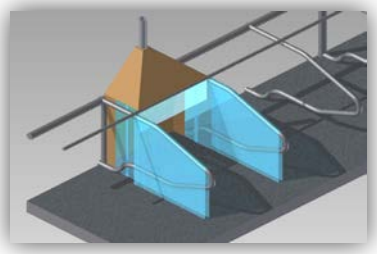
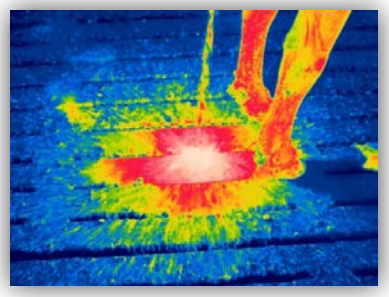
FARM TECHNOLOGY GROUP

ANNUAL REPORT 2014





WAGENINGEN UNIVERSITY
WAGENINGEN UR

Wageningen University
Farm Technology Group
Building 107 (Radix)
Droevendaalsesteeg 1
6708 PB Wageningen

Contact:
+31 (0)317-482980
Miranda.tap@wur.nl

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Objectives and Research Area

Vision, Mission and Objectives

The mission of the Farm Technology Group (FTE, further denoted as 'the group' and 'we') is: "To enhance, exploit and disseminate the potential of technology in agricultural production systems to fulfil the needs of mankind in a sustainable way".

We strongly believe that agricultural production can be sustainable and that technology addressing agricultural production at systems level is indispensable to achieve this. Specific sustainability challenges for our working field relate to the scarcity of labour, plant and animal health, the depletion of inputs and resources used in production systems, and losses and emissions to the environment with negative side effects. In our view, the only way to improve global food security is to significantly improve on these multiple sustainability challenges at the same time.

1.2 Research Area / research line(s)

The group works in the field of *Biosystems Engineering* (formerly called Agricultural Engineering). Biosystems Engineering is defined as an inter-disciplinary scientific approach that investigates, develops and combines methods and tools from technical sciences with biological, environmental, agricultural and social sciences. Building on the fundamental scientific approaches of studying and understanding systems, we aim to actively deploy the gained knowledge in and develop new knowledge and methods for the design and operation of production systems. These production systems, also called biosystems, encompass technical components and biological organisms (i.e., plants and animals), as well as human interactions in both 'traditional' systems (i.e., arable and livestock farming, and protected cultivation) and novel production systems (e.g., aquaculture, algae, seaweed and insects).

The group focuses on two research lines:

1. System design:

- This design approach is based on established engineering design methods that enable the
- generation of new and break-through solutions, and combinations thereof, for identified
- functions within given requirements.
- Challenge: the complexity of designing systems that can fulfil multiple long-term sustainability
- requirements and that do not generate new unwanted side-effects.
- Our focus/approach: further development of the design methodology and real-life application.

2. Sensing, modelling & operation:

- Sensing refers to using technical sensors to measure phenomena of interest, including data and
- signal processing; modelling refers to formalizing application-specific knowledge and signals;
- and operation refers to manipulating system inputs so that the system shows predefined desired
- behaviour in space and time.
- Challenge: to understand and to control biosystems in the face of biological variability and uncertainty in inputs like the weather.
- Our focus/approach: to systematically explore, translate and build models, algorithms and
- technologies for biosystems up to the level of proof of principle.

1.3 Strategy

The group's research strategy consists of the following:

- We apply a systems approach that starts from the needs of humans, animals and plants, instead of one that is technology driven. We concentrate on a generic approach, i.e., developed methodologies and technology should be transferable to other domains. This approach results in a profile with ample attention to understanding why technology and solutions work, instead of simply making technology work.
- We focus on four different areas of technical expertise: 1) sensors and data processing, 2) modelling
- and simulation, 3) design methods, and 4) systems control.
- We prefer to collaborate on inter-disciplinary projects with experts from the application domains and other scientific fields, inside and outside WUR.
- In the past 6 years, we have realized the following key achievements:
- The group has grown in several ways: three new staff members have been appointed; the number of
- PhD candidates has risen; output has focused more on fundamental research, which has increased
- the number of journal articles and their impact.
- The group has become better embedded in the international network through membership in
- multiple organizations, networks and editorial boards, has collaborated more with industry in BSc,
- MSc and PhD projects, and has shown a growing exposure in the press.
- Following the advice of the peer review committee in 2009, the group focuses its work on two
- research lines: 1) System design, and 2) Sensing, modelling and operation.
- We strive to become a leader in our research domain in the coming 5-10 years. To achieve this goal, we will implement the following actions:
- We will create stronger cooperations with life-sciences groups and expand our research's
- interdisciplinary character.
- We will establish closer collaborations with technical universities to bridge the gap between up-front technology and applications in agriculture.
- We will investigate possibilities and challenges of novel upcoming applications in precision livestock farming and precision agriculture, phenotyping, intercropping, and novel production systems.

1.4 Research environment and embedding

The group participates in two graduate schools: PERC (Production Ecology and Resource Conservation) and WIAS (Wageningen Institute of Animal Sciences). The group also has well-established connections with individual groups both at the University (Horticulture and Product Physiology, Plant Production Systems, Crop Systems Analysis, Plant Physiology, Animal Production Systems, Adaptation Physiology, Quantitative Veterinary Epidemiology, Geo-information Science and Remote Sensing) and at DLO (Wageningen Livestock Research, Greenhouse Technology, Plant Research International, and Food and Biobased Research). Through these solid collaborations, our work is well embedded in WUR's active research fields in traditional plant and animal production systems; in linking themes like manure and nutrients, vision and robotics; and in work on new production systems for insects, algae and fish.

The Farm Technology group occupies a unique position as the only academic group in the Netherlands in the field of Biosystems Engineering that connects life sciences and technology. Collaboration in the Netherlands is established with Dutch technical universities that have a stronger mono-disciplinary focus on technology.

Worldwide, several academic groups work in the field of Biosystems Engineering. Our group, however, distinguishes itself from these groups through the following four aspects: 1) a stronger

interdisciplinary systems approach, 2) a research focus that is societally driven instead of technology driven, 3) a stronger focus on design, and 4) an interconnection between System design and Sensing, modelling, and operation.

Our international collaborations are exemplified by the following:

1) Visiting professorship Van Henten at Ehime University (Japan) in the field of sensing and robotics,
2) Coordinator of the Field Robot Event with 10 European universities, e.g., Hohenheim University
3) (Germany) and Helsinki University of Technology (Finland).
4) Collaboration on EU projects (FutureFarm, CROPS) in the field of robotics with universities in Spain, Finland, Greece and Israel.
5) Member of the advisory board ABC Robotics Institute associated with Ben Gurion University (Israel),
6) EU project BioBusiness with KU Leuven (Belgium), Agric.Research Organisation (Israel), and 5 other universities and 3 commercial partners.
7) EU project ReUse Waste with 10 universities and research centres in Europe.
8) Membership and participation in the IRCAEW centre with several universities in the USA, Aarhus
9) Univ. (Denmark), Univ. South Queensland (Australia), North-East agricultural Univ. and Chinese Agricultural University (China).

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.wageningenur.nl/fte

Prof.dr.ir. E.J. van Henten

Prof.dr.ir. P.W.G. Groot Koerkamp

General information

Wageningen University

Plant Sciences Group

Farm Technology Group

Address: Droevendaalsesteeg 1

6708 PB Wageningen

The Netherlands

Phone: +31 (0) 317 482980

Email: miranda.tap@wur.nl

Website: http://www.wageningenur.nl/fte

Group members – permanent staff

Professors

Prof.dr.ir. P.W.G. Groot Koerkamp	peter.grootkoerkamp@wur.nl	+31 317 480831
Prof.dr.ir. E.J. van Henten	eldert.vanhenten@wur.nl	+31 317 483328

Assistant professors/lecturers

Dr. F. Helderman	frank.helderman@wur.nl	+31 317 482129
Dr.ir. J.W. Hofstee	janwillem.hofstee@wur.nl	+31 317 484194
Dr.ir. W.B. Hoogmoed	willem.hoogmoed@wur.nl	+31 317 482980
Dr.ir. S. van Mourik	simon.vanmourik@wur.nl	+31 317 481275
Ir. A. van ’t Ooster	bert.vantooster@wur.nl	+31 317 482143
J.C.A.M. Pompe, MPS	hanneke.pompe@wur.nl	+31 317 484193

Teaching assistant

Ing. S.K. Blaauw	sam.blaauw@wur.nl	+31 317 482131

Secretary

M. Tap - de Weme	miranda.tap@wur.nl	+31 317 482980

Group members – temporary staff

P.J.M. van Beveren, MSc	peter.vanbeveren@wur.nl	+31 317 483383
Drs. I.D.E. van Dixhoorn	ingrid.vandixhoorn@wur.nl	+31 320 293514
J.M.M. IJsselmuiden, MSc	joris.ijsselmuiden@wur.nl	+31 317 481258
Ir. M.F. Mul	monique.mul@wur.nl	+31 320 293535
J.W. Snoek, MSc	dennis.snoek@wur.nl	+31 317 484947
H.K. Suh, MSc	hyun.suh@wur.nl	+31 317 483320
B.A. Vroegindeweij, MSc	bastiaan.vroegindeweij@wur.nl	+31 317 482154
H.J.E. van Weeghel, MSc	ellen.vanweeghel@wur.nl	+31 320 238240
L. Wu, MSc	liansun.wu@wur.nl	+31 317 482202

Prof.dr.ir. Eldert (E.J.) van Henten

Contact information

Prof.dr.ir. E.J. van Henten
Email: eldert.vanhenten@wur.nl

Function(s)

Professor of Biosystems Engineering
Head of Farm Technology Group.

Education

1994 PhD, Wageningen University, Wageningen, The Netherlands
1987 MSc, Wageningen University, Wageningen, The Netherlands (with honours)

Expertise

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

Current activities and memberships

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: EurAgEng, ISHS (chair of working group on sensors, vision and robotics), BSHS, IFAC TC 8.1 Control in Agriculture, IEEE Robotics and Automation Society (co-chair of the TC agricultural robotics and automation), RoboNed (chair of SIG on agricultural robotics), NVTL, euRobotics (coordinator of TG Agricultural Robotics).

Contribution to courses

FTE12303, FTE12803, FTE31306, SCO22306, FTE32806, FTE34806, YEI80812, FTE80436

Sweet pepper harvester developed in EU project CROPS

Prof.dr.ir. Peter (P.W.G.) Groot Koerkamp

Contact information

Prof.dr.ir. P.W.G. Groot Koerkamp
Email: peter.grootkoerkamp@wur.nl

Function(s)

Professor of Biosystems Engineering
Senior scientist at Wageningen UR Livestock Research

Education

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

Expertise

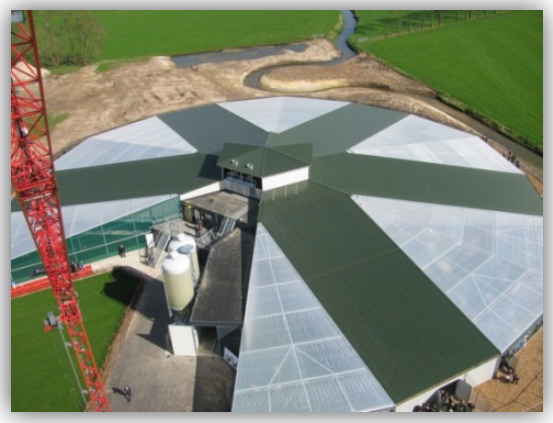
System thinking, production technology for animal production systems, innovation processes, sustainability of animal production systems, technology development, measurement of environmental aspects of animal production systems (gaseous emissions, dust, losses, energy), poultry and dairy production, statistical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

Current activities and memberships

Management of Farm Technology Group, teaching, supervision of PhD, MSc and BSc students. Membership of editorial board of IJABE (China), and member of several international professional organizations (president of NVTL, EurAgEng, WPSA, ISAH).

Contribution to courses

FTE-12303/12803, FTE-30306, FTE-33806, FTE-80436, FTE-34306



Roundel

Ing. Sam (S.K.) Blaauw

Contact information

Ing. S.K. Blaauw
Email: sam.blaauw@wur.nl

Function(s)

Practical supervisor, Farm Technology Group, Wageningen UR
IT support engineer, Facilities and Services, Wageningen UR

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, Teaching

Current activities and memberships

As a practical supervisor at the Farm Technology Group I teach various practical trainings in technical drawing, 3D design and programming robots. I give technical support to research projects, including setup and execution of measurements. I am responsible for the IT of the chaigroup, webmaster of www.fieldrobot.com and www.ieee-ras.nl and member of the field robot event team.

Contribution to courses

FTE-13807, FTE-24806, FTE-32806, FTE-34306

Students at Field Robot Event 2014

Dr. Frank (F.) Helderman

Contact information
Dr. Frank Helderman
Email: frank.helderman@wur.nl

Function(s)
Lecturer, Farm Technology Group.

Education
2012 PhD, VU University Amsterdam, Amsterdam, The Netherlands
1996 MSc, VU University Amsterdam, Amsterdam, The Netherlands

Expertise
Physics, biophysics, bioengineering, optics, fluid mechanics, modelling, finite element modeling, computational fluid mechanics

Current activities and memberships
Teaching and coordinating courses

Contribution to courses
FTE-13303, FTE-13807, FTE-25303, FTE-30306, FTE-31306, FTE-34806, FTE-34306

Lecture room C 103 in Forum

Dr.ir. Jan Willem (J.W.) Hofstee

Contact information

Dr.ir. J.W. Hofstee
Email: janwillem.hofstee@wur.nl

Function(s)

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

Education

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

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). Member of editorial board Computers and Electronics in Agriculture. Member of the editorial Advisory Board of Agricultural and Food Science. Treasurer of NVTL.

Current activities and memberships

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

Contribution to courses

FTE12303, FTE12803, FTE13303, FTE13807, FTE25806, YEI80324, FTE804nn

Automated detection and control of volunteer potato plants

Dr.ir. Simon (S.) van Mourik

Contact information

dr.ir. Simon van Mourik
Email: simon.vanmourik@wur.nl

Function(s)

Assistant Professor of Biosystems Engineering, Farm Technology Group
Wageningen University

Education

2008 PhD, Twente University, the Netherlands,
2003 MSc, Groningen University, the Netherlands

Expertise

Mathematics, statistics, transport physics, fluid mechanics, systems and control theory, systems biology, biosystems engineering, dynamic systems, numerical mathematics. Current objective is to integrate dynamic systems with statistical modeling, for experiment-driven, model-based analysis and control of variable and uncertain biosystems.

Current activities and memberships

Research, teaching, supervision of PhD, MSc and BSc students. Acquisition. Educational courses (BKO).

Contribution to courses

FTE-26306, FTE-25806, FTE-34806, FTE-24306

LED it be

Ir. Bert (A.) van ’t Ooster

Contact information

ir. A. van ’t Ooster
Email: bert.vantooster@wur.nl

Function(s)

Assistant professor at Farm Technology Group, Wageningen University,
PhD student at Wageningen UR Greenhouse Horticulture

Education

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

Expertise

Methods in biosystems design, System analysis, Modelling, Discrete-event modelling of operational processes, Physical transport phenomena, Dynamic balance equations, Greenhouse technology, Modelling of crop growth, Use of resources, Indoor climate, Energy demand, Natural and forced ventilation, Air conditioning, Psychrometrics, Active and passive solar energy use.

Current activities and memberships

PhD-research, teaching and coordinating courses, supervision of MSc and BSc students, acquisition.
Member of (inter)national professional organizations: ISHS, EurAgEng, NVTL, KLV.

Contribution to courses

FTE-24306, FTE-24806, FTE-25303, FTE-33806, FTE-31306

Greenhouse Technology course 2013-2014 (FTE-31306) received: Excellent Education Prize 2015

Hanneke (J.C.A.M.) Pompe, MPS

Contact information

J.C.A.M. Pompe, MPS
Email: hanneke.pompe@wur.nl

Function(s)

Lecturer in Biosystems Engineering
Coordinator of Farm Technology Internships

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

Systems thinking; Technology for dairy production systems; Sustainability of animal production systems; Automatic feeding and milking systems; Relations between dairy cow behaviour, labour requirement, technology and facility lay-out; Discrete-event simulation and logistics.

Current activities and memberships

Coordination of Farm Technology Internships; Process coaching for ACT (Academic Consultancy Training) teams; Teaching; Acquisition of ACT cases
Member of NVTL, EurAgEng, VIAS, VWI

Contribution to courses

FTE-25806, FTE-70400, YMC-60809

Organizations that hosted Farm Technology interns in 2014

Dennis (J.W.) Snoek MSc

Contact information

Dennis (J.W.) SnoekMSc.
Email: dennis.snoek@wur.nl

Function(s)

PhD candidate in Biosystems Engineering, and
Teacher in Biosystems Engineering.

Education

2010 MSc, Wageningen University, Wageningen, The Netherlands
2008 BSc, Wageningen University, Wageningen, The Netherlands

Expertise

Ammonia emission in livestock farming, especially from dairy cow houses; Measurement of gaseous emissions from livestock housing; Housing of livestock, with respect to all aspects being animal welfare, environment, and technological; Engineering Design, system thinking.

Current activities and memberships

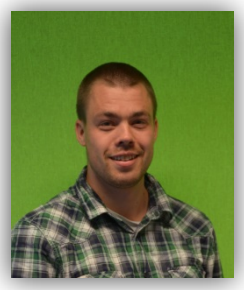
Working on PhD research project entitled: “Development of an assessment strategy to determine the ammonia emission from dairy cow houses”. This work consist of modelling, development of measurement equipment and methods, execute measurements, and statistics. Within this project supervise MSc and BSc students doing their thesis. Teach the course “Engineering Design” and support other courses. Membership of professional organisation NVTL, EurAgEng, CIGR.

Contribution to courses

FTE-24806, FTE-25806, FTE-33806, FTE-34306, FTE-80436, YEI-80324>

Measure urine puddle depth in a Dutch dairy cow house, together with a student.

Bastiaan (B.A.) Vroegindeweij MSc



Contact information

Bastiaan Vroegindeweij
Email: bastiaan.vroegindeweij@wur.nl

Function(s)

PhD Candidate

Education

2007 BSc Agrotechnologie, Wageningen University, Wageningen, The Netherlands
2010 MSc Agricultural and Bioresource Engineering, Wageningen University, Wageningen, The Netherlands (with honours)>

Expertise

Automation and robotics, localisation, path planning, machine vision
livestock production and related technology with focus on poultry,
system analysis, systems design, software development, hands-on engineering

Current activities and memberships

PhD research on Automation for Poultry Production and supervision of MSc and BSc students.

Contribution to courses

YEI80324, FTE804nn

Poultrybot driving among young white hens in a commercial setting

Ellen (H.J.E.) van Weeghel MSc

Contact information
H.J.E. van Weeghel
Email: ellen.vanweeghel@wur.nl

Function(s)
PhD candidate at Biosystems Engineering

Education
2011 PhD, Wageningen University, Wageningen, The Netherlands
2001 Biology, Wageningen University, Wageningen, The Netherlands

Expertise
Design methodology of complex adaptive systems, system thinking, innovation and transition processes, sustainability of animal production systems, multi-stakeholder processes. Special interest in animal welfare and design methodology for sustainable production

Current activities and memberships
PhD work and activities

Contribution to courses

Example of overcoming trade-offs

Dr. ir. Joris (J.M.M.) IJsselmuiden

Contact information

Dr. ir. Joris IJsselmuiden
Email: joris.ijsselmuiden@wur.nl

Function(s)

Postdoc agricultural robotics and informatics

Education

2014 PhD Informatics, Karlsruhe Institute of Technology, Germany (sehr gut)
2006 MSc Artificial Intelligence, University of Groningen, The Netherlands (with honor)

Expertise

Robot cognition (modelling, reasoning, and planning)
Machine perception / computer vision
Robotics in the agricultural domain
Machine learning / pattern recognition
High-level reasoning based on fused heterogeneous machine perception
Human machine interaction

Current activities and memberships

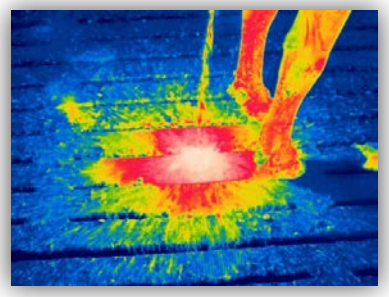
In 2014, I was directly or indirectly involved in the following robotics projects: 1) Monitoring crops from the sky: visual navigation and image analysis, 2) Collecting floor eggs: localization, path planning, and vision in a crowded and repetitive environment, 3) Detetcing weeds in sugar beet fields: dealing with varying light conditions, and 4) Harvesting sweet peppers: object classification and localization, motion planning, dealing with variation.

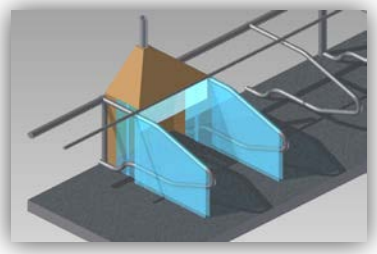
Contribution to courses

FTE-32806 (Automation for Bioproduction), Capita Selecta (Field Robot Event), Pattern recognition (new MSc course in 2016), FTE-80400 (MSc thesis), YEI-80324 (BSc thesis)

Development of a UAV for autonomous crop monitoring

Research projects





Bastiaan (B.A.) Vroegindeweij MSc

Email: bastiaan.vroegindeweij@wur.nl
Supervisors: Dr.ir. Joris IJsselmuiden, Prof.dr.ir. Eldert van Henten, Prof.dr.ir. Peter Groot Koerkamp
In collaboration with: -
Project funding: partial funding from Fonds Pluimveebelangen

Automation for Poultry Production

In the project Automation for Poultry Production, we work on the development of automation to take over heavy, repetitive, and/or less challenging tasks in the poultry house, to improve welfare of both farmer and animal. More specifically, we work on an autonomous vehicle that has the ability to localise and navigate safely throughout the poultry house, and is capable of collecting floor eggs. To reach this, we have the following needs or objectives:

1. Accurate localisation inside the poultryhouse
2. (path) planning for specific tasks
3. Sensing the environment to recognize relevant objects
4. Integrate this into a vehicle that can operate autonomously and safe to collect floor eggs

For the first objective, we implemented a PF-based localisation methods of which in-depth evaluation is expected to be finished in the beginning of 2015. Furthermore, we developed and published an algorithm for path planning with a special focus on the collection of floor eggs. Initial testing was done for object detection and recognition. Finally, we developed, tested and published a prototype for egg collection and evaluated animal behaviour as response to the autonomous vehicle.

Acquiring data in an empty poultry house for the

Evaluation the egg collection device under

Ir. Bert (A.) van ’t Ooster

Email: Bert.vantOoster@wur.nl
Supervisors: Prof.dr.ir. E.J. van Henten, Dr. J. Bontsema and Dr. S. Hemming
In collaboration with: Wageningen UR Greenhouse Horticulture
Project funding: Dutch Ministry of Economic Affairs

Systematic design of automated sustainable horticultural production systems

Growers face numerous competitive challenges, which urge them to continuously improve labour efficiency and to innovate crop operations. The research objective was to obtain a quantified understanding of labour and crop operations in horticultural production systems materialised in a generic model based method. The purpose of this method is to analyse, simulate, and evaluate work methods and labour management scenarios in existing or redesigned greenhouse crop cultivation systems. This research contributes to effective greenhouse crop cultivation systems with efficient use of human labour and technology. Simulation of crop operations in greenhouse facilities consider the viewpoints of the system designer in research and industry, the facility manager and the worker.

Until the end of 2014, three journal papers were published and a fourth paper was submitted for publication. These papers are on modelling, simulation and evaluation of crop operations in mobile and static cultivations systems for cut-rose. In cooperation with Ben Gurion University a paper was contributed to the conference Advances in Production Management Systems 2014, where the model based method was used for a simulation analysis of sweet pepper harvesting operations in the Netherlands and Israel. The model-based method can handle simulation of multi-worker and multi-operations cases.

Mobile cultivation system for cut-rose

Static cultivation system for cut-rose

Dennis (J.W.) Snoek MSc

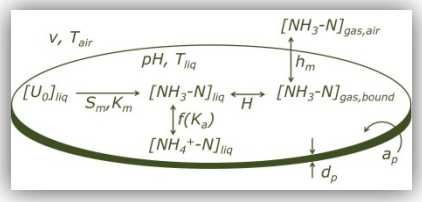
Email: dennis.snoek@wur.nl
Supervisors: Prof.dr.ir. P.W.G. Groot Koerkamp; Dr.ir.N.W.M. Ogink; Dr.ir. J.D. Stigter
In collaboration with: Wageningen UR Livestock Research and Biometris
Project funding: BO

Development of an assessment strategy to determine the ammonia emission from dairy cow houses

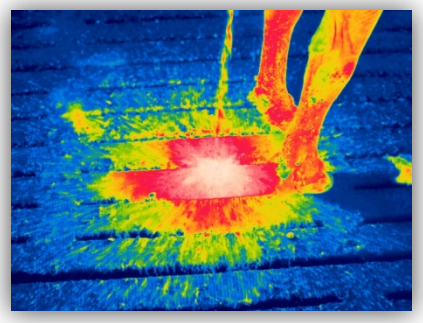
This PhD research project is to develop an ammonia assessment strategy. This strategy will consist of an emission model in combination with measurements of key variables of the ammonia emission processes under practical circumstances. The goal is to determine the ammonia emission in a dairy cow house in a precise and cost effective way. The strategy should apply for any dairy cow house with a specfic design, at a specific location, with specific climate conditions. To develop the assessment strategy the following objectives are formulated:

1. Evaluate each input variable and each model parameter of the current mechanistic ammonia emission model “Snelstal” (Monteny, Schulte et al. 1998). In order to determine the key variables.
2. Develop and improve measurement methods for the measurement of the key variables in commercial dairy cow houses.
3. Execute measurements, and compare it with the ammonia emission model predictions
4. Improve the ammonia emission model based on the knowledge gained with steps 1, 2, and 3.
5. Validate the developed ammonia emission assessment strategy, for practical circumstances.

By the end of 2014 the key variables were selected, and a variety of measurement methods were developed. These methods were combined in one measurement setup to measure fresh dairy cow urine puddles in commercial dairy cow houses. In the end of 2014 the measurements of the key variables started, and the first results look promising!



<Urine puddle with emission process steps>



<Thermal image of a dairy cow urine puddle>

Ellen (H.J.E.) van Weeghel MSc

Email: ellen.vanweeghel@wur.nl
Supervisors: Prof.dr.ir. P.G.W. Groot Koerkamp en A.P. Bos
In collaboration with: Wageningen UR Livestock Research
Project funding: <KB-12-002.04-004

Unifying heterogeneous needs in design for system innovation

This PhD project generates knowledge on:
- unifying different needs and requirements of heterogeneous actors / sustainability aspects in the design process of sustainable animal husbandry systems. Thereby overcoming persistent current trade-offs, experienced in animal production systems.
- how to acknowledge the animal as an actor in the design process and more specific
- how to involve the animal as an active contributor in the design process and in solutions. Objective is to do this in such a way that the animal benefits in terms of positive welfare and at the same time that it is beneficialfor other sustainability goals.

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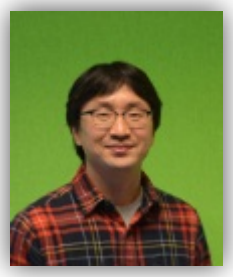
Design for system innovation

Example of overcoming trade-offs

Hyun (H.K.) Suh MSc

Email: hyun.suh@wur.nl
Supervisors: Prof.dr.ir. E.J. van Henten and Dr.ir. J.W. Hofstee
In collaboration with: EU Smartbot
Project funding: <Smartbot project, EU

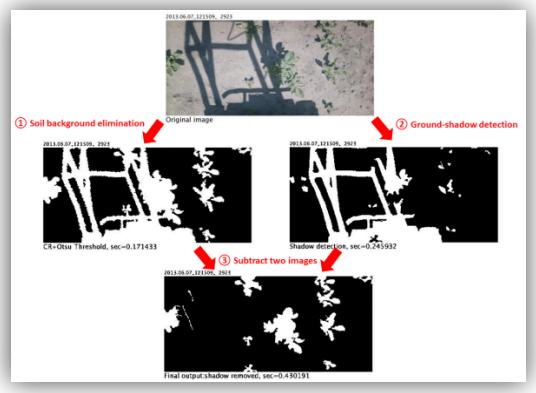


Mobile-based autonomous system for real time detection and removal of volunteer potato plants in sugar beet field

This research, funded by EU Smartbot Project, is to develop an autonomous weed detection module that works robustly under natural conditions. A major need for an automated weed control system together with consideration of environmental issues and concerns leads to develop small and lightweight, but self-guided and fully autonomous, mobile based system for efficient control of volunteer potatoes in sugar beet field.

A vision-based automated weed control system requires robust vegetation segmentation, for its output is the fundamental element in weed/crop discrimination and crop row detection. However, unpredictable varying natural illumination and unavoidable shadows under direct sunlight conditions make extremely difficult for proper vegetation segmentation. Illumination condition constantly changes in agricultural field environment depending on sky and weather condition. This often leads unexpected segmentation output. Shadows are also inevitable in natural field environment. Shadows are often rendered in the view of camera when vision acquisition device or neighbouring plant is occluded by sunlight source, which creates an extreme illumination contrast. When shadows are partially presented in the image scene making extreme intensity/luminance difference within a single image, segmentation becomes challenging task. Beside, shadows tend to be classified as part of vegetation or connected plant material, further processing on shadows is often required.

To build a robust vision system, shadow detection and removal algorithm is developed using by High Dynamic Range(HDR) camera images. The algorithm is robust against illumination differences and it takes into account shadows from direct sunlight. Hybrid plant segmentation approach is also applied whose algorithm effectively selects the best performed segmentation technique in the given image. Ground shadow which is rendered onto the background soil surface is detected and removed from hybrid plant segmentation output which provides robust segmentation output under natural field condition.



Shadow removal procedure

Husky in the field

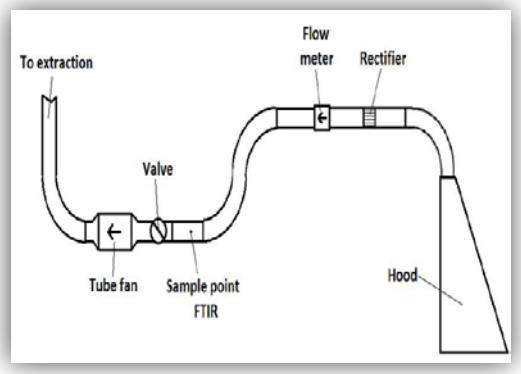
Liansun (L) Wu Msc

Email: Liansun.wu@wur.nl
Supervisors: Prof.dr.ir. P.W.G. Groot Koerkamp, Dr.ir. N.W.M. Ogink
In collaboration with: Wageningen UR Livestock research center
Project funding: <CSC and KB Sustainable Agriculture

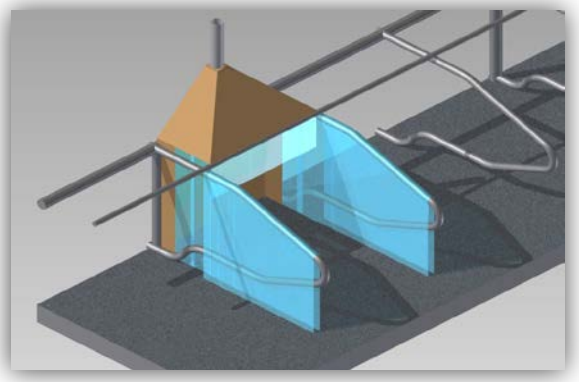
Assessment of the methane emission of individual dairy cows at farm house level

Methane emission from dairy cattle accounts for a significant portion of the global CH4 budget which is a substantial contributor to the Global Greenhouse effect. In this project we shall design, test and validate an assessment method to determine the methane emission of individual dairy cattle at farm house level. Herewith we measure the variation of the methane emission between a large numbers of cows in practice. Through understanding and evaluating methane emission from individual dairy cattle in large numbers, the methane conversion expressed as the methane emission per unit of milk production can be assessed within the dairy cattle. This information can be used for breeding dairy cattle with low methane conversion which contributes to reducing the environmental impact of dairy farms and increasing the productivity. Besides breeding, also the effect of other mitigation measures can be assessed at animal level, like feeding measures. This project includes following studies: 1) Design and construct the measurement equipment & set-up for methane emission from individual dairy cattle and test under experimental small-scale condition; 2) Evaluate and validate different set-up measurement methods under practical conditions by measurements with real cows; 3) Carry out a proof of principle under practical conditions where methane emission and conversion will be measured during a long period. Strengths and weaknesses of each method were evaluated what further research should be undertaken to improve the methodology according to measurement requirements at farm level.

In 2014, we designed and constructed an on-farm methane flux measurement method. The method was first tested and evaluated with the artificial reference cow in the lab. The results showed that the method can capture 99% methane flux emitted by the artificial cow in the lab. After this, we validated this new methane measurement method in a commercial cubicle house with the artificial reference cow. The results showed that this method can still detect the variations of methane emission between cows under disturbant ariel condition.



Schematic overview of the method



The application of the method in the cubicle

Peter (P.J.M.) van Beveren MSc

Email: peter.vanbeveren@wur.nl
Supervisors: Prof.dr.ir. E.J. van Henten, Dr. J. Bontsema (Wageningen UR Greenhouse Horticulture), Prof.dr.ir. G.van Straten (BRD)
In collaboration with: Wageningen UR Greenhouse Horticulture, Hortimax B.V., Lek Habo Groep B.V., Boonekamp Roses B.V.
Project funding: <STW

Optimal management of energy resources in greenhouse production systems

In the interest of reducing energy consumption and CO2 emissions, while maintaining productivity, greenhouse growers have installed a wide range of equipment to produce, transport, and store heat and cold. The case study of this project is the 4 ha greenhouse of Boonekamp Roses BV. In this greenhouse, a pipe rail heating system, heat exchangers for heating or cooling, natural ventilation, screens, and supplementary lighting are present to control the greenhouse climate. Next to the greenhouse, a combined heat and power installation, boiler, heat pump, short term low temperature heat and/or cold storage, high temperature heat storage, long term storage in aquifers, and cooling towers are present. Because of the increasing number of equipment and the interconnectivity of all systems, the management of these systems has become a very complex task. Therefore, the main goal of this project is to come to optimal utilization of all equipment in the most efficient manner.

In order to come to optimal utilization of resources, the optimization problem is split into two stages. In the first stage, a desired greenhouse climate is created with minimal energy input (both heat and cold) to the greenhouse. Bounds for temperature, humidity, and CO2 are specified by the grower. An optimization framework is developed to optimize the energy input given these bounds. A dynamic model for greenhouse air temperature, humidity, and CO2 concentration is developed and validated with measurement data, which is needed for the optimization. The optimization is done for a whole year and showed that a substantial amount of energy can be saved. The second stage of the project is to generate the heat and cold that have to be supplied to the greenhouse as efficient as possible with the available equipment.

This project is part of the STW Smart Energy Systems programme.

Inside the rose greenhouse.

Installations for heating and cooling.

BSc projects completed in 2014

Aantjes, Wiger

Data analysis and simulation trials of harvest in sweet pepper – diagnosis of the GworkS model

Agricola, Sido

pH development in a urine puddle under practical circumstances – experimental results and model development

Bergwerff, Emiel

Sensorfusie voor plaatsbepaling poultrybot

Bosscha, Albert

Plantonderscheid met behulp van fluorescentiemetingen

Dreessen, Sebastiaan

Meetmethode voor het bepalen van vloeistoflaagdikte van koe-urineplassen voor verschillende vloereigenschappen

Galen, Evert van

Performance assessment of a soil moisture sensor tag

Kortlever, Jan-Willem

Development and a test of an egg-collecting device for floor eggs in loose housing systems for laying hens

Meer, Andries van der

Machine vision based navigation in a sugar beet crop field of a Husky robot

Meer, Jasper van

Optimale padplanning voor aardappelopslagbestrijding in suikerbieten

Ras, Dini

Ontwikkeling van een warmtemodel voor voedsters met jongen

Spek, Lars van der

Navigation of husky in a sugar beet field

Vergouw, Bastiaan

Detection of eggs inside poultry houses for vehicle that collects floor eggs automatically

Verploegen, Thijs

Design of a system for the onfarm production of concentrated feed from roughages

Vollering, Maaike

Scharrelbehoefte van de kip

Wijk, Sjoerd van

The use of drones in agriculture

MSc projects completed in 2014

Antonakou, Ioulia

Minimising nutrient emissions from greenhouses

Besuijen, Henja

Large-scale algae production in greenhouses

Bouwman, Stephan

Modelling anti-solvent crystallisation of pure sucrose with ethanol

Haperen, Matthijs van

Vision based row navigation and control of quadcopter

Hoveling, Jorrit

Defects segmentation on apples using VIS-NIR multispectral reflectance images

Huting, Menno

Phenotyping of plants inside a greenhouse with a light field camera: Crop registration and assessment

Lambers, Theo

Design and implementation of a slave control unit in a master slave system

Lieshoud, Cora van

Minimum space needed for a 9-DOF manipulator to harvest sweet-pepper on the back-side of the stem

Oorbeek, Dirk

Analysing the failing attempts of attaching cups to the teats with a milking robot using machine vision

Ormel, Rob

Modelling and simulation of the perceived value and cost price of technological products for the dairy farm

Schetters, Krijn

Analyzing scale size of Agricultural Machinery

Slootweg, Anthon

Monitoring dairy cow morphology using 3D vision technology

Tielen, Toon

Advanced weed recognition in perennial plants

Tilburgs, Hein

Design of a control system for the OSCAR project

Verhoijsen, Wilco

Improving indoor climate and energy efficiency in pig houses by using heat recovery systems

Education

The Farm Technology Group offers a wide range of courses related to biosystems engineering on BSc and MSc level. The group is a main contributor to the BSc and the MSc Biosystems Engineering.

Education of the Farm Technology Group

The Farm Technology Group offers courses on bachelor and master level. The course offer ranges from basic engineering principles in the course Engineering 1 for the BSc to the advanced courses for the MSc, as for example Greenhouse Technology of Automation for Bioproduction. Many courses are general engineering courses with many examples from the biosystems engineering domain. The course offer also comprises resarch methods courses for the BSc Biosystems engineering and – in cooperation with several other chairs – an introduction course for the BSc Biosystems Engineering. In addition to the courses there are also thesis and internship courses.

An important part of the work of the group is design in the biosystems engineering context and several courses taught by the group are related to this. Engineering Design as introduction for the bachelor students and Biosystems Design and Quantitative Analysis of Innovative Biosystems courses for the MSc. In addition to these more general courses the group offers advanced technology courses for the MSc on livestock, greenhouse, automation and soil.

The following courses are offered by the group:

FTE-12303	Introduction Biosystems Engineering part 1 (Dutch)
FTE-12803	Introduction Biosystems Engineering part 2 (Dutch)
FTE-13303	Engineering 1 (Dutch)
FTE-13807	Engineering 2 (Dutch)
FTE-24806	Engineering Design (Dutch)
FTE-25303	Building Physics and Climate Engineering (English)
FTE-25806	Research Methods Biosystems Engineering (Dutch)
FTE-26306	Data Analysis Biosystems Engineering
FTE-30306	Livestock Technology (English)
FTE-31306	Greenhouse Technology (English)
FTE-32306	Advanced Soil Technology (English)
FTE-32806	Automation for Bio-production (English)
FTE-33806	Biosystems Design (English)
FTE-34306	Quantitative Analysis of Innovative Biosystems (English)
FTE-34806	Modelling of Biobased Production Systems
FTE-50806	Conservation Agriculture (English)
FTE-704nn	MSc Internship Farm Technology (24, 27, 30, 33, 36, 39 credits)

FTE-804nn MSc Thesis Farm Technology (24, 27, 30, 33, 36, 39 credits)

BRD-22306 Sensor Technology

YEI-80324 BSc 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 continuous with lectures, tutorialls, 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 Excell). 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.

The first part consists of 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 1 (Dutch)

This course is the continuation of FTE-12303 Introduction Biosystems engineering part 1. See the description of that course for the contents. This second part of the course consists of the remaining three relevant topics (welfare and environment, climate control, and (agro)production chains and logistics, the module oral presenting and the preparation of the technical paper.

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 and energy. 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 a continuation of the course Engineering 1. In this course there are modules on CAD (Computer Aided Design), and 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 mechanics part the students are introduced to the topics stress and strain and the relation between them. Main focus will be on the calculation of the deformation of a structural member, based on the size, acting forces, and moments. The required size of a structural member, bases on design constraints as limiting stress or deformation will be calculated too. In the CAD module the students learn the basic principles of CAD. It starts with making sketches of simple technical objects and continues with the learning of a 3D modelling programme AutoDesk Inventor). In this programme parts of technical systems are modelled and technical drawings produced. Finally, calculations on mechanical stress will be done. Here the theory from the lectures and the tutorials is integrated in the 3D modelling program.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-24806 Engineering Design

In this course the students learn six consecutive steps of the structured design methodology according to Cross. They practice application of these steps and their related tools in groups of two or three students in a case study. Each group chooses a pre-defined simple (agro)technological design problem. They start analysing the problem and in the end of the course they present their solution and hand in a report. Each step of the methodology starts with a lecture with the theory, an example, and a small exercise. After this the groups apply the theory to their case. They get 2 to 4 days to finish the case work. After these days all groups have to hand in discussion points, a small report, and a presentation. Two groups are selected to present their result, followed by a general discussion. In step five each group selects systematically a solution for their problem. During the sixth step they model the selected solution in CAD, apply motion, and check for collisions. From the CAD model, drawings, pictures and videos are produced to be used in the final presentation and the final report. The course includes an excursion to a manufacturing industry to show the students the practice of engineering design and manufacturing in industry.

FTE-25303 Building Physics and Climate Engineering

This course is closely related to the course Physical Transport Phenomena (BCT-22803) and has the objective to introduce the students to the climate engineering items relevant for the bachelor Biosystems Engineering (BAT). 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 agro-production in buildings;
- Solar energy – passive and active for solar energy collection and use;
- (data processing in Excel).

FTE-25806 Research Methods Biosystems Engineering

In this course the students learn the different steps of doing research:

- Problem analysis;
- Problem definition;
- Objective of the research;
- Research questions;
- Execution of the research (measuring and data analysis);
- Presentation of results;
- Discussion;
- Conclusion.

The students will exercise these different steps in a small (pre-selected) research project they have to execute with a group. The students start with making a proposal for their project and subsequently execute this project as a team. They get feedback on each of the steps in the research process. They also have to incorporate the literature they collected in the Information literacy module in the course FTE26306. The students have to prepare a well-structured report on their projects according to scientific standards and present the results orally. Part of the course is a module on debating. In this module the students will learn how to set up a good oral argumentation in relation to the right context and purpose. Explicit attention in this course will be given to the different aspects of group work (tema activities, organizational, social).

FTE-26306 Data Analysis Biosystems Engineering

The following topics will be addressed in the course:

- Linear regression and multiple linear regression: model formulation, meaning of model parameters, checking model assumptions and prediction;
- Data transformation;
- Experimental design: completely randomized design, block design and factorial design.

Calculating the required sample size to obtain a certain precision;

- Analysis of variance and pair-wise testing;
- Selection of variables (quantitative and/or qualitative) to find the optimal linear regression model (checking assumptions);
- Repeated measurements;
- Calibration, validation and cross-validation.

These methods are relevant for further data analysis in the biosystems engineering domain. The theory of the course will be supported by practical's in which relevant data sets from the biosystems engineering domain will be analysed. Part of the course is the module Information literacy and is a continuation of the information literacy module in the first year of the programme. In this module the students will learn the more advanced searching techniques and strategies for relevant (scientific) papers and other information. The topic for the module will be the same as the topic for the research project in the course FTE25806 Research Methods Biosystems Engineering. Students will also participate in a professional assessment and, supported by staff, will translate these outcomes in the context of their current programme and future choices.

FTE-30306 Livestock Technology

Sustainability and sustainable development of animal production systems form the start of this course. This course focuses on the interaction between engineering and technology on the one hand, and biology and animals on the other hand in on-farm animal production systems. The course is organized

along four themes, with one theme per week: 1) animal welfare and health (animal needs) and overview of sustainability issues of livestock production and production chains, 2) building physics and indoor climate (management and ventilation of the aerial environment of the animal), 3) current engineering topics in livestock research (air quality & dust, emissions, waste, animal health, design), and 4) farm management of automation and logistics (sensors, precision livestock farming). 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 to support sustainable development of production systems.

FTE-31306 Greenhouse Technology

The content of the course focuses on engineering aspects of greenhouse horticulture systems in interaction with crop growth and development. In a general introduction an analysis of the sector will be presented, followed by the basics of crop growth and development and the physical principles of the greenhouse climate. The main in depth topics of the course are: physics of greenhouse climate, crop production (biological mechanisms, crop growth and development, crop responses to growth factors), management of the aerial environment (functions, manageable parameters and greenhouse climate engineering: radiation management, energy sources and distribution systems, ventilation, air conditioning and cooling systems, screens, CO2-sources and distribution), management of the root environment (factors, tools, control of water and mineral balance, water quality, salinity effects), and greenhouse systems (passive, climate controlled, (semi) closed greenhouse, greenhouse types, constructions, cover materials, and crop systems). The course puts emphasis on calculation and analysis. It aims to prepare for a major in greenhouse engineering. As a student you will be confronted with systems, theoretical backgrounds and methods that are generally used in analysis of the topics mentioned. You will learn to understand and apply theory, and to analyse problems given to you during the course. Both in exercises (manual exercises and model based exercises) and in trainings on a deeper problem analysis by means of simulation, you will be trained in methods to analyse, predict and evaluate crop production, greenhouse climate, and performance of climate engineering solutions, including integration of these fields of knowledge. Focus is not only on the Dutch situation but also on the international protected cultivation. In an excursion near the end of the course you will visit several locations to see and understand implementations of the learned matter.

FTE-32306 Advanced Soil Technology

This course offers an in-depth treatment of various aspects of soil technology and tillage, such as:

- Soil physical characteristics and conditions which are crucial for an understanding of the effect of mechanical manipulation of the soil and for processes in the field such as compaction and erosion;
- Methodologies and techniques for measuring soil physical, mechanical and dynamical parameters, both in the field and in the laboratory;
- State-of-the-art approaches for research in tillage and soil mechanics, including modelling the effects of tillage on soil structure and related parameters (water, gas, strength, erosion).

Each student studies a scientific paper and reports on the approach, methodology and findings to fellow students, followed by discussion.

In addition to this common part, each student:

- Chooses a topic related to soil technology and writes an essay/literature review which is presented to fellow students by a poster
- Assesses various scenarios of soil management under different soil, terrain, crop and climate conditions with respect to crop yields, soil structure and erosion.

FTE-32806 Automation for Bioproduction

Agriculture is challenged to overcome increasing labour costs, decreasing availability of labour 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 labour 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 a robot manipulator and an autonomous vehicle.

FTE-33806 Biosystems Design

In the course students will apply a structural engineering design method to a biosystems engineering related design problem with a focus on system innovation. Sustainability aspects, that is ecological, economic and social aspects, 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). The design methods taught in FTE-24806 are extended with new ones. The structure of the course is based on Reflexive Interactive Design, with main steps 1) system and actor analysis and 2) structured design. Methods in systems engineering and in Theory of Inventive Problem Solving'and keyword for search) like Technology Landscaping, Innovation Trend Analysis and resolving Design Contradictions are taught. The course includes an extensive state-of-the-art analysis (based on intellectual property (IP)

- Research, knowledge, research, market exploration). Also the organisation of a design project gets attention.

Some typical examples of technological innovations in biosystems are presented, discussed and studied. Students will spend most of the course time on applying the theory and the ideas behind it to their own design case.

The case is meant to develop competence in contributing to design teams at the level of:

- Problem analysis (analysing the need and setting the design objective);
- IP-research (able to perform a state-of-the-art analysis for a design case);
- Generating and evaluating stakeholder requirements and design constraints;
- Function and device analysis of hybrid systems or new systems;
- Generating working principles with functions and manage proven solutions;
- Proposing well-founded design concepts;
- Evaluating their compliance with the given requirements;
- Presenting and passing on design concepts through visual, oral and textual expression.

FTE-34306 Quantitative Analysis of Innovative Biosystems

This course focuses on the quantitative analysis of new design concepts, innovative ideas and technology for biosystems. The analysis of biosystems is performed at farm level or parts of it. Sensitivity analysis is applied to biosystems with greenhouse production or dairy production. The students will learn to analyse the effects on various aspects of sustainability issues: costs and benefits of investments, various environmental impacts, animal welfare, labour requirement, and products

quality. The results of the analysis cover 1) type of effects or relationships, 2) pros and cons, 3) limiting and/or critical factors and variables, and 4) options for improved performance. A full assessment of all aspects of the design concepts is characterized by limited availability and uncertainty of information and students have to consult experts and various information sources to make best educated assumptions. Students work in small groups on case studies (dairy or horticulture), analyse the feasibility of innovative farm systems designs, and reflect on the chosen assumptions and calculation methods. Methods of engineering design will not be covered during the course, but we do expect that students are able to apply these methods.

FTE-34806 Modelling of Biobased Production Systems

Advanced biobased production systems are expected to provide society with food, fuel and biomaterials in the post-fossil fuel era. Reaching beyond farm level, these production systems combine product flows and waste flows from plant and animal production processes together with novel bioprocessing technologies. Testing such novel concepts by building pilot plants usually is too expensive. The same holds for evaluation of modifications to the production system. Then mathematical models of the novel biobased production process can be a powerful tool to predict the performance and behaviour of the proposed system solutions. In view of the above, this course discusses a systematic approach for modelling biobased production systems. The approach starts with the analysis of a complex biobased production process combining plant production, animal production and local processing. This is followed by a breakdown of the system into subsystems. Static and dynamic models for the subsystems will be developed, implemented in simulation software and analysed. Subsequently the models of the subsystems are integrated to predict and to analyse the total system. The behaviour of the total system is studied by a systematic design of simulation experiments, and is analysed with respect to the performance in terms of economy and greenhouse warming potential. Methods for assessing model uncertainty and sensitivity will be introduced and applied in the case study. The course focusses both on the background of the methodologies for modelling, simulation and analysis, and at experiencing the development, implementation in simulation software and use of models. For this purpose basic models for plant growth, animal production systems and processing technology at farms are discussed and exercised. Students will work in groups on an application example. This course gives an overview of the different modelling and simulation techniques available for a biosystems engineer and provides a link to later courses and thesis work in the program. This course is the first course in the MSc Biosystems Engineering. Besides modelling biobased production systems the course comprises therefore an orientation on the study domain and a multiple day field trip with visits to relevant organizations, universities and industries in The Netherlands and surrounding countries. The students have to write a report about this field trip.

FTE-50806 Conservation Agriculture

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 use 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 agricultural 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 analyse the bottlenecks in application of CA in order to find an explanation of the successes as well as the failures.

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