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Preface

In front of you is the annual report of the Farm Technology Group of 2016. The report contains mission, vision and focus of the group, cv’s and contact information of the staff, a short description of on-going PhD projects, finished MSc projects, a list of publications, and last but not least a list of courses we teach in the BSc and MSc programmes Biosystems Engineering.

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. Eldert van Henten  Prof. Peter Groot Koerkamp
Mission, vision and focus 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 fulfil 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 during the past decades. With a growing global population, the demand for food is increasing continuously and food production is and will be the key issue of agricultural production in years to come. However, the past decades have also shown a gradual diversification of the product portfolio in Western Europe. Feed, fuel and fibres are gaining importance besides food and flowers and production of functional foods, pharmaceuticals, renewable resources from plants etc. will appear on the agenda. Also the character of farm enterprises is changing. Being a part of society at large, nowadays farms in the Netherlands also 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 and calls for more sustainable agricultural production.

In the coming years key issues in this field will be: 1) effective 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 labour. 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 focus: 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 Farm Technology Group focusses on two main research areas within the broader field of Biosystems Engineering, being:

1. Design of sustainable systems and technology, and development of improved methods,
2. Sensing, data processing and interpretation, followed by intelligent operations e.g. process management, manipulation, robotics and precision agriculture / precision livestock farming.
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 leading 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.

**Challenges for research**

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 typical for engineering, also on management, control and (re)design of such systems, with a special focus on the technology. With a growing number of PhD students we address the above topics yielding a growing number of scientific publications in peer reviewed journals and knowledge and experience that can be applied in agricultural practice. Various examples of our research done by staff, post-doc, MSc and BSc students is presented in this annual report.

**High quality education**

The Farm Technology group is one of the main suppliers of the BSc and MSc programmes Biosystems Engineering at Wageningen University. In the Netherlands these programmes are singularly unique within the higher education landscape. The group provides 17 courses at bachelor and master level, besides an internship programme as well as bachelor and master thesis projects. Both education programmes rank high in the yearly student evaluation of higher education in the Netherlands.
General information

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Farm Technology Group
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Group members - permanent staff

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Prof.dr.ir. E.J. van Henten  eldert.vanhenten@wur.nl  +31 317 483328

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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

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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),

Cooperation within Wageningen University & Research
Wageningen University and Research consists of two parts; 1) Wageningen University focussed on more fundamental research and education at BSc, MSc and PhD level, 2) Wageningen Research focussed on contract research with a more applied nature. As both of the chair leaders started their careers within the Wageningen Research community, there is a strong collaboration between the Farm Technology Group and various contract research groups within Wageningen Research. This collaboration is of interest to Wageningen Research groups since PhD projects will be aimed at 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 to and anticipate developments in primary production and society and to obtain research funds more easily. A strong collaboration also exists with various research groups within Wageningen University. Currently, more than 50% of the current (PhD-) projects are based on collaboration with groups within WUR.

Cooperation with universities and research institutes outside WUR
A growing number of projects are carried out in collaboration with groups outside WUR. In various modalities the members of the Farm Technology Group collaborates with the following universities and research institutes world-wide:
1. EU Trimbot2020,
2. EU Echord++,
3. Field Robot Event, University of Hohenheim, Germany and University of Applied Sciences, Osnabrück, Germany
4. RDA Korea,
5. Technical University Eindhoven, The Netherlands
6. Ehime University, Japan
7. Chinese Academy of Agricultural Sciences, Beijing, China
8. EU Bio-Business (University of Leuven, Belgium)
9. IAM-BRAIN, Japan
10. Forschungzentrum Jülich, Germany
11. Public University of Navarra, Pamplona, Spain
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. Claas, Harsewinkel, Germany
2. Rijk Zwaan, Fijnaart, The Netherlands
3. Vencomatic bv. & Rondeel bv, Eersel, The Netherlands
4. GD, Deventer, The Netherlands
5. Commercial Farms
6. Monteny Milieu Advies, Renkum, The Netherlands
7. Swaans beton, Heeze, The Netherlands
8. Hortimax, De Lier, The Netherlands
9. Lely Industries, Maassluis, The Netherlands
10. Avular, Eindhoven, The Netherlands
11. Schippers Bladel
12. JOZ (mestschuiver en robots)
13. SAPEC
14. Beerepoot stalinrichting BV
15. Big Dutchmann
16. Friesland Campina
17. Greefa
18. CLAAS
19. Ice Ireland
20. Lely Industries NV
21. PFA Pelagic Freezer – Trawler Association
22. Proti-Farm Rearing BV
23. TechNature BV

24. Wireless Value BV
People of the farm technology group
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 Livestock Research
Coordinator for Fundamental Plant Research topsector Agri&Food

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

Expertise
System thinking, technology for animal and plant production systems, innovation processes, sustainability of 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 and memberships
Management of the Farm Technology Group, teaching, supervision of PhD, MSc and BSc students.
Membership of the editorial board of IJABE (China), and member of several international professional organizations (EurAgEng, WPSA, ISAH), president of the Dutch society of agricultural engineers (NVTL), member of the Panel of Experts Agro/Food of ‘Milieukeur’.

Contribution to courses
FTE-12303/12803, FTE-30306, FTE-33806, FTE-80436, FTE-34306

The first Windstreek house for broilers was opened on November 12th, 2015 on the Farm of family Nijkamp in Raalte
Prof.dr.ir. Eldert 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. Visiting professor Ehime University, Matsuyama, Japan. Member of editorial boards of Biosystems Engineering, Computers and Electronics in Agriculture and International Journal of Agricultural and Biological Engineering. Member of: EurAgEng, ISHS, BSHE, IFAC TC 8.1 Control in Agriculture, IEEE Robotics and Automation Society (co-chair of the TC agricultural robotics and automation), NVTL, euRobotics (coordinator of TG Agricultural Robotics).

Contribution to courses
FTE12303, FTE12803, FTE32806, BCT22306, FTE34806, YEI80812, FTE80436

Sweet pepper harvester developed in EU project CROPS
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
Nedup Dorji, MSc

Contact information
Nedup Dorji
Email: nedup.dorji@wur.nl

Function(s)
PhD candidate at Wageningen UR

Education
2010 MSc, Khon Kaen University, Khon Kaen, Thailand
2005 BSc, Sherubtse College, Delhi University, Bhutan

Expertise
Poultry Production. Special interest in animal health and welfare.

Current activities and memberships
Research project. Membership of editorial board of BJNRD (Bhutan).

Contribution to courses
Dr. Frank Helderman

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

Function(s)
Lecturer at Wageningen UR.

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

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

Current activities and memberships
Teaching, examinations, coordinating courses, coordinating internships, supervision of MSc and BSc students and a PhD candidate

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

Fluorescence during an experiment to estimate the size of a simulated urine puddle.
Dr. ir. Jan Willem (J.W.) Hofstee

Contact information
Dr. ir. Jan Willem (J.W.) Hofstee
Email: janwillem.hofstee@wur.nl

Function(s)
Lecturer Biosystems Engineering
Programme director BSc and MSc Biosystems Engineering

Education
1993 PhD, Wageningen University, Wageningen, The Netherlands
1986 MSc, Wageningen University, Wageningen, The Netherlands (with honours)

Expertise
Machine vision, automation, precision farming, yield mapping, computer integrated agriculture, precision weed detection and weed control, physical properties of fertilizers, spreading fertilizers

Current activities and memberships
Teaching and supervision of MSc and BSc students; Member of editorial board of Computers and Electronics in Agriculture; Member of committee for assessment of technology related to environmental issues (water quality); Member of NVTL, EurAgEng, ASABE; Treasurer of NVTL.

Contribution to courses
BCT22306, FTE12303, FTE12803, FTE13303, FTE13807, FTE25806, YE180324, FTE804nn, YMC60809
Dr. ir. Joris (J.M.M.) IJsselmuiden

Contact information
Dr. Joris IJsselmuiden
Email: joris.ijsselmuiden@wur.nl

Function(s)
Postdoc agricultural robotics and computer vision

Education
2014 PhD, Department of Informatics, Karlsruhe Institute of Technology, Germany (with honours)
2006 MSc, Artificial Intelligence, University of Groningen (with honours)

Expertise
Agricultural use case development, computer science, software engineering, artificial intelligence, machine learning, machine perception (with focus on computer vision), modelling and reasoning of autonomous systems, task/path/motion planning, actuation strategies

Current activities and memberships
Leading role in the group’s research line Agricultural Robotics and Computer Vision, teaching, MSc/BSc thesis supervision, PhD supervision, project acquisition, publishing and reviewing scientific papers. Current projects: TrimBot (garden trimming robotics), Saga (swarm robotics for weed monitoring), Sweeper (sweet pepper harvesting robotics), PoultryBot (robotics for floor egg collection and environmental monitoring), SmartBot (autonomous weed control), and more.

Contribution to courses
MSc Thesis Biosystems Engineering, BSc Thesis Agrotechnologie, FTE-35306 (Machine Learning), FTE-32806 (Automation for Bioproduction), FTE-26812 (Field Robot Design)

TrimBot2020 prototype: the world’s first garden trimming robot.
Ir. Nan Jia

Contact information
Ir. Nan Jia
Email: Nan.jia@wur.nl

Function(s)
External researcher at Wageningen UR Farm Technology Group

Education
For now, PhD student, China Agricultural University, Beijing, China
2014 MSc, Guilin Electronic Technology University, Guilin, China
2010 BSc, The PLA Information Engineering University, Zhengzhou, China

Expertise
Machine vision, system design, software engineering

Current activities and memberships
PhD research on automation for cow hygiene score system.

Contribution to courses

Cow hygiene score system
**Dejan Kaljaca, MSc**

**Contact information**
Dejan Kaljaca MSc  
Email: dejan.kaljaca@wur.nl

**Function(s)**
PhD student at Farm Technology Group.

**Education**
2015 MSc, University of Genova, Genova, Italy and Ecole Centrale de Nantes, Nantes, France  
2010 BSc, University of Calabria, Cosenza, Italy

**Expertise**
Robotics, Computer Vision, Machine Learning

**Current activities and memberships**
I'm currently working as a PhD researcher within the scope of a novel EU Horizon2020 project called TrimBot2020.

**Contribution to courses**
David Katzin, MSc

Contact information
David Katzin
Email: david.katzin@wur.nl

Function(s)
PhD candidate at Farm Technology Group, Wageningen UR

Education
2016 MSc Pure Mathematics, Tel Aviv University, Tel Aviv, Israel

Expertise
Crop Modelling, Greenhouse Modelling, Probability Theory, Probability Measures, Convex Geometry

Current activities and memberships
PhD candidate

Contribution to courses
Ir. Inge (I.M.) Krijger

Contact information
Phone:+31 6 14323958
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Function(s)
Promovendus at Wageningen UR Plant sciences and Livestock Research

Education
2015 MSc Animal Sciences, Wageningen University, Wageningen, The Netherlands.
Specialisation: Applied Zoology, Individual minor: Biological aspects of host/vector interactions in disease transmissions

Expertise

Current activities and memberships
Working as promovendus for Farm Technology Group, teaching FTE24806. Membership of PE&RC

Contribution to courses
FTE-24806

Harvest losses by rodents

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**Francisco D. Mondaca Duarte MSc**

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Francisco D. Mondaca Duarte MSc  
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**Function(s)**  
PhD Candidate

**Education**  
2014 MSc Biosystems Engineering – Universidad Autonoma de Queretaro UAQ. Queretaro, Mexico  
2011 Biotechnology Engineering – Instituto Tecnologico de Sonora ITSON. Sonora, Mexico

**Expertise**  
Agriculture, Agrotechnology, Arable Farming, Crop growth modelling, Crop Production, Dynamic Modelling

**Current activities and memberships**  
Working on PhD research project: Decision making in soil based irrigation systems for high water use efficiency and minimized leaching of nutrients. Use of crop growth, water status and soil infiltration models to predict leaching events dependant on irrigation schedules. Included in this project is supervision of MSc and BSc students during their thesis timeframe.

**Contribution to courses**  
N/A

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*Water balance in soil-crop-atmosphere*
Dr. ir. Simon 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 Mathematics, Twente University, the Netherlands,
2003 MSc Applied Mathematics, Groningen University, the Netherlands
2002 MSc Theoretical Mathematics, Groningen University, the Netherlands

Expertise
Applied mathematics, applied statistics, transport physics, fluid mechanics, machine learning, dynamic optimization, model reduction, systems and control theory, systems biology, biosystems engineering, numerical mathematics.

Current activities and memberships
Research: biosystems engineering under variation and uncertainty, by integrating systems and control with statistics. Supervision: PhDs (Francisco Mondaca, Ingrid van Dixhoorn, Xiangyu Song, David Katzin 15+MSc and BSc students. Research consortia: LED it be 50%, Veerkracht 2, SCOUT.
Education: following courses (BKO and supervision), developed 3 statistics and systems theory courses for BSc, MSc, and PhD students.

Contribution to courses
FTE-26306, FTE-25806, FTE-80400, FTE-35306, YEI-80324, Statistical Uncertainty Analysis of Dynamic Models (PhD tutorial, PERC)

\[
\begin{align*}
\alpha(x, \theta) &= p(x(t), \theta, u, \delta) \\
\beta(y) &= p(x(t), \theta, u, \epsilon)
\end{align*}
\]

\(x = \) state (weight, health, heart rate, temperature)
\(\theta = \) parameter (rate of change)
\(u = \) input (feed, antibiotics, stress)
\(y = \) output (measurements related to states)
\(\delta, \epsilon = \) disturbance, variation
\(p = \) probability, risk
Dr. ir. A. (Bert) van ’t Ooster

Contact information
Dr. ir. A. van ’t Ooster
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Function(s)
Lecturer at Farm Technology Group, Wageningen University

Education
1984 – MSc Agricultural Engineering, Wageningen University (with honours)
2015 – PhD Wageningen University

Expertise
Methods in biosystems design, System analysis, Modelling, Discrete-event modelling of operational processes, Physical transport phenomena, Dynamic balance equations, CFD, 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
Teaching and coordinating courses, intake and supervision of MSc and BSc students.
Member of (inter)national professional organizations: ISHS, EurAgEng, NVTL, KLV.

Contribution to courses
FTE-12303, FTE-13303, FTE-24806, FTE-25303, FTE-25806, FTE-30306, FTE-31306, FTE-33806, FTE-704xx, FTE-804xx, YEI-80324

Greenhouse Technology course 2015-2016 (FTE-31306) received: Excellent Education Prize 2017
Bastiaan Vroegindeweij MSc

Contact information
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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 among young white hens in our test setup
Research projects
Nedup Dorji, MSc

Email: nedup.dorji@wur.nl
Supervisors: Prof.dr.ir P.W.G. (Peter) Groot Koerkamp and Dr. E.A.M (Eddy) Bokkers
In collaboration with: Wageningen UR Farm Technology; Animal Production System
Project funding: NUFFIC

The welfare and health of yaks in transhumance yak farming system in Bhutan (in the past, present and future)

Objectives are
- Assess the current situation and recent developments in four yak farming regions of Bhutan;
- Compare and evaluate the health and welfare of yaks among four yak farming regions in order to identify welfare problems in yak farming;
- Evaluate the effects of external factors on the health and welfare of yaks in Bhutan;
- Build scenarios to contribute to sustainable development of yak farming in Bhutan.
Dr. Joris IJsselmuiden

Email: joris.ijsselmuiden@wur.nl
Supervisors: Prof. dr. ir. Eldert van Henten
In collaboration with: WUR Agrosystems Research (Pieter Blok)
Project funding: RDA South Korea

Autonomous Orchard Mower

In this project, we are developing a robot for autonomous orchard mowing. Our colleague at WUR Agrosystems Research Pieter Blok, is contributing to the computer vision, motion control, and integration of this system. WUR Farm Technology is supervising Pieter’s PhD on these topics.
Dr. Joris IJsselmaiden

Email: joris.ijsselmaiden@wur.nl
Supervisors: Prof. dr. ir. Eldert van Henten
In collaboration with: WUR Agrosystems Research (Pieter Blok)
Project funding: Industry

Robotic Broccoli Harvester

In this project, we are developing a robot for harvesting broccoli. Our colleague at WUR Agrosystems Research Pieter Blok, is contributing to the computer vision, motion control, and integration of this system. WUR Farm Technology is supervising Pieter’s PhD on these topics.

Early prototype of the broccoli harvesting machine
WEpods: development of an autonomous transporation system in Gelderland

In WEpods, we are developing autonomous vehicles for public transporation, on the Wageningen Campus and to the Ede-Wageningen trainstation. We work on the localization system of these vehicles, based on advanced GPS positioning, vehicle pose sensors, wheel odometry, and an advanced laser scanning solution. A good estimate of the vehicle’s pose on the map is essential for most other subsystems of WEpods.
Dr. Joris IJsselmuinden

Email: joris.ijsselmuiden@wur.nl
Supervisors: Prof. dr. ir. Eldert van Henten
In collaboration with: WUR Greenhouse Horticulture (Ruud Barth)
Project funding: <EU H2020

SWEEPER: Sweet Pepper Harvesting Robot

In Sweeper, we are developing a robot for harvesting sweet pepper. Our colleague at WUR Greenhouse Horticulture Ruud Barth is contributing to the computer vision, motion control, and integration of this system. WUR Farm Technology is supervising Ruud’s PhD on these topics.

Sweeper prototype for robotic pepper harvesting
Dr. Joris IJsselmuiden

Email: joris.ijsselmuiden@wur.nl
Supervisors: Prof. dr. ir. Eldert van Henten
In collaboration with: ISTC National Research Council Italy, Avular B.V.
Project funding: <EU FP7 ECHORD++

SAGA: Swarm Robotics for Agricultural Applications

In SAGA, we research and develop drones for automatic weed detection and mapping. By mapping the weeds with drones, farmers will be able to better time their weeding operations, for individual parts of their fields. In the future, the drones may even be used to perform spot-spraying from the sky, replacing or complementing conventional weeding.

The computer vision system is based on excessive green segmentation, DBSCAN clustering, and a deep learning classifier. Drone localization and navigation, as well as geo-referencing and mapping the detected weeds, is achieved through RTK-GNSS (satellite navigation) and/or using ultra-wideband radio beacons. The drones use swarm behavior to focus their efforts on the areas that are affected the most. Like bees attracting each other to the richest flower patches.
Automatic assessment of dairy cow hygiene condition score

Hygiene/cleanliness scoring systems for dairy cows where the herd or a representative proportion of the herd is scored on the basis of how much muck and dirt adheres their back legs and udders. They can be used to broadly measure the standard of various aspects in the management of dairy cows. Cow hygiene assessment is considered as an observational work in recent studies. Cow hygiene systems are procedures used to evaluate the cleanliness and its usefulness is dependent on the performance of raters. The objective of this research is to develop an automatic hygiene scoring system based on 3D cameras for dairy cow.
Motion planning and vision-based control for an outdoor gardening robot

TrimBot2020 is a novel EU project that aims at investigating the robotics technologies that will allow to prototype the next generation of intelligent gardening robots. Specifically, the project is focused on the design and implementation of advanced outdoor hedge, rose and bush trimming capabilities, leading to the development of the first robot ever able to navigate in a garden, approach hedges and topiary-styled bushes, and restore them back to their ideal shape. The new robot will be a manipulator arm mounted on top of a modified commercial robotic lawnmower, and will exploit a set of stereo cameras to get 3D information about the environment.

The two components that will be developed during my research are the motion planning module and the vision-based control system for the trimming action. The motion planning algorithm will generate a trajectory to be followed by the end-effector in order to perform the given cutting task. Vision-based control will allow to reshape the motion of the robot in real-time according to the information instantaneously gathered by means of 3D visual sensing.

At the current state a preliminary literature review and several simulations in a suitable virtual environment have been carried out. Before the end of the year, a first set of real-world experiments is expected to be conducted.
Reduction energy use in horticulture through smart use of LEDs: decision support system

The greenhouse sector in the Netherlands is a major consumer of energy: 10% of the natural gas used in the country is devoted to horticulture. This high energy consumption has negative implications in terms of sustainability, environmental impact, economic costs and competability on the international market. Therefore, considerable efforts are made to improve the energy efficiency of greenhouse in the Netherlands.

LED lights are a promising technology for energy reduction. Such lamps are more efficient than conventional HPS lamps in converting electricity to light. Furthermore, LEDs offer a wide range of lighting strategies: as opposed to HPS lamps, they may be placed very close to the crop and even inside the canopy, and may be designed to generate specific wavelengths of light. This provides opportunities for various lighting strategies, but the optimal strategy for growing under LEDs is still not known.

The goal of the “LED it be 50%” consortium is a reduction in greenhouse energy consumption by 50%, through smart use of LEDs. The consortium comprises of 11 researchers from 5 universities. Within each project, the effects of LEDs on various crop processes are investigated.

My project focuses on combining the results of all participants in the project, and translating them to applicable strategies for growers. For this, a model of a crop and greenhouse will be built, and will include the effects of lighting strategies under LEDs. Model simulations will predict the outcomes of lighting strategies in terms of energy consumption and expected economical return, thus assisting growers in making decisions regarding greenhouse light and climate management.

One of the challenges of such a project is generating fruitful cooperation between researchers from different fields and backgrounds. While setting up and planning the upcoming work, several meetings and outings in 2016 were devoted to getting to know the other researchers in the consortium, learning about their work and establishing positive communication and work relations for the upcoming years.
Asia has the highest undernourishment globally with an estimated amount of over 280 million people suffering from hunger. Although Asia has the largest share of cereal production with rice as one of its most important food crops, pre- and post-harvest losses are part of the underlying problems causing undernourishment. Many undernourished would profit from reduction of grain harvest losses by rodents, as rodents cause a loss of approximately 11 kg food per person per year. Little quantitative data on post-harvest losses of cereals due to rodents is available. To gain insight in this matter, we selected the South-Asian country Bangladesh as study case. It is known that significant losses of stored rice occur mostly because current rice storage systems are not rodent-proof. Besides food loss, current storage methods also lead to damage and contamination of food by rodents, and to potential disease transmission via contamination of the food by rodent droppings, urine, and saliva. Inferior or absence of rodent management could lead to an increase of rodents living and foraging nearby households, which upsurges both undernourishment and the probability on zoonotic disease transmission. As rodents are a major factor for post-harvest losses of stored produce/rice, the focus of this PhD project is aimed at (I) measuring the actual post-harvest losses by rodents in Bangladesh, (II) what rodent pest control methods currently are used and their effects, (III) the prevalence of two pathogens (Leptospira and Toxoplasma gondii) rodents are able to transmit to humans (IV) how Integrated Pest Management in Asia can be optimized.

The full PhD project proposal is sent to reviewers in January 2016, in November 2016 a formal notification on the granted admission was received.

Fieldwork in Bangladesh started in the summer of 2016 and will end December 2017.

In 2016 also field work in The Netherlands started. This was part of a project to investigate the role and influence of rodent presence on 10 conventional Dutch pig-farms on the seroprevalence of Toxoplasma gondii in slaughter pigs. Rodents were trapped Nov/Dec 2016 on 10 farms (5 case –high seroprevalence, and 5 control – low seroprevalence) and will be tested on Leptospira (in cooperation with KIT Amsterdam) in March 2017, and tested on T. gondii DNA by using RT-PCR in April 2017 (in cooperation with WBVR, Lelystad).
Decision making in soil based irrigation systems for high water use efficiency and minimized drainage.

The main objective of this PhD project is to investigate the best way to use the least amount of water during irrigation considering the trade-off between soil drainage and crop water stress. This project consists in using a crop growth model in combination with a spatial soil water infiltration model to develop an optimal control approach to irrigation. The project is divided into four objectives to follow:

1. Study the problem of drainage using soil water flow dynamics. The focus will be on how timing, time duration and volume of irrigation can produce drainage events.
2. Study the problem of crop water stress using a crop growth model and crop water flow dynamics. The focus will be on how timing, time duration and volume of irrigation create crop water stress events.
3. Study the performance of irrigation strategies taking into account the trade-off between drainage and crop water stress using an optimal control approach.
4. Include unforeseen variations and how they affect performance of irrigation strategies. Variations like climate changes and model error by using uncertainty analysis.

Greenhouse cultivation of Butterhead Lettuce was conducted during spring season 2016 and was exposed to different water stress conditions. Data on dry weight, fresh weight, yield, leaf area and variation on water stress over time was obtained. This data will be used for model calibration. As far as January 2017, Development of a spatial soil model based on Richard’s equation and sensitivity analysis has already been developed in Matlab. Validation on different Netherlands types of soils will start soon.
Development of an automated monitoring system for Dermanyssus gallinae

The poultry red mite Dermanyssus gallinae is the most common ectoparasite in poultry farms worldwide and can be a true pest as a D. gallinae infestation may result in high economic losses, veterinary risks and allergic reactions among farm workers. The main objective of my research is to obtain knowledge and insights to facilitate the implementation of IPM regimes for D. gallinae in laying hen facilities. The research focuses on preventive measures and continuous monitoring of D. gallinae as being key advances in IPM. The main objective is divided into three sub objectives:

1) Assessment of the state of the art knowledge on the biology of D. gallinae, the negative effects of this pest in laying hen facilities and available and promising control methods for D. gallinae in laying hen facilities.


2) Provide insight into routes of introduction and spread of D. gallinae in laying hen facilities to enable preventive measures to be identified.


3) Obtain knowledge and develop methods enabling the development and validation of a monitoring tool to evaluate the D. gallinae population dynamics and treatment efficacy in laying hen facilities

Results: Mul et al. (2016) Biosyst Eng 151: 126-140
Mul et al. submitted Model based approaches to forecast Dermanyssus gallinae population dynamics and to describe the source of population growth variation in laying hen facilities for advancing Integrated Pest Management.
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 cultivation 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.
Hyun (H.K.) Suh, MSc

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Supervisors: Prof.dr.ir. E.J. van Henten, Dr.ir. J.W. Hofstee
In collaboration with: EU SmartBot

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 automated system based on the mobile platform for fast and efficient control of volunteer potato (weed) in sugar beet field. 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, the mobile-based system for efficient control of volunteer potato in the field. The work mainly consists of three procedures including weed detection, weed control, and the integration into a mobile platform with Robot Operating System (ROS).

In 2015, we developed a novel discrimination (weed and crop discrimination) procedure that performs robust under the natural outdoor conditions. The procedure is based on machine learning approach using counter-intuitive advanced features. The camera was fully exposed to outdoor sunlight conditions without having any covering material that protects the camera from direct and strong sunlight. Thanks to our novel discrimination procedure, varying sunlight and shadows are no longer the challenges for our weed control robot.
Bastiaan Vroegindeweij

Email: bastiaan.vroegindeweij@wur.nl
Supervisors: Dr.ir. Joris IJsselmuïden, 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, PoultryBot, 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

In the years 2011-2015, components for each of these objectives where developed. In 2015, they were also integrated into PoultryBot, followed by a final demonstration of its capabilities in December 2015. In 2016, more extensive tests and evaluations were performed on the PoultryBot, to investigate its performance for localisation, navigation and egg collection in more detail in a test environment with hens. Also, PoultryBot appeared several times in national media, such as newspapers, radio interviews and tv shows. With this, the research phase of the Automation for Poultry Production was completed, although dissemination of the scientific results is still going on.

Furthermore, the company Livestock Robotics was founded as spin-off of this research project, to bring knowledge and technology from this project to poultry and livestock practice.

Autonomous navigation of PoultryBot
Autonomous floor egg collection by PoultryBot
Ellen van Weeghel MSc

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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 beneficial for other sustainability goals.
BSc projects completed in 2016

M. van den Aker

*Design van Poultrybot 2.0*

I.P. Andela

*Safety for poultrybot*

F.J. Baron

*Bodemscans en opbrengstmeting in de aardappelteelt op zandgrond*

T.H. van Beers

*Design van Poultrybot 2.0*

E.H.L. ter Beke

*Design of a Brief of Capacities op the pig*

D. Berenpas

*Toepassing van infrarood technologie in de rundveehouderij*

F.H. Brouwer

*Performance assessment of a CH4 flux measurement method for cows in barn conditions*

K.W.A.J. van Dinther

*Robotic picking of grapes*

W.P.G. Dirks

*Analyzing body variables extracted from 3D vision*

E.S.M. van Esbroeck

*Predicting the susceptibility and degree of a co-infection with different variables*

D.J.M. Groeneveld

*Comparing different swarm robotic strategies for agricultural applications*

W.J. de Laat

*Automated counting of potato plant stems*

D.H. Schrijver

*De relatieve bijdrage van urine aan de zijkanten en onderkant van een roostervloer*
J.J. van der Stok

*Prediction biomass yield of grass with drone based measurements*

H.J.M. Tummers

*The performance of a cubicle based measurement system in a dairy barn*

C.J.W. Uijterlinde

*Performance assessment of methane*

A. Verduijn

*Methane emission analysis*

J.A.A. Verstegen

*De invloed van korstvorming*

J.T.A. Vervoort

*What is the effect of conventional....*
MSc projects completed in 2016

T.H. Peterhans

*Precision feeding of mealworms*

R.H.L. Cornelissen

*Robotic handling of chicken breasts*

Y. Hao

*Modelling and validation of different*

M.H. Jansen

*Incorporating animal capacities*

A.J. Jol

*Particle filter based navigation*

A.J. Lopez Lopez

*Risk assessment and feasibility study*

A.J.J.M. van Meer

*Controlled traffic farming in the cultivation*

I.P. Moutsinas

*Integrated simulation of the most....*

D.C. Ras

*3D crop mapping and analysis*

M. Schlepers

*Development of a measurement*

H. van den Top

*Towards a new method for urine puddle*

B.C. Vergouw

*Calibration and application of moisture*
M.J.J. Verploegen

Technical configuration and application

C.J. Voorkamp

Application of machine learning
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 a wide range of 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 or Automation for Bioproduction. Many courses are general engineering courses with many examples from the biosystems engineering domain. The course offer also comprises research 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 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 (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 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.

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 2 (Dutch)

This course is the continuation of FTE-12303 Introduction Agrotechnology part 1. See the description of that course. This second part covers 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 a continuation of the course Engineering 1. This part contains 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, based 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 documented. 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 analysed 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 typical for most biosystems.

Part of the course is the module Information Literacy B in which the students learn how to perform a proper literature search in (scientific) databases.

Students will participate in a professional assessment and, supported by staff, will translate these outcomes in the context of their current programme and future choices.

**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.
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 (English)**

This course is closely related to the course Physical Transport Phenomena (BRD-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 agroproduction in buildings;
- solar energy - passive and active for solar energy collection and use;
- (data processing in Excel).

**FTE-25806 Research Methods Biosystems Engineering 2 (Dutch)**

In this course the students have to execute in groups a small research project. The projects are pre-selected. The students start with making a proposal for their project and subsequently execute this project as a team. They also have to search for scientific literature related to their project and incorporate the literature in the report. In the end, students have to prepare a well-structured report on their project according to scientific standards and present the results orally. Explicit attention in this course will be given to the different aspects of group work (team activities, organisational, social).

**FTE-30306 Livestock Technology (English)**

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 (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 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 modeling 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 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 collaborative design teams. The design methods taught in FTE-24806 are starting point and extended with methods like technology landscaping, theory of inventive problem solving and intellectual property (IP). 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. The case results are reported in oral presentations and in written team reports.

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 Quantitative Analysis of Innovative Biosystems (English)**

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 product quality. The results of the analysis covers 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 system designs, and reflect on the chosen assumptions and calculation methods. The course comprises a multiple day field trip with visits to relevant organisations, universities, and industries in the Netherlands and surrounding countries. The students have to write a report about this field trip. This multiple day field trip is jointly organized with the field trip in the course FTE-33806 Biosystems Design. Methods of engineering design will not be covered during this course, but we do expect that students are able to apply these methods.

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

**BRD-22306 Sensor Technology**

Sensing is an important part of automation in agriculture and the Farm Technology Group provides major contributions to this course. 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.
Scientific publications 2016

Development of a method for prediction of eggshell damage in order to improve egg handling and packing processes

Measurement methods to assess methane production of individual dairy cows in a barn
Wu, L.2016190 p.

Stochastic control of crop growth, a simulation study

Stochastic control of crop growth, a simulation study

Testmodel voor urine-afstroming op nieuwe vloer

Effects of variation in rainfall on rainfed crop yields and water use in dryland farming areas in China

Composition and biogas yield of a novel source segregation system for pig excreta

Probabilistic localisation in repetitive environments: Estimating a robot's position in an aviary poultry house

One tamed at a time: A new approach for controlling continuous magnitudes in numerical comparison tasks
Robotics in agriculture and forestry

Involving the animal as a contributor in design to overcome animal welfare related trade-offs: The dust bath unit as an example

Evaluation of oil spraying systems and air ionisation systems for abatement of particulate matter emission in commercial poultry houses

Temporal and spatial variation of methane concentrations around lying cubicles in dairy barns

Predicting hairline fractures in eggs of mature hens

Plasmodel voorspelt ammoniakemissie van vloer
Snoek, J. W.2016

Dynamic behavior of PH in fresh urine puddles of dairy cows
Snoek, D. J. W., Ogink, N. W. M., Stigter, J. D., Agricola, S., Van De Weijer, T. M. & Groot Koerkamp, P. W. G. 2016 In : Transactions of the ASABE / American Society of Agricultural and Biological Engineers. 59, 5, p. 1403-1411

Assessment of porous media instead of slatted floor for modelling the airflow and ammonia emission in the pit headspace
Robotzwermen gaan onkruid te lijf
1/11/16
Joris IJsselmuiden

Raprobot voor eieren
9/01/16
Bastiaan Vroegindeweij