potential of technology is the way to meet this complex and challenging set of objectives. We refer to our work as Biosystems Engineering.

Our core business: Biosystems Engineering

We define 'Biosystems Engineering' as a scientific approach that combines methods and tools from technical sciences with biological, environmental, agricultural and social sciences in order to study, understand, manage and design biosystems that encompass technical components and biological organisms (plants, animals) as well as human interactions with both these groups of entities.

The main scientific challenges in Biosystems Engineering are the complexity of production systems including many and usually non-linear interactions between the various entities. Additionally, variability of nature apparent through variation in position, size, shape and colour of objects as well as variability in the response of processes in time together with uncertainty in for instance the weather, pose considerable research challenges. Focus is not only on studying and understanding these complex systems, but typically for engineering, also on management, control and (re) design of such systems, with a special focus on the technology.

Our research instruments and expertise cover fields like sensor technology, data analysis, systems analysis, continuous time and discrete time modeling, systems engineering, integral systems design, systems optimization and management and control of production processes, mechatronics and precision agriculture techniques.

Being an intermediate between plant sciences, animal sciences, environmental sciences and sometimes social sciences on one hand and technology on the other hand, the group holds a unique position both within Wageningen UR and nationally. Many scientific challenges arise on the edge between nature and technology. It is the ambition of the Farm Technology Group to play a competitive role in this scientific field, nationally and globally. We expect to achieve this through targeted networking and collaboration with research groups in related non-technological and technological fields to develop new scientific knowledge in support of the challenging field of Biosystems Engineering.

Exploiting the potential of technology, some examples

Systems engineering and systems optimization. Through networking with stakeholders, group members identify needs of mankind and nature as well as the pertaining sustainability issues and translate these in innovative system designs. Instead of focusing on single disciplinary solutions but using the paradigm of systems engineering and the development of new methods, the group is able to produce new farm system concepts based on a multidisciplinary approach. Examples of projects include the design of protected cultivation systems with for instance low inputs of fossil energy when focusing on the Netherlands. Another project, with a more global view, deals with the design of protected cultivation systems that are adapted to local climate and economic conditions. In a parallel project especially the ecological sustainability of organic laying hen systems is analyzed and redesign of such systems is pursued. In past years a new system for laying hen production was developed, the so called Roundel. A pilot of that system is currently being built and under investigation.

Welfare of animals and health of animals, plants and humans. Assuring health of animals, plants and humans in agricultural production is of growing concern in the Netherlands and considerable costs are associated to maintain required health levels not to mention the input and potential emission and transfer to the food chain of chemicals to cure occurring diseases. One way our group tackles this issue is to design so called robust livestock systems in which implicit robustness of the system with animals reduces health problems. The group is involved in projects on the design of husbandry systems where welfare, health and environment are substantially improved. An alternative approach we take is to detect health issues for instance in plants as soon as possible, so that early and plant specific treatment is possible. Stress detection based on the emission of volatile organic compounds by the stressed plants is used as a cue in this line of research. This approach will be extended to livestock farming as well.

High-tech automation and robotics. To maintain a healthy and productive crop, satisfy food safety concerns, reduce the use of chemicals and improve the efficiency of production, all within the limitations of the availability and cost of labor, requires automation and precision technology. A system has been developed for plant specific removal of volunteer potatoes in sugar beet fields to prevent spreading of *Phytophthora infestans*. It includes vision, perception and precision spraying. Such fundamental technical components are also used in other farm automation projects. The group developed a small robot WURking to be used for crop scouting in arable farming as well as a large autonomous robot called the Intelligent Autonomous Weeder (IAW). Complexity and variability of the biological working environment are challenging issues.

The research network of the Farm Technology Group

Embedding in graduate schools

Research of the Farm Technology Group is embedded in the following graduate schools:
1. De Wit Graduate School of Production Ecology and Resource Conservation (PE&RC),
2. Wageningen Institute of Agricultural Science (WIAS),
3. The Netherlands Graduate School of Science, Technology and Modern Culture (WTMC).

Cooperation within Wageningen UR

The two current chair leaders also hold a part time position at DLO institutes within the Plant Sciences Group (van Henten) and the Animal Sciences Group (Groot Koerkamp). The past three years, this has resulted in many new, funded, collaborative research initiatives. There is a strong mutual interest to extend this collaboration. The DLO institutes show a strong interest in PhD projects to work on themes of long-term strategic interest. On the other hand, through the link with these institutes, the chair group is able to more proactively respond and anticipate to developments in primary production and society and to obtain research funds more easily. But there is also a strong collaboration with various research groups within Wageningen University. Currently, more than 50% of the current (PhD-) projects are based on collaboration with groups within WUR. These groups are mainly located in the Plant Sciences Group and the Animal Sciences Group, to a lesser extent in the Environmental Sciences Group and occasionally in the Social Sciences Group and the Agrotechnology and Food Sciences Group.

Cooperation with universities and research institutes outside WUR

A growing number of projects is done in collaboration with groups outside WUR. In various modalities the members of the Farm Technology Group collaborate with the following universities and research institutes world-wide:
1. EU FutureFarm (University of Almeria, Spain; Helsinki University of technology, Finland; Aarhus University, Denmark; University of Copenhagen, Denmark; Aristotle University of Technology, Greece; Centre for Research and Technology, Greece)
2. EU CROPS (University of Leuven, Belgium; Ben-Gurion University of the Negev, Israel; University of Ljubljana, Slovenia; Umeå University, Sweden; Università degli Studi di Milano, Italy; Instituto de Automatica Industrial, Spain; Technical University Munich, Germany; Swedish University of Agricultural Sciences, Sweden)
3. RoboNed (TU Twente, TU Delft, TU Eindhoven)
4. EU Bio-Business (University of Leuven, Belgium et al.)
5. Ehime University, Japan
6. IAM-BRAIN, Japan
7. Forschungzentrum Jülich, Germany
8. Public University of Navarra, Pamplona, Spain
9. China Agricultural University, China
10. Chinese Academy of Agricultural Sciences, Beijing, China
11. MIT, Boston, USA
12. Field Robot Event, University of Hohenheim, Germany and University of Applied Sciences, Osnabrück, Germany
13. University of Illinois, Urbana-Champaign, USA
14. CRA, Agricultural Research Council, Italy

15. University of Milan, Italy
16. Cranfield University, UK

Cooperation with industry

Science yields impact when results of research are really implemented and used in agricultural practice. Therefore the Farm Technology Group seeks support and collaboration with commercial companies in its research projects. The group collaborates with:

1. Agritechnics, Doetinchem, The Netherlands
2. Claas, Harsewinkel, Germany
3. Kverneland Mechatronics, Nieuw Vennep, The Netherlands
4. Rijk Zwaan, Fijnaart, The Netherlands
5. Tyker Technology, Wageningen, The Netherlands
6. Vencomatic bv. & Rondeel bv, Eersel, The Netherlands
7. GD, Deventer, The Netherlands
8. Commercial Farms
9. Monteny Milieu Advies, Renkum, The Netherlands
10. Swaans beton, Heeze, The Netherlands

CV's of teaching and research staff


















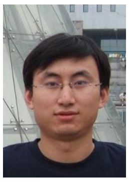

Prof.dr.ir. Peter Groot Koerkamp

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Affiliations:
Professor of Biosystems Engineering
Senior scientist at Wageningen Livestock Research.

Education
1998 PhD, Wageningen University, Wageningen, The Netherlands
1990 MSc, Wageningen University, Wageningen, The Netherlands (with honours)

Expertise
System thinking, production technology for animal production systems, innovation processes, sustainability of animal production systems, technology development, specialization in measurement of environmental aspects of animal production systems (gaseous emissions, dust, losses, energy), specialization in poultry and dairy production, statistical techniques for precision livestock farming. Special interest in animal health and welfare and design methodology for sustainable production.

Current activities
Management of Farm Technology Group, teaching, supervision of PhD, MSc and BSc students. Membership of editorial board of IJABE (China), Journal of the Science of Food and Agriculture, and member of several international professional organizations (NVTL, EurAgEng, ASABE, WPSA, ISAH).

Contribution to courses
FTE11306, FTE30306, FTE80812, FTE80436

Opening of the first Roundel house for laying hens on April 9, 2010 in Barneveld
Left: top view with 5 sections, right laying hens foraging in the day light area

Prof.dr.ir. Eldert van Henten

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Prof.dr.ir. E.J. van Henten
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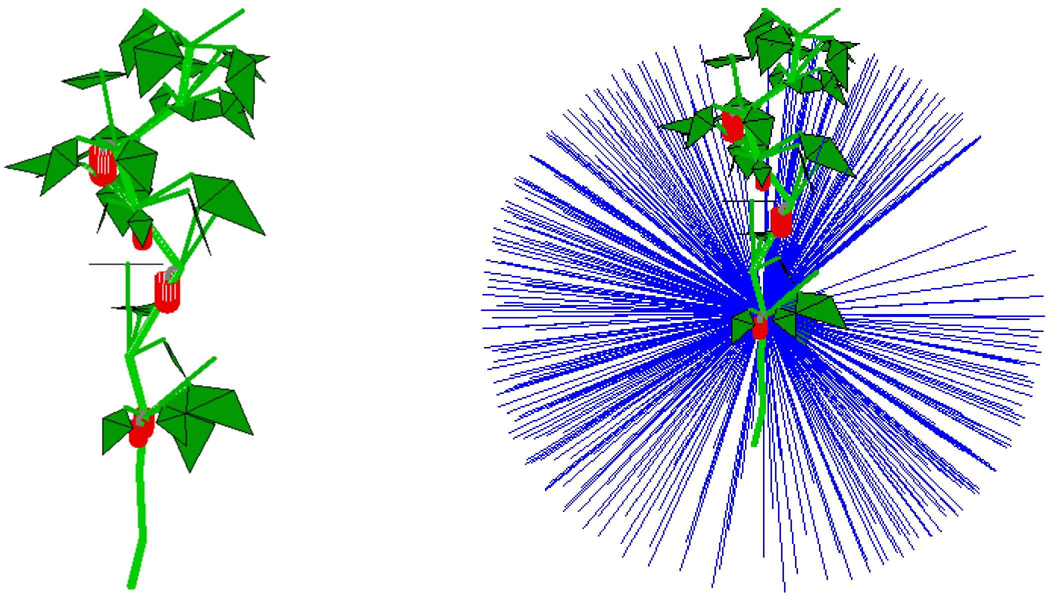
Affiliations
Professor of Biosystems Engineering
Head of Farm Technology Group
Senior scientist at Wageningen UR Greenhouse Horticulture

Education
1994 PhD, Agricultural and Environmental Sciences, Wageningen University, Wageningen, The Netherlands
1987 MSc, Agricultural Sciences, Wageningen University, Wageningen, The Netherlands (with honours)

Expertise
Protected cultivation, arable farming, sensing, modelling, design and (optimal) control of bio-systems, bio-robotics, high-tech automation, company logistics.

Current activities
Management of Farm Technology Group, project acquisition, teaching, supervision of PhD, MSc and BSc students. Member of editorial boards of Biosystems Engineering, Computers and Electronics in Agriculture and International Journal of Agricultural and Biological Engineering. Member of various (inter)national professional organizations (EurAgEng, ASABE, ISHS, BSHS, IFAC, IEEE Robotics and Automation Society, RoboNed, NVTL).

Contribution to courses
FTE12303, FTE12803, FTE31306, SCO22306, FTE32806, FTE33306, YEI80812, FTE80436



Robotic harvesting of sweet pepper; model calculation of the visibility of a fruit in a sweet pepper plant (De Swart, 2012)

Ing. Sam Blaauw

Contact information:
Ing. S.K. (Sam) Blaauw
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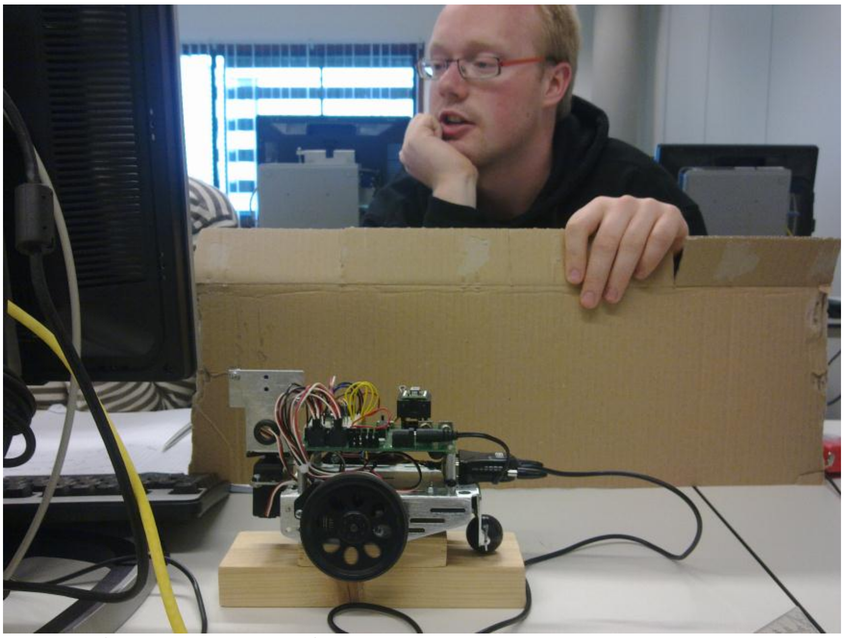
Affiliations:
Teaching assistant Farm Technology Group
IT support officer at WUR Facilities and Services

Education:
1989 Bachelor Dutch Agriculture (Specializations: agricultural engineering, IT) Prof. H.C. van Hall institute for higher agricultural education, Groningen (The Netherlands)

Expertise:
Agricultural Engineering, Computers and Internet, CAD, Education

Current activities:
Teaching various practical trainings, technical support of research projects of PhD and MSc students, IT support chair group, webmaster www.fieldrobot.nl, member WURking field robot team

Contribution to courses:
FTE32806, FTE24806, FTE13807, FTE34306



Practical of the course Automation for Bioproduction

Dr.ir. Jan Willem Hofstee

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Affiliations

Assistant professor at Farm Technology Group
Programme director BSc Biosystems Engineering (BAT) and MSc Agricultural and Bioresource Engineering (MAB)

Education

1993 PhD Agricultural and Environmental Sciences, Wageningen Agricultural University
1986 MSc Agricultural Engineering (with honours), Wageningen University, Wageningen, The Netherlands

Expertise

Machine vision, automation, precision farming
Physical properties of fertilizers, spreading fertilizers
Computer Integrated Agriculture
Precision detection and control of weeds
Yield mapping of potatoes with machine vision
Member of NVTL, EurAgEng, ASABE
Member of committee for assessment of technology for environmental issues (water quality)

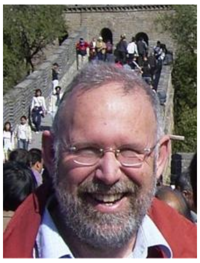
Current activities

Teaching courses, supervision of BSc, MSc and PhD students, research on precision farming, automation and machine vision.

Contribution to courses

SCO22306, FTE12303, FTE12803, FTE13303, FTE13807, FTE25806, YEI80324, FTE804nn, YMC60809, Academic Consultancy Training

Automated detection and control of volunteer potato plants



Dr.ir. Willem Hoogmoed

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Function:
Assistant professor at Farm Technology Group

Education:
1999 –PhD "Tillage for soil and water conservation in the semi-arid tropics" (Wageningen University)
1974 – MSc Agricultural Engineering, Wageningen University

Expertise:
Agricultural engineering with focus on soil tillage / soil technology; conservation tillage; soil structure; farm mechanization, including animal traction; soil sensors; soil physics

Current activities:
Research and consultancy in (tropical) soil & water management, conservation agriculture and mechanization
Research on application of modern (on-the-go) soil sensors for precision farming
Teaching (MSc-level students) on various aspects of tillage: sensors, precision farming, conservation tillage systems. Supervision PhD students

Contribution to courses:
FTE24306, FTE32306, FTE33306, FTE50806, YMC60809

Controlled traffic in Dutch organic farming

Conservation agriculture in Africa

Ir. Bert van ’t Ooster

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Ir. A. van ’t Oooster
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Function:
Assistant professor at Farm Technology Group
PhD student stationed at Wageningen UR Greenhouse Horticulture

Education:
1984 – MSc Agricultural Engineering, Wageningen University (with honours).

Expertise:
Agricultural engineering, biosystems design, horticultural production systems, animal production systems, indoor climate in agricultural production facilities (animal houses, greenhouses, and product storages mainly potato and root crops), physics, psychrometrics, climate equipment, solar energy, (natural) ventilation.
Simulation of crop handling processes in horticultural production systems.
Model development on continuous and discrete processes in matlab, simulink, simevents, visual basic, visual Fortran and c.

Current activities:
Teaching of several courses, supervision of BSc and MSc students, PhD research on Systematic design of automated sustainable horticultural production systems

Contribution to courses:
FTE33806, FTE31306, FTE25303

Simulation flow scheme crop handling processes cut rose

Hanneke Pompe, MPS

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Function:
Assistant professor

Education:
1983, MPS (Master of Professional Studies) Agricultural Engineering, Cornell University, Ithaca, New York, USA
1973, BSc Horticulture, Higher Horticultural College, Utrecht, The Netherlands.

Expertise:
Integrated design of agricultural systems with a focus on the technical aspects labor requirement, mechanization and lay-out of facilities; discrete-event simulation and logistics

Current activities:
Teaching of several courses, supervision of BSc and MSc students, research on automatic feeding systems for dairy farms, behavior of dairy cows and management actions

Courses:
FTE24806, FTE34306

Research on automatic feeding systems for dairy farms in cooperation with Italian scientist

Research projects

- ***Systematic design of automated sustainable horticultural production systems***
- ***An autonomous robot for weed control – design, navigation and control***
- ***Development of a robotic system for sweet-pepper production***
- ***Ecological impact of organic egg production***
- ***Resilience in farm animals***
- ***Design methods for sustainable production systems***
- ***Improving the agro-environmental value of cattle straw manure***
- ***Prevalence, causes and prevention of bruises in Chilean beef cattle at slaughter, and its implication for animal welfare***
- ***Airborne transmission of pathogens and the relation to dust in livestock production***
- ***Sensor data fusion for measuring soil properties***
- ***Moving beyond manure***
- ***Automation for Poultry production***
- ***Determine ammonia emission from a dairy cow house***
- ***Modeling and analysing the roughness of field and road surfaces***
- ***Optimal management of energy resources in greenhouse production systems***

Ir. Bert van ’t Ooster

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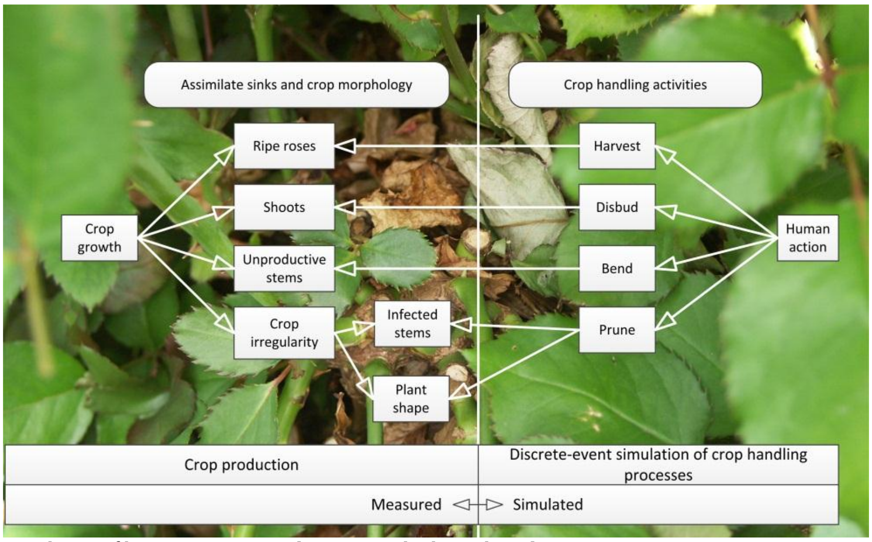
Supervisors: Prof. Dr. Ir. E.J. van Henten, Dr. S. Hemming, Dr. J. Bontsema
In collaboration with: Wageningen UR Greenhouse Horticulture

Systematic design of automated sustainable horticultural production systems

Labour and energy are the top two cost factors in greenhouse horticulture. Current technological trends offer good opportunities for improving economic robustness and sustainability of production. These trends are precision agriculture and logistics, ambient intelligence, wireless communication, new sensor technology and introduction of robotics. The direct challenge is to support, alleviate or replace human labour on crop handling processes and to realise more efficient production systems that use facilities and human resources (= labour) effectively and, where possible, optimized in place and time. This project’s focus is a systematic design of automated sustainable production systems in greenhouse horticulture. It’s our ambition to contribute to system innovations on the longer term by making innovation processes more transparent and structured and by supporting decision making with quantitative methods and model evaluation. The research objective is to develop methods to analyse, design, simulate and optimize (semi) automated greenhouse crop production systems. The methods focus on company layout and scheduling of business processes. A generic tool for designers of automated sustainable horticultural production systems must result from this as an instrument for multi-factorial systematic design. Designers create a system concept where human labour is supported or taken over by automated tools or robots. The generic tool supports the design process itself and it assesses proposed concepts in the design phase with respect to effectiveness, bottlenecks and indicators for sustainability. Cost effective well equipped greenhouses with optimal execution of production processes and optimal internal logistics should result from this on the long term.

In 2011, main effort was given to model evaluation based on data from reference grower companies producing truss tomato and rose. Labour data were collected and analysed. The generic discrete event model is fully functional for harvest in mobile and static growing systems for cut rose. One paper and two student reports (one BSc and one MSc) were completed.



Simulation of human or automated action in a biological production system

Ir. Tijmen Bakker

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Supervisors: Prof.dr.ir. G. van Straten, Prof.dr. J. Müller, Dr. J. Bontsema

An Autonomous Robot for Weed Control - Design, Navigation and Control

The objective of this research is to replace manual weeding in organic farming by a device working autonomously at field level. Developing such a device is considered as a design problem. The device is designed using a structured design approach, which forces the designer to systematically review and compare alternative solution options, thus preventing the selection of solutions based on prejudice or belief. The result of the design is a versatile research vehicle with a diesel engine, hydraulic transmission, four-wheel drive and four-wheel steering. The robustness of the vehicle and the open software architecture permit the investigation of a wide spectrum of research options for intra-row weed detection and weeding actuators. The concept design regarding navigation consists of both vision based crop row following and GPS based navigation in a field. The resulting concept design identified the issues that required further investigation. Results from field experiments show that the robot can navigate autonomously in a field.

The Intelligent Autonomous Weeder (IAW)

Ir. Wouter Bac

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In collaboration with: Wageningen UR Greenhouse Horticulture

Development of a robotic system for sweet-pepper production

Development of a robotic system is performed in the EU funded CROPS project. CROPS will develop scientific know-how for a highly configurable, modular and clever carrier platform that includes modular parallel manipulators and intelligent tools (sensors, algorithms, sprayers, grippers) that can be easily installed onto the carrier and are capable of adapting to new tasks and conditions. Several technological demonstrators will be developed for high value crops like greenhouse vegetables, fruits in orchards, and grapes for premium wines. Wageningen UR Greenhouse horticulture leads the development of a sweet-pepper robotic system which is the demonstrator for greenhouse vegetables.

Most emphasis will be put on harvesting during the development of a robotic system for sweet-pepper production. However other functions such as pruning, attaching plant to supporting wires and planting will be investigated as well. It is expected that learning algorithms, path planning and image processing will become the most involved disciplines in this research. Furthermore, methodological design will be used as a supportive tool to select the components of the robotic system.

Artist impression of the concept of an intelligent harvester of high-value crops

Ir. Sanne Dekker

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Supervisors: Prof.dr.ir. P.W.G. Groot Koerkamp, Dr.ir. I. de Boer, Dr.ir. A.J.A. Aarnink

Ecological impact of organic egg production

In 2006 organic Dutch egg production has grown to a number of 863.000 laying hens. According to the ecological principle of the International Federation of Organic Agricultural Movements (IFOAM) "*organic farming should be based on living ecological systems and cycles, work with them, emulate them and help sustain them"* (IFOAM, 2005). Nevertheless, in practice organic egg production has a number of ecological problems: 1) an intensive and international oriented production cycle, 2) a high level of ammonia emission from the hen house and 3) a high load of nitrogen and phosphorus in the outdoor run, resulting in harmful losses into the environment, leaching of nitrate and emissions of ammonia and nitrous oxide. To evaluate and solve these problems a chain oriented research approach is necessary. Also the offered solutions should optimize ecological, economic and societal sustainability of the production chain as a whole. Based on these two insights the main research question has been formulated: How can ecological sustainability of organic egg production chains as a whole and organic egg production farms in particular, be assessed and improved. To answer this question the following methodology is used. First the ecological impact of the organic egg production process is computed using Life Cycle Assessment. Second important parameters of the main polluting processes will be measured in practice. Third solutions for the main environmental polluting processes are modeled.

Organic laying hen production

Drs. Ingrid van Dixhoorn

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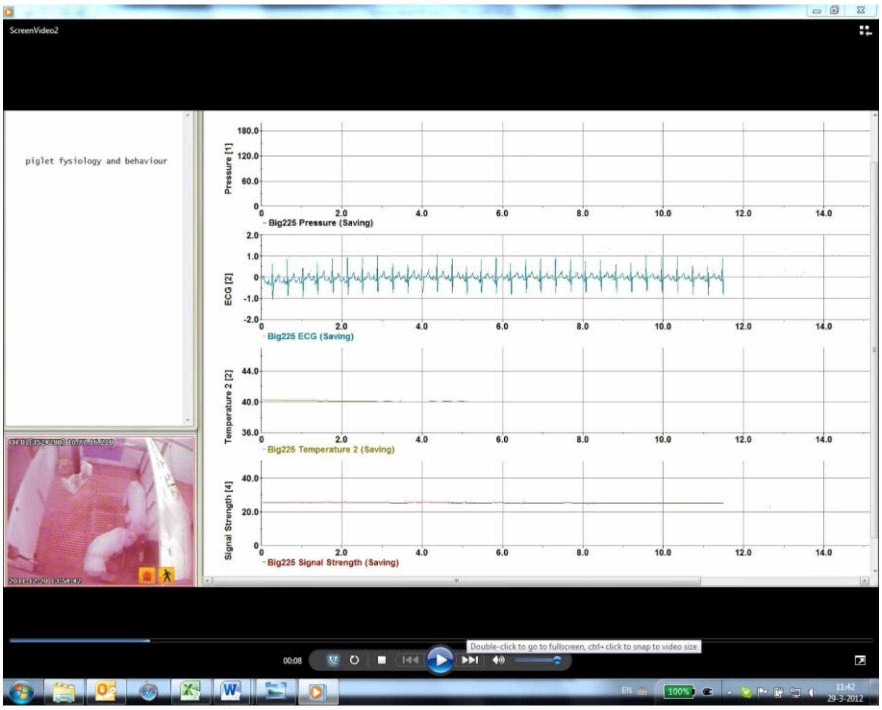
Supervisors: Prof.dr.ir. P.W.G. Groot Koerkamp, Prof.dr.ir. B. Kemp, Bert Lambooij

Resilience in Farm animals

The main objective of this research is to identify and quantify generic measures that indicate the capability of individual animals (at a particular moment) to cope with (infectious) disruptions. This is referred to as the resilience, or more precisely *the precariousness*, of individual farm animals and it will be quantified by describing the dynamics of one or more physiological variables (referred to as biomarkers) which can be measured easily and repeatedly in growing piglets.

The hypotheses that will be tested in this research are:

1. There are biological variables within the complex system of an animal that can be used as indicators for the resilience concept of precariousness and can be measured continuously during (long) periods of the life time of an animal
2. The continuous dynamic signal of this indicator can be analysed and modelled so that the characteristics of the biomarker can be assessed.
3. The biomarker varies in time and between animals, and has a predictive value with respect to the ability of the animal to respond to infectious disturbances and other perturbations.
4. The theory of critical slowing down as assessed by Scheffer *et al.*, (2009) on population dynamics can be applied to individual animals. Precariousness is reduced whenever critical slowing down is approaching, meaning that it is more difficult for these animals to adapt after only small perturbations.



Continuous monitoring of physiological parameters and behavior

Hanneke Miedema

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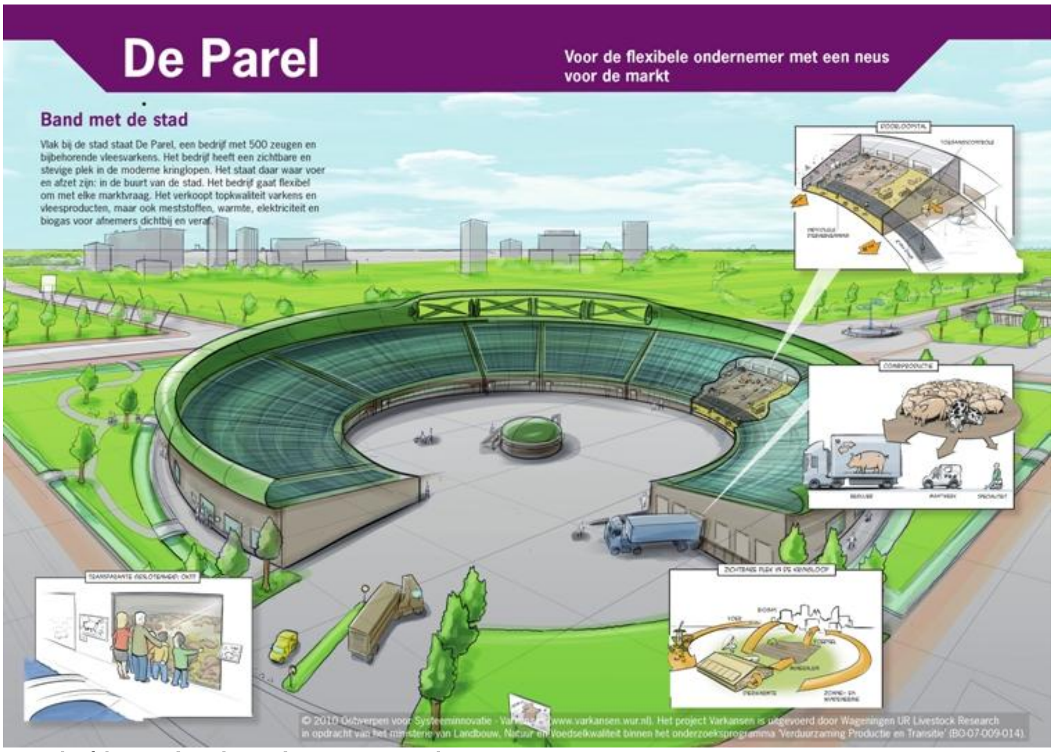
Design methods for sustainable production systems

Hanneke's research is about the design of sustainable animal husbandry systems. A research group at Wageningen University developed a design approach in which Science and Technology Studies (STS) and engineering design converge in one interdisciplinary approach. Converging STS and engineering design is not self-evident. STS deconstructs technology development and considers technology and society as a two-foldness. Engineering design actively constructs new technologies, and thereby deliberately separates the intended technology from its (social) context. However, engineering design has troubles gearing technology to a complex and rapidly changing society. STS insights about technology development and the two-foldness of technology and society seem to be of value for engineering design, but those insights have a completely different origin and function than engineering design methods. STS is about the meaning of technologies, and engineering design about the function of technologies.

The research project focuses on the question whether the two-foldness STS describes can be inserted in engineering design, and how this can be done. A design project is studied, called Varkansen, in which several stakeholders work together on the design of sustainable pig husbandry systems, following the interdisciplinary design approach.



A result of the interdisciplinary design project Varkansen

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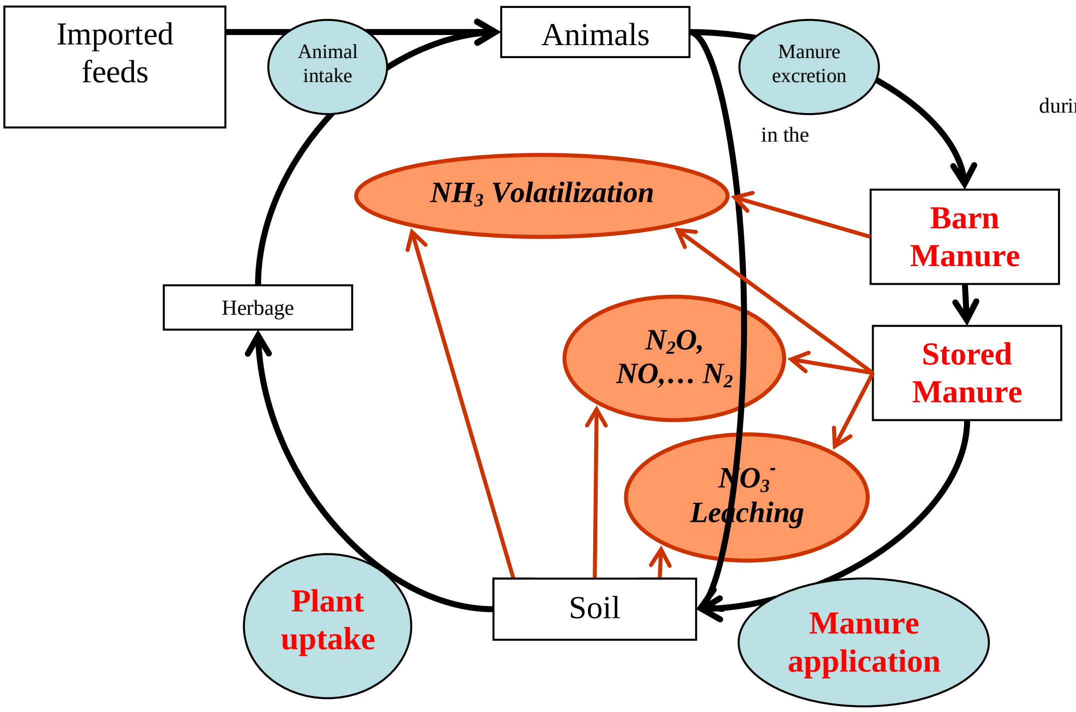
In collaboration with: Organic Farming Systems group – Wageningen UR

Improving the agro-environmental value of cattle straw manure

Considerable amounts of nitrogen (N) are lost during each phase of the manure management chain (animal housing, manure storage and manure application) as ammonia (NH_3), nitrogen oxide (NO_2), nitric oxide (NO), nitrous oxide (N_2O) and dinitrogen (N_2) emissions, and some as leached nitrate (NO_3^-). However, the control of N losses during one phase could enhance them in subsequent phases (Rotz, 2004). Therefore, it is crucial to develop and evaluate effective measures that could reduce the emissions throughout the whole manure management chain and enhance crop N utilization after manure field application.



Rotz, C.A. (2004): *Management to reduce nitrogen losses in animal production.* J. Anim. Sci. 82, pp. E119-E137. *Manure management chain and N-flow routes in cattle production systems. The current project focused on barn manure, stored manure and its application phases.*

The overall aim of this project is to gain insight and knowledge on the sources, magnitude and influencing factors of N loss routes from straw-manure based cattle farming systems (of NH_3, N_2O and other N-containing gases, especially N_2) in the barn, the storage facility and during field application, and to develop smart strategies to reduce these losses throughout the whole manure management chain and improve N utilization by the crop.

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In collaboration with: Adaptation Physiology Group, WU, Animal Science Institute, Universidad Austral de Chile, Quantitative Veterinary Epidemiology Group, WU

Prevalence, causes and prevention of bruises in Chilean beef cattle at slaughter, and its implication for animal welfare

In the last years, the beef meat industry in Chile has grown and expanded owing to the fact that exportation has steadily increased in this country. In spite of all technological advancements, losses in the form of carcass condemnation and meat trimmed due to bruises continue. This is an important problem since bruises reduce the ethical quality of the product and may therefore reduce the possibilities of exporting meat to welfare demanding markets.

But bruises not only cause economic losses. This type of lesions is also an indicative of violence and pain that animals underwent, referring thereby to poor welfare conditions during *ante mortem* period. Knowing the causes of the bruises might help to decide who is accountable for the losses, and moreover, might provide information about the suboptimal handling conditions during the *ante mortem* period.

The research objectives of this project are:

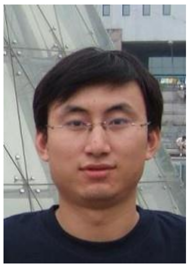
1) To quantify the prevalence of bruises in Chilean bovine carcasses
2) To study the relationship between animal factors, pre-slaughter transport, method of selling, lairage time, and handling procedures with the presence of bruises
3) To estimate the causes and time of occurrence of bruises
4) To propose, based on objectives 1 to 3, recommendations for pre-slaughter handling. By relating the conditions in the pre-slaughter phase also with the question of animal welfare, the project focuses clearly on consumer demands in Western countries, i.e. the main market for Chilean beef.

This project is a major international example of a possible synchrony of two main aims in the animal production chain: to guarantee high product quality, and to ensure reasonable conditions for animal welfare, areas that are of main international concern.

Carcass bruise evaluation at a Chilean slaughterhouse using a detailed protocol for animal welfare assessment

Prof. Jos Metz visiting a Chilean dairy farm with postgraduate student from the Universidad Austral de Chile

Yang Zhao, MSc



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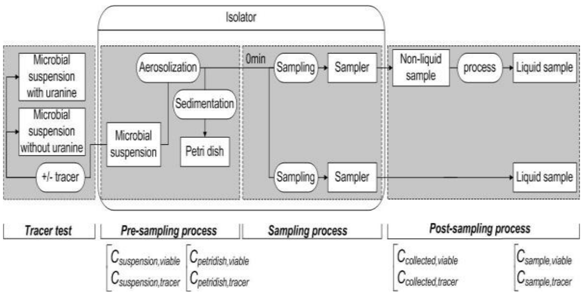
Airborne transmission of pathogens and the relation to dust in livestock production

Airborne transmission of pathogen is suspected as one of the mechanisms for disease spreading between livestock farms. In a whole process of airborne transmission, the pathogens are firstly shed to the air through respiratory tracts of animals or animal feces. Then, the pathogens may stay either stay in the air as a single particle, but in most cases, attach to dust. They are transported in the air stream to the healthy animals or farms. The distance, that the pathogens can be transported, depends on the size of dust particles they combined and their ability of survival in the dust. Eventually, the pathogens are inhaled by the healthy animals and cause infection. So far, knowledge is lack in several aspects, including sampling techniques of airborne pathogens, their viability, sources, concentrations, emissions, dispersions and emission control techniques.

The objective of this research tries to answer the following questions:

1. How effective of different samplers on collecting airborne pathogens and dust?
2. How do the airborne pathogens survive under different climate conditions (temperature and humidity) in droplets and dust particles?
3. Where do the airborne pathogens come from (exhalation or excretion)?
4. What is the concentration and emission of airborne pathogens?
5. What is the size distribution of airborne pathogens?
6. How effective of multi-stage air scrubbers on reducing airborne pathogens and dust from livestock houses?



A method for evaluating sampling efficiency of Bio-samplers for Airborne Bacteria and Virus

Bio-samplers awaiting for efficiency test

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In collaboration with: Soil Quality group, WUR

Sensor data fusion for measuring soil properties

Precision agriculture is an emerging high-technology agricultural management system whose fundamental aim is to increase the profitability of crops, to optimize the use of agricultural inputs and to reduce potentially negative environmental impacts by localized management based on the quantification of in-field spatial and temporal variability. The development of various types of soil sensors is expected to increase the effectiveness of soil characterization in precision agriculture. There are different satellite-based, airborne and ground-based soil sensors used to characterize important soil properties. Satellite or aerial remote sensing suffer from inadequate spatial and temporal resolution, while the proximal remote sensing methods may give fine-scale information on soil properties of interest. Therefore, the conventional laboratory methods are being replaced or complemented with proximal or ground-based soil sensors as analytical soil sensing techniques. Keeping in view the above facts and issues, we therefore hypothesized that:

1. The fusion of multiple soil sensors (combining the outputs of different sensors) will improve the accuracy of predictions of various soil properties and permit their application over a greater range of soil physical and chemical properties.
2. Sensor data fusion system for sensing soil properties can form an integral component of technology in precision agriculture.

The overall objective of this PhD study is to use multiple soil sensors data fusion technique for modeling important soil properties and to assess and evaluate its significance and scope in precision agriculture.

In this study three different types of soil sensors with different measuring principles have been used. They include an EM38 (an electromagnetic induction sensor), a visible-near infrared spectrometer and a gamma radiometer. Field experiments are in Lelystad, within the 'BASIS' project using a controlled traffic farming system. Two types of crop management systems, conventional and organic are under three different types of tillage practices e.g., ploughing, minimal tillage and in-between ploughing and minimal tillage. Near Wageningen measurements were done on a heavy clay soil. Data handling and analysis is now underway applying different multivariate statistical techniques

Use of EM38 in the field

Use of VNIR (visible-infrared) sensor in the laboratory

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In collaboration with: Department of Soil Quality and Animal Production Systems

Moving beyond manure

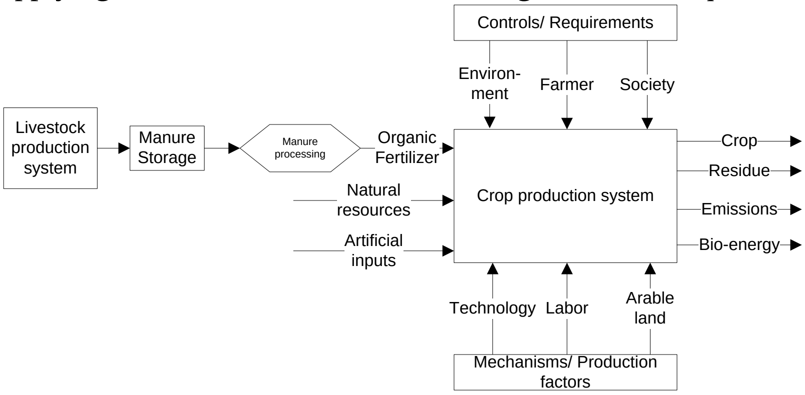
Integrating cropping systems and manure products and management to reduce environmental impact.

Strong intensification of animal and crop production systems in the past 50 years has led to disintegrated farming systems resulting in displacement of crop and livestock farming and higher environmental impact. Manure and fertilizer management are key areas in the related environmental impact of modern farming systems. Innovations in crop and animal production systems, such as anaerobic digestion of manure for energy production and processing of manure into liquid fertilizer, have emerged, which can partly counter negative environmental side effects. However, little research has been done on the integration of measures addressing more managerial aspects and including multiple environmental effects in the chain from animal to crop.

This research aims at improving the environmental performance through reductions of nitrogen, phosphorus and carbon emissions, in the chain from animal to crop by tailoring manure products and management and soil management tot crop production needs (Figure 1). Managerial aspects included in the study are: manure product and quality, application amount, timing, placement and application technology and soil tillage.

By setting environmental goals and by using a methodical approach to engineering design, new chains from animal to crop and management approaches are designed aiming at low environmental impact. Life Cycle Assessment (LCA) is applied as a methodology to quantify the environmental consequences of these designed chains. Environmental indicators included in the assessment are greenhouse gas emissions, acidification potential, eutrophication potential, fossil fuel depletion and particulate matter formation. Lacking emission data are assessed in experiments. A field experiment will be conducted to obtain information on greenhouse emissions and the effect of soil tillage combined with application of different manure products.

Final results of the research give essential insight in the environmental consequences of applying several manure and soil management techniques in the chain from animal to crop.



Schematic overview of the manure management and crop production system

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Automation for Poultry Production

As a result of the current change to loose-housing systems with more freedom for the animals, also working methods and management strategies are changing. In modern poultry housings for example, farmer have to manage a flock instead of a housing as with the traditional cages.

Next, also some old problems reoccur, like the presence of misplaced eggs, caused by hens placing their eggs outside the laying nests. These eggs create an extra workload for the farmers and reduce their profits. A lot of research has been done to decrease the number of floor eggs, but a solution to overcome this problem was not yet found.

Current measures to deal with these issues all rely on manual labour and control. For example, the (preventive) collection of these floor eggs is currently done by the farmer by hand. It is a physically and time demanding job, so that there is a need to ease and improve this collection. During the Field Robot Event of 2007, the idea of collecting floor eggs (outer-nest eggs on the litter) with help of a robot emerged.

In my research, I'm working on the evaluation of current & new technology for use in automation on their potentials when dealing with such problems. Target of this research is to come up with new solutions for further automation of poultry production, and more specifically for a vehicle that collects floor eggs autonomously and with special attention for the characteristics of this problem.

Specific examples are the testing of localization methods on their accuracy inside modern aviary housings and modeling floor laying behavior and using this to perform path-planning for the collection of floor eggs. The latter one is designed specific for the complex task of gathering floor eggs, but can also be used for other purposes like cleaning areas or searching for objects. Another important issue is object recognition, which can be used for performing desired tasks as well as ensuring operational safety of the vehicle. Finally, also the financial aspects and the machine-animal interactions are taken into account.

The first trials with a robot inside a commercial poultry house, to assess the localisation systems and the reaction of the animals

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Modeling and Analyzing the Roughness of Field and Road Surfaces

It is difficult for terrain reconstruction by classic method, because the original terrain of roughness is random, non-period, and chaos. Terrain roughness has spatial and temporal characteristics, so it is possible to use fractal theory to simulate and reconfigure terrain roughness. If original terrain of roughness can be simulated, resulting in geographical details can be represented precisely while reducing the data size, then an effective reconstruction scheme is essential. This project measure real-world 2D and 3D terrain profile data in different original terrain, that is the field surfaces and the road surfaces. Then reconstruct them through 2D or 3D fractal reconstruction to proceed data reducing, i.e. data sampling randomly. Meanwhile, the quantitative and qualitative difference generated from different reduction rates were evaluated statistically.

The research results will be applied in interaction between tire and soil or road, vibration analysis for vehicle drive on terrain, and so on.

We are studying as follow:

1. Measured the field surface roughness after ploughing, harrowing, rolling.
2. Analyzed the fractal characteristics of the field surface roughness.
3. Analyzed the non-scale distance of field surface roughness.
4. Modeling the field surface roughness of 2D by fractal interaction.
5. Modeling the field surface roughness of 3D by fractal interaction.
6. Measured the surface roughness of three type of brick, concrete and soil roads.
7. Analyzed the fractal characteristics of the surface roughness for the three type of roads.
8. Analyzed the non-scale distance of the surface roughness for the three type of roads.
9. Modeling the 2D road surface roughness of the three type of roads by fractal interaction.
10. Modeling the 3D road surface roughness of the three type of roads by fractal interaction.

Measuring the roughness in field

Measuring the roughness on road

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In collaboration with: Wageningen UR Greenhouse Horticulture and Hortimax B.V.

Optimal management of energy resources in greenhouse production systems

Greenhouse horticulture is a large consumer of fossil energy. Therefore, targets are set to reduce the use of fossil energy and CO2-emission by 45% in 2020 compared to 1990 (Valk and Poll, 2007). A lot of different conditioning equipment is available for growers to control the greenhouse climate and to produce and store energy. Because of that, the optimal utilization of energy resources has become a complex matter. The symbolic overview of all energy resources in the greenhouse involved in this research is shown in figure 1.

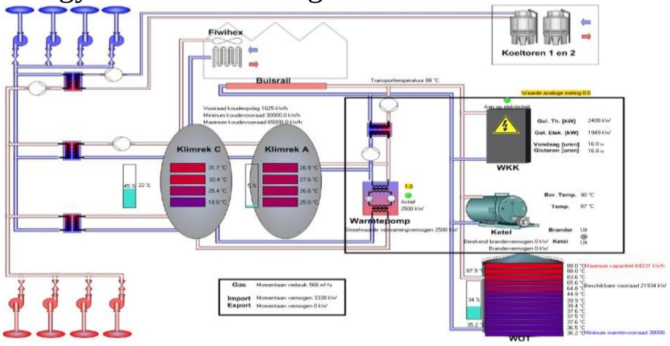

Figure 1 Symbolic overview of all energy (re-)sources in the greenhouse

The main challenge of this project is to formulate and solve the optimizations problem, which can be characterized as a non-linear dynamic optimization problem with uncertainty in the outdoor weather. This problem is divided into the following research questions:
How to properly define and solve the optimization problem?
How to deal with uncertainty in the weather?
How much energy conservation is achieved with optimal resource management compared to standard management practice?
How to implement the solution into the currently available ICT environment?
Different studies have clearly demonstrated the potential of model based dynamic optimization in greenhouse climate management. These studies form the basis to formulate the control problem. A roadmap with five steps (figure 2) is defined to find an answer to the research questions stated before. The focus of this research will be on dealing with uncertainty in the weather during the scheduling and the generation of simplified operating schemes.
The final product will be the core of a control decision support system to help growers making operational decisions. Furthermore, a solution of the optimization problem associated with scheduling of the available energy resources under uncertainty is presented and proven to increase the energy efficiency compared to the current situation. Other results are the control strategies for a wide range of climate conditioning equipment available nowadays. Also insight into and explanation of the particular characteristics of the operating strategies are important for the interpretation of the results and the use of the system by growers.

This project is financed by STW

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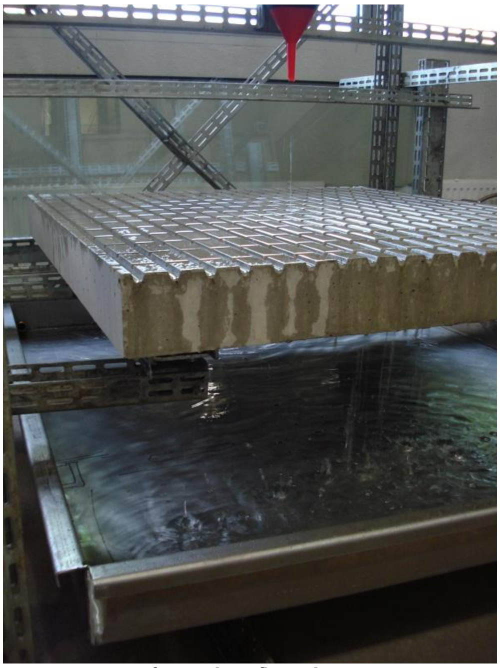
Determine ammonia emission from a dairy cow house

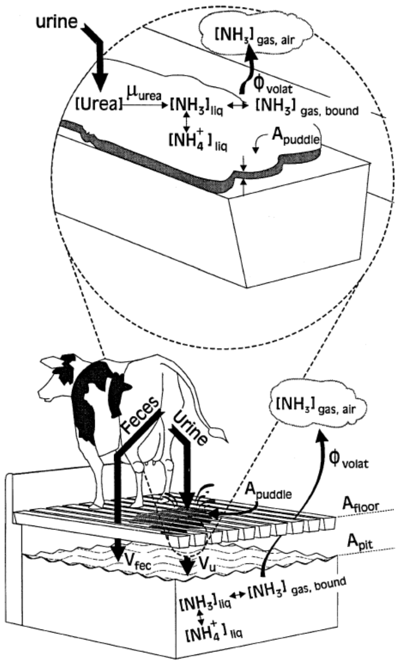
During my MSc. thesis I worked on urine transportation at floor level in dairy cow houses. This transportation is important because the emission of ammonia start from an urine pool, on a floor element. An experimental setup was build and different floor elements were tested. Afterwards the idea raised to continue this work but within a wider scope: To determine ammonia emission from a dairy cow house.

At the moment there is still no final solution to determine ammonia emission from livestock houses. Especially for the naturally ventilated dairy cow houses. There are measurement methods. But they are time consuming, expensive and still problems occur at house level. On the other hand there is a simulation model (Monteny *et* al., 1998). This model is useful to make an estimation of NH_3 emission of a dairy cow house, but is not able to determine the NH_3 emission of an specific, practical dairy cow house.

Within this PhD thesis project I will work on a better understanding of the origin and processes of ammonia in dairy cow houses and to improve the determination of the emission. Main hypothesis is: A newly developed model in combination with simple, online measurements of parameters of the NH_3 emission process, is able to determine actual NH_3 emission of an arbitrarily dairy cow house.



Transportation of water by a floor element, from a simulated urination; experiment to gain knowledge about urine transportation at floor level in a dairy cow house (Snoek, 2009)



Sketch of a dairy cow urinating at a slatted floor in a dairy cow house, and the related parameters and processes which take place (Monteny et al., 1998)

BSc projects completed in 2011

Straver, Jeroen (2011, January 25)
Onderzoek naar druppelvorming onder een vloerelement in een koeienstal

Wennekers, Michiel (2011, February 16)
De mogelijkheden van kleine, autonome landbouwmachines

Boogaard, Frans (2011, February 24)
Connection and integration of agricultural spraying activities and information systems via business process modeling

Sijbrandij, Fedde (2011, March 8)
Het gebruiksvriendelijker maken van CoBuS

Booij, Johan (2011, March 31)
Voorbehandeling houtige biomassa bij vergisting

Jager, Martijn de (2011, April 7)
Het ontwikkelen van een eenvoudige methode om de flow van kunstmest uit een kunstmeststrooier te voorspellen

Helm, Bob van der (2011, May 9)
Rijpheidbepaling van paprika's met behulp van chlorofylfluorescentie

Ven, Tom van de (2011, May 12)
Ei-herkenning voor het autonoom verzamelen van grondeieren

Schutte, Jort (2011, May 17)
Plaatsbepaling van koeien in de stal

Honcoop, Patrick (2011, May 24)
Evaluatie en verbetering autonoom padvolgen trekker

Waal, Niels van der (2011, June 6)
Karteren van bodemweerstand

Boonman, Jan-Kees (2011, June 23)
Plaatsspecifiek bespuiten in fruitboomgaarden met behulp van lidar techniek

Koolen, David (2011, July 11)
Het verloop van de chlorofylratio van rijpende paprikavruchten aan de plant

Fransen, Thomas (2011, August 18)
Determination of specific reflectance curves for different parts of the sweet pepper plant

Zundert, Tom van (2011, August 22)
Data acquisitie voor de validatie van het GWorkS-tomato model

Hoog, Dirk de (2011, August 22)
Meetmethoden voor oppervlaktebepaling van urineplassen op betonnen stalvloeren

Oomen, Mark (2011, August 23)
Milieubelasting van dierlijke mest verlagen door middel van een TMCS-installatie

Jongmans, Dré (2011, August 25)
Ontwikkeling van een algoritme voor de verwerking van brandstofmetingen gekoppeld aan RTK-GPS gegevens

Vollebregt, Maurice (2011, August 25)
Ontwerp en implementatie van een hardware architectuur voor master-slave control

MSc projects completed in 2011

Marx, Gaston (2011, January 6)
Measuring leaf movement of tomato plants

Kemp, Hendrik (2011, January 18)
Methodical design for an integral sustainable laying hen husbandry system

Stols, Hans (2011, February 28)
Cucumber volume measurement for an augmented reality harvest support system

Laar, Teus van (2011, March 11)
Improved modeling of ammonia emissions from dairy cow houses

Kea, Maarten (2011, March 31)
Cow behaviour in a mobile AMS farm system

Middel, Wicher (2011, April 7)
Volume estimation of potatoes using 3D machine vision

Rahmann, Mohammad Moshiur (2011, April 14)
Root-zone Eca measurement with an EM38; spatial interpolation techniques

Haesen, Gaston (2011, May 24)
A new floor design for a dairy cow house to reduce ammonia emission

Slingerland, Reino (2011, May 31)
Innovative way of applying rapeseed oil on bedding in broiler houses to reduce dust emission

Boomen, Henri van den (2011, June 23.)
New heat exchanger applications for sustainability broiler production

Ubaghs, Guido (2011, July 14)
Validation of an ethylene sampling system in the transport of perishable products

Rahmann, Mohammad Moshiur (2011, August 10)
Verification of the GWorkS-rose model for a stationary rose production system

Uijterlinde, Gerard (2011, October 04)
Navigation of an agricultural master-slave system

Ruizendaal, Jos (2011, October 27)
Fruit visibility analysis for different camera positions in sweet peppers

Slager, Bart (2011, November 8)
Feasibility of combined production of algae and tomatoes in a Dutch greenhouse

Education

The Farm Technology Group is one of the main suppliers of courses for the Bachelor Biosytems Engineering (BAT) and the MSc Agricultural and Bioresource Engineering (MAB). For that program, the chairgroup has the following courses on offer:

FTE-12303 Introduction Biosystems Engineering part 1 (Dutch)
FTE-12803 Introduction Biosystems Engineering part 2 (Dutch)
FTE-13303 Introduction to Engineering 1 (Dutch)
FTE-13807 Engineering 2 (Dutch)
FTE-24306 Research Methods Biosystems Engineering 1 (Dutch)
FTE-24806 Engineering Design (Dutch)
FTE-25303 Building Physics and Climate Engineering (English)
FTE-25806 Research Methods Biosystems Engineering 2 (Dutch)
FTE-30306 Livestock Technology (English)
FTE-31306 Greenhouse Technology (English)
FTE-32306 Advanced Soil Technology (English)
FTE-32806 Automation for Bio-production (English)
FTE-33306 Advanced Biosystems Engineering (English)
FTE-33806 Biosystems Design (English)
FTE-34306 Evaluation and Redesign of Biosystems (English)
FTE-50806 Conservation Agriculture (English)
FTE-704nn MSc Internship Farm Technology
FTE-80812 Bachelor completion Agrotechnology
FTE-804nn MSc Thesis Farm Technology (24, 27, 31, 33, 36, 39 credits)
SCO-22306 Sensor Technology
YEI-80324 Contribution Bachelor thesis Biosystems Engineering

FTE-12303 Introduction Biosystems Engineering part 1 (Dutch)
This course is the introduction course to the domain biosystems engineering. Students get an overview of the technology used in different biosystems for the production of food and non-food and they will get a good insight into the role of the different courses in the study programme.

Systems approach is the connecting thread in the course and the course will start therefore with an introduction to systems theory and analysis. The course then continues with lectures, tutorials, and practicals on topics relevant in nowadays biosystems engineering: automation, energy, environment and welfare, climate control, and (agro)production chains and logistics. Special attention is given to the importance of the (agro)production chain for technology in biosystems. Students work in small groups on calculations and computer simulations related to real problems in the area of biosystems engineering. Excursions are organized to make the technology visible to the students on different levels in the production chain (farm, processing industry, wholesaler) visible.

The course also incorporates some skills modules. The module CCI makes the students acquainted with the more advanced functions of office applications (Word, PowerPoint and especially Excel). The module Information literacy makes the students acquainted with retrieval of information from different sources. Students have to prepare a report on relevant technology in the framework of biosystems engineering. An introduction to oral presenting is also part of the course and at the end of the course the students have to give a brief presentation on the report they prepared.

In the first part are the introduction to systems theory and analysis, two of the five relevant topics, the module CCI and the introduction of the module information literacy.

FTE-12803 Introduction Biosystems Engineering part 2 (Dutch)
This course is the continuation of FTE-12303 Introduction Agrotechnology part 1. See the description of that course. In the second part consists of the remaining three relevant topics, the module oral presenting and the preparation of the report.

FTE-13303 Introduction to Engineering 1
In this course the students are introduced to selected engineering topics that demonstrate how engineers approach problem solving and arrive at correct solutions. These subject areas are common to most engineering disciplines that require the application of fundamental engineering concepts. Subjects in the course are engineering solutions, presentation of technical information, engineering measurements and estimation, dimensions and units, mechanics, material balance, energy, and electrical theory. Students will also follow some practicals at ptc+ in Ede. Attention is also paid to the engineering profession. This course includes some excursions to relevant companies. The students also have to prepare a brief internship to be spent (in the next period) at a relevant company or organization in the field of biosystems engineering.

FTE-13807 Engineering 2 (Dutch)
This course is the second part of introduction to engineering. In this part there is a module on CAD (Computer Aided Design), electronics, and lectures and tutorials on mechanics. There are also some excursions to relevant industries or organizations and students have to fulfil a brief internship. At the end they have to prepare and present a poster on their experience and inform the other students on their experience.

In the CAD module the students learn the basic principles of CAD. It starts with making hand sketches of simple technical objects and continues with the learning of a 3D modelling programme (AutoCAD Inventor). In this programme parts of technical systems are modelled and technical drawings documented. Finally, calculations on mechanical stress will be done.

The module electronics gives an introduction to the basics of modern electronics. From the basic elements (resistors, capacitors and coils) circuits will be built and analyzed with a focus on the frequency response. The theory of diodes and transistors will be explained and tested in practice. All this being the start of more advanced elements like the operational amplifier in both feedback and non-feedback applications. Furthermore the production process (steps and techniques) of integrated circuits (chips) will be presented. In the course students will also learn about basic digital circuits (gates, flip-flops) forming the fundamental base of modern digital computers.

FTE-24306 Research Methods Biosystems Engineering 1 (Dutch)
In this course the students learn the different steps of doing research: problem analysis - problem definition - objective of the research - research questions - project proposal - execution of the research - presentation of results - discussion - conclusion. The students will exercise these different steps by a number of related assignments.

Included in the course are practical exercises where the students are faced with biological and natural variability and where they are instructed how to approach this phenomenon present in most biosystems.

In this course the students prepare (in groups) their own research project (selecting topic, making project proposal, search for information) which is to be executed in the course Research methods biosystems engineering 2.

FTE-24806 Engineering Design

In this course the students will learn the consecutive steps of the structured design methodology according to Van den Kroonenberg and exercise the related tools. Main content parts of the course are making an inventory of the needs, defining the design problem, perform a novelty and state-of-the-art research (patent search), learn and apply intuitive and discursive methods, setting up a brief of requirements, assessment of the main function, function analysis (IDEF0), developing a morphological chart, evaluation of alternatives, and systematic choosing of solutions.

In groups students will design a technical device in CAD. They have to create the different parts, assemblies and documentations of the device. As a result 3D model of the device is generated with engineering drawings that allow prototyping of the (best) concept. The student will exercise methods and use design supporting software in the case study. An excursion will be made to manufacturing industry to show the students the practice of engineering design and manufacturing in industry.

FTE-25303 Building Physics and Climate Engineering (English)

This course is the continuation of Physical Transport Phenomena and has the objective to introduce you to the climate engineering items relevant for biosystems engineering. The following subjects are part of the course:

- building physics - thermal insulation of constructions and thermal stability of constructions and room systems;
- psychrometrics - Physical properties of humid air and air conditioning processes;
- comfort areas for indoor climate;
- ventilation requirement calculation;
- design and evaluation of air distribution systems;
- energy demand for agroproduction in buildings;
- solar energy - passive and active for solar energy collection and use;
- (data processing in Excel).
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FTE-25806 Research Methods Biosystems Engineering 2 (Dutch)

In this course the students have to execute in groups their own small research project. The students have to prepare a report on their project and present the results orally. Explicit attention in this course will be given to the different aspects of group work (team activities, organizational, social).

FTE-30306 Livestock Technology (English)

Developments in livestock production systems are driven by (internal) farm and sector opportunities, market & consumer demands, national and international legislation and societal issues, as covered by the sustainability concept People, Planet & Profit. This course focuses on technological aspects and processes in livestock production systems and on development and application of new technology to support realization of sustainable animal production systems. In this course these systems are mainly delimited to on farm production and directly related links in the food chain. The interactions and relations between the biological entities (at animal level), technological artifacts and human management play a central role. The course deals with technological aspects of five sustainability themes and with three engineering themes. The five sustainability themes are animal welfare (animal needs & surroundings), animal health, and environment (gaseous emissions and animal waste handling), food safety, and food quality. The three engineering themes are 1) building physics and indoor climate 2) mechanics of building constructions (statics) and 3) farm management and logistics. For each theme current systems and technology are described, in depth knowledge on the technology is presented, management and control of related problems are dealt with as well as the latest innovations in each area. Typical examples of subjects are 1) constraints for the design of sustainable systems including societal demands, 2) sensors and information technology for quality monitoring, product processing, milking and feeding systems, 3) the concept of precision livestock farming, 4) management of the aerial environment of animals, 5) minimization of emission hazardous gases, and waste processing.

FTE-31306 Greenhouse Technology (English)
The content of the course focuses on engineering aspects of greenhouse horticulture systems in relation to crop growth and development. The course aims to prepare for a major on Greenhouse Engineering and puts emphasis on calculation and analysis. In depth topics of the course are crop response and growth factors, physics of the greenhouse climate, cultivation systems, greenhouse construction, aerial environment, root environment, greenhouse climate and equipment for climate control, new and smart technology.

As a student you will be confronted with theoretical backgrounds and with methods that are generally used in protected cultivation. You will use this knowledge in exercises (both manual and model based) and in analysis of an integrated system. Focus is both on the Dutch and on the international protected cultivation.

FTE-32306 Advanced Soil Technology (English)
This course offers a common part with an in-depth treatment of various aspects of soil technology and tillage, such as: (a) methodologies and techniques for measuring soil physical, mechanical and dynamical parameters, both in the field and in the laboratory; (b) approaches for research in tillage and soil mechanics, modeling the effects of tillage on soil structure and related parameters (water, gas, strength, erosion), including prediction methods. In this part, each student studies a scientific paper and reports approach, methodology and findings to fellow students, followed by discussion.

In addition to this common part, the student chooses to study in detail a case, leading either to a specialization in 'agro technology' (labor, machinery, agronomy) or to an emphasis on tropical subjects (tillage systems for various climatic regions, irrigated farming and conservation tillage systems).

FTE-32806 Automation for Bio-production (English)
Agriculture is challenged to overcome increasing labor costs, decreasing availability of labor and increasing demands concerning precision, product quality and reduction of environmental and animal load. As can be seen in Western Europe an important solution is to replace human labor by automation in areas such as arable farming, livestock farming, and horticulture. Examples of automation are milking robots, GPS steering of tractors, autonomous vehicles and automated harvesting in greenhouse production. The design and implementation of such automated systems is expected to be at the heart of agricultural innovation the next decades.
The guideline for this course is taken from the robotics domain and is stated as: 'Robotics is the intelligent transformation of perception into mechanical action'. To realize these transformations sensors, actuators, manipulators, vehicles, computers and decision systems, are important components. These components and how they may be applied to design automated agricultural systems constitute the contents of this course.

The theoretical part of this course will be presented during lectures. Practical assignments concern the design, programming and control of robot manipulators and autonomous vehicles.

FTE-33306 Advanced Biosystems Engineering (English)

This course is the introductory course for the MSc Biosystems engineering. The central theme for the course is how society is going to be prepared in the post-fossil fuel area for the production of food, fuel, and biomaterials. The main objective is to introduce a systematic approach to technology development and engineering of systems for a biobased society. The starting point is the technology for sustainable (future) production of biomass for food or non-food. An important connecting thread throughout the course is the development of alternative systems for the production of biomass where system boundaries may move. Today's production of biomass is organized on-farm and the processing is off-farm but this may be challenged in the future to reach a more optimal and sustainable system. Chains and cyclic processes are important since solutions are expected to arrive from approaches beyond farm level.

The course also gives an overview of the different techniques available for a biosystems engineer and provides a link to different other courses in the programme.

FTE-33806 Biosystems Design (English)

In the course the students apply a structural engineering design method to a typical biosystems engineering related design problem with a focus on system innovation. Sustainability aspects of ecological, economical and social order play an important role in the course. The problems / cases in this course are more complex and on a higher systems level than in the course Engineering Design (FTE-24806). It includes an extensive state-of-the-art analysis (semantic search, patent and knowledge research, market exploration and innovation trend analysis). Important aspects of the course are also the organizational aspects of the design project, e.g. the role of stakeholders and the design contract. The design methods taught in FTE-24806 are starting point and extended with methods like technology landscaping, theory of inventive problem solving and predictive failure analysis. Some typical case studies of technological innovations in biosystems have to be studied and will be presented and discussed. Students have to apply the theory and the ideas behind it to their own design case.

Part of the course is a multiple day excursion in which relevant organisations, universities, and industries in the Netherlands and surrounding countries are visited. The students have to write a report of this excursion. This multiple day excursion is organised together with the excursion in the course FTE-34306 Evaluation and Redesign of Biosystems.

FTE-34306 Evaluation and Redesign of Biosystems (English)

This course focuses mainly on the evaluation of design concepts based on innovative ideas and technology for new biosystems. These biosystems have to be evaluated on different aspects to determine whether the ideas are realistic or not (the critical success factors). A preliminary design will be evaluated on different aspects to determine whether the idea will be feasible or not and determine the critical success factors. The students will learn and apply different types of evaluation (economical costs and benefits, various environmental impacts, physical layout and impact, timeliness, work methods and labor requirement,.....) Important aspect is that for a full assessment on all aspects the evaluation of the design concepts has to be performed under limiting availability and uncertainty of information. Students have to address experts and various information sources to make best educated assumptions, and analyze the importance of the different factors by a sensitivity analysis of the different success factors for the unknown parameters. They have to reflect on the chosen assumptions and calculation methods and indicate which of them are limiting.

The course comprises a multiple day excursion with visits to relevant organizations, universities, and industries in the Netherlands and surrounding countries. The students have to write a report of this excursion. This multiple day excursion is a joint activity with the excursion in the course FTE-33806 Biosystems design.

FTE-50806 Conservation Agriculture (English)

This course examines the concept of Conservation Agriculture (CA) and its effects on ecosystem services. CA is a system based on integrated management of available soil, water and biological resources, combined with as little external inputs as feasible. CA relies on three principles, which must be considered together for appropriate understanding, design and application:

- a (semi-)permanent organic soil cover in order to protect the soil physically from sun, rain and wind and to feed the soil biota;
- minimal disturbance to the soil through no or reduced tillage, and;
- crop rotations to optimize the use efficiency of natural and external resources. CA is spreading rapidly in Europe and abroad as a potentially powerful basket of technologies, applicable in a wide range of environments to achieve sustained production, reduce environmental and economic risks and protect land and water resources. However, its effect on soil ecosystem services generally receives little attention.

Course components:

- replacement of mechanical by biological tillage (soil micro-organisms, roots and soil fauna taking over the tillage function)
- biological soil fertility management and water balancing through soil cover and crop rotation management
- trade-offs between various uses of crop residues;
- the choice and management of (cover) crops and crop rotations are meant to ensure sufficient biomass production of food and other crops, livestock feed and residue cover for the soil.

Crop residue management is meant to stimulate soil structure formation by the soil biota, improve soil fertility and soil water management and help to control diseases, pests and weeds with less dependence on pesticides. Novel technologies and equipment for field operations CA implies the design and use of modern precision agriculture technologies such as the use of RTK/GPS and adapted equipment to cultivate the land without trafficking; Management and management options at farm level;

CA demands a different, unconventional way of making choices on crops and crop rotations, and needs to consider alternative and additional factors for taking decisions on how to manage the farm Soil ecosystem services

CA claims to be beneficial in terms of reduction of soil erosion and water run-off and the sustained provision of ecosystem services, such as water storage and supply under conditions of water surpluses and shortages, respectively; the retention of nutrients; the reduction of soil-borne pests and diseases; and the sequestration of carbon.

The course critically addresses the above issues by discussing and studying the various components of CA, with special emphasis on management and soil. It will analyze the bottlenecks in application of CA in order to find an explanation of the successes as well as the failures..

SCO-22306 Sensor Technology
Sensing is an important part of automation in agriculture. The focus of the course is on a proper usage of sensors. Therefore this course presents briefly a number of different sensors to measure pressure, temperature, pH, velocity, acceleration, position, distance and angles etc. This course teaches you how to obtain information concerning accuracy and disturbances from datasheets and other documentation that comes with any sensor. Different types of sensor errors and ways to suppress them can be distinguished and are addressed in this course. This course also teaches different measurement principles such as compensation and Wheatstone bridges. These principles guide the engineer when designing a measurement set-up. The accuracy of sensors can often be improved by calibration that is also considered in this course.

Signal conditioning, analog to digital (A/D) conversion and sampling (frequency spectrum, Shannon' s theorem, spectral analysis of signals) are important issues treated in this course as well as related phenomena as aliasing and filtering.

Considerable attention will be given to imaging sensors. Imaging sensors are a very special, sophisticated type of sensors that are being used to obtain 2 or 3 dimensional information of a system. These sensors become increasingly important in agricultural automation. The processing of the resulting images using computer vision techniques constitutes an important part of this course.

YEI-80324 Bachelor thesis Biosystems Engineering

The student works individually under supervision of a staff member on a thesis subject relevant for the domain of the study programme. The student has to analyse the problem, prepare a project plan, execute the project plan, do experiments if necessary, write a thesis report and present the work in an oral presentation. The essence of the course is that the student proofs that she/he master the competences related to the BSc Biosystems Engineering.

Publications

Papers in peer reviewed journals

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Bontsema, J.; Henten, E.J. van; Gieling, T.H.; Swinkels, G.L.A.M. (2011)
The effect of sensor errors on production and energy consumption in greenhouse horticulture
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Farmers' assessment of soil quality in rice production systems
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Hugo
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