MULTIDISCIPLINARY EXERCISES: COORDINATION PRACTICES AND APPLICATIONS FROM FUNDAMENTAL TO APPLIED SUBJECTS IN AGRICULTURE ENGINEERING

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Abstract

This activity is carried out in the framework of an innovation project, whose main objective is to coordinate mathematical, physical and engineering contents for a transversal educational path focused on mechatronics, automated control and information and communication technologies.

In such sense one important task in this project is the elaboration of practices and joint applications which will be proposed to the students in successive matters upon different points of view: *"Common Practices".* Through this activity students will be guided to establish relationships between their scientific basic training and their technological formation.

The students will work on the same example during different academic years and semesters using common materials and working spaces. The whole experience will be displayed in Moodle, a virtual learning environment.

A preliminary proposal of *"Common practice"* is presented in this paper as one example: *"Design and Analysis of Suspensions Systems for Stabilizing the Roll of Spray Booms"*. In this example students of different academic levels are asked to solve the complexity of the problem along different subjects: Field measurements (analysis of variability on chemical applications using a spray boom) will be realized in the Agriculture Machinery topic - equivalent to 4.5 ECTS -. Analytical models for the analysis of different suspension systems in the Mechanics and Mechanisms topic -4.5 ECTS -. In Agriculture Applied Electronics – 2.5 ECTS – sensors and actuators will be studied to design controllers. Control strategies for damping the resonance frequency of the suspension will be studied in Process Simulation and Optimization – 3.5 ECTS –. And, finally, the design and development of a vehicle with a spray bar and the corresponding suspension systems will be done in the Robotics topic – 7 ECTS –.

Keywords - Innovation projects, common practice,

1 THE CONTEXT: A TRANSVERSAL EDUCATIONAL PATH

The first function assigned to the Technical University of Madrid (UPM) is to promote engineers, and for the ETSIA (Escuela Técnica Superior de Ingenieros Agrónomos), to promote Agricultural Engineers. The agronomist engineer is a top technician who knows, develops and applies the sciences and agrarian technologies for the agricultural production.

The current study plan, with a global duration of five years, is constructed in two cycles, the first one by a duration of two years, and the second one by a duration of three years. The first cycle includes the basic educations and general formation (training), whereas the second cycle devotes itself to the deepening and specialization in the corresponding educations, as well as the preparation for the exercise of the professional activities. This structure allows therefore the first cycle of scientific basic training, and a subsequent specific formation (training) and of technological orientation in three posterior years that shape the second cycle.

The academic global load, for both cycles, supposes 400 credits distributed in main, non main matters (obligatory and optional) and of free configuration, besides a final work for graduation.

Educational paths at the ETSIA orientate the election of the optional credits and the free election credits of both cycles towards a certain field of knowledge. The pupil who realizes an educational path receives an additional certificate, besides the Agronomist Engineer's official degree.

In order to improve the training of the new graduates in the Information Technologies and due to the higher demand of engineers qualified in this field, an educational path on Information Technologies and Automatic has been promoted from the departments of Rural engineering, Applied Mathematics and Cartographic Engineering, Geodesy and Aerial map-making [6]. For the study, design and roll over of this educational path, the UPM has financed a coordinated project of educational innovation during the course 2007/2008.

The set of topics elaborated for this purpose is given in Table 1.

Table 1. Innovative educational path

Topic	Department	Topic type	Credits (UPM)
Computer methods	Math.	opt.	6,0
Simulation and optimization computing	Math.	opt.	4,5
Agriculture applied electronics	Rural eng.	free elect.	4,5
Computer aided design and drawing	Cartog. eng.	free elect.	4,5
Robotics applied to agriculture	Math.	free elect.	9,0
Process simulation and optimization	Math.	opt.	4,5
Terrestrial and geographical information systems	Cartog. eng	opt.	4,5
Automatic control of facilities	Rural eng.	opt.	3,0
Precision agriculture	Rural eng.	opt.	3,0
		total	43,5

The acceptance of the educational path has been very good on the part of the direction of the ETSIA, the companies of the sector, the teachers and the pupils.

2 MULTIDISCIPLINARY APPLICATIONS

Frequently agricultural engineers and researchers have to solve complex problems that require the application of various aspects of their knowledge. However, the different matters included in the degree programs are usually presented without relationships between their contents. In such sense, the team of professors involved in the educational path are promoting methodologies focused toward a coordinated and multidisciplinary formation, trying to cover adequately the knowledge on mathematical and physical required on applied matters such as robotics, electronic or automated control of facilities. Complex agronomic problems and applications are being defined to be analysed simultaneously from different subjects trying to obtain a complete approximation to the solution.

In this context, practices and joint applications are being prepared in order to be carried out along next years. In the following sections, one of them is explained.

Different aspects related to the suspensions systems of spray booms will be analysed along the Common Practice I. This activity will be developed in four topics spread through the second cycles (from third to fifth year), according to the chronogram showed in Table 2. Green colour represents applied topics and red colour represents fundamental topics (physical and mathematical contents).

Table 2. Topic involved in "*Common Practice I"* and its corresponding schedule.

2nd cycle Topic (Type)	1st semester	2nd semester	3rd semester	4th semester	5th semester	6th semester
Agriculture Applied Electronics (Free election)	green					
Mechanics and Mechanisms (Free election)		red				
Agriculture Machinery (Optative)			green			
Process Simulation and Optimization (Optative)			red			
Robotics (Free election)					green	green

3 COMMON PRACTICE I: "DESIGN AND ANALYSIS OF SUSPENSIONS SYSTEMS FOR STABILIZING THE ROLL OF SPRAY BOOMS"

3.1 Defining the problem

Application of chemical plant protection means and fertiliser is one of the most important field operations. Pesticides and some fertiliser are dissolved in a carrier liquid and sprayed by means of an agricultural spray boom. This activity concentrates on agricultural spray booms.

Spray-boom vibrations are one of the main causes of non-homogeneous distribution of agro-chemicals. Theoretical studies, simulations and field experiments have indicated that due to spray boom vibrations, spray deposit distribution varies between 0 and 800%. The most important vibrations (Fig. 2), affecting the spray distribution pattern, are rolling (rotational motion around an axis along the driving direction) spray boom motions in the vertical plane and two types of vibrations in the horizontal plane, yawing and jolting (anti-symmetric and symmetric motions, respectively)

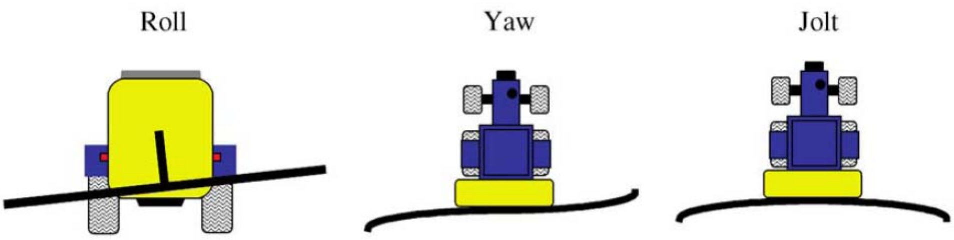


Figure 2. Most important vibrations affecting the distributions of agro-chemicals. [1]

Despite the fact that horizontal boom movements are much more critical for the spray deposit distribution, the designs of manufacturers are focused on rolling. To reduce the effect of boom roll, almost as many variants of passive suspensions exist as there are manufacturers. On other hand most of the researches are also focused on rolling, as practice shows that proper tuning of the vertical suspension is still problematic.

3.2 Activity in Agriculture Applied Electronics

A. Title: Sensors and actuator for agricultural control system (1 ECTS)

B. Materials

In this activity the students are provided with a wide variety of transducers: potentiometers, accelerometers, inclinometers, compass and ultrasound sensors together with solenoid valves and pulse with modulated valves, steps motor and cylinders.

The aforementioned equipment will be used in standard IP65 Agricultural format as well as adapted for Lego Mindstorms. The former will be used in the framework of Agricultural Machinery while the later will performed on automated robots.

C. Introduction

Applied electronics cover the fundamentals of signal transducer which is the field that faces the translation of any physical or chemical magnitude into an electrical signal that can be interpreted by automatic control system [2].

This subject was included in the degree program in 2001 and has been evolving ever since from very fundamental knowledge towards design and manufacture of agriculture oriented sensing systems by the students. This subject also covers analogical and electrical signal conditioning and corresponding actuators and the hardware needed for control.

D. Tasks

To be able to install a wide variety of sensors with the ability of capturing data with dedicated electronics. Such data will be used as the input for active and passive control systems, and will be used at Process Simulation and Optimization for designing the best control strategy and optimize performance.

3.3 Activity in Mechanics and Mechanisms

A. Title: Analytical models of suspensions systems in spray booms (0.8 ECTS)

B. Materials

In this activity students are provided with fundamental bibliography and specific research papers.

C. Introduction

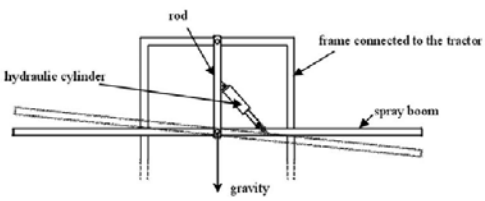
In order to reduce the effect of boom roll manufacturers use passive suspensions systems. They all use gravity as a reference and move back the boom into its correct position. Commonly arte pendulum or trapezium based suspensions. As vertical suspensions attempt to position the boom perpendicular or at least angle with the direction of gravity, problems occur when driving over inclined fields.

Active suspensions systems include sensors and actuators to determine the distance between the spray boom and the soil and correct the position of the spray boom according to the acquired data. These systems allow vertical booms corrections on hilly fields.

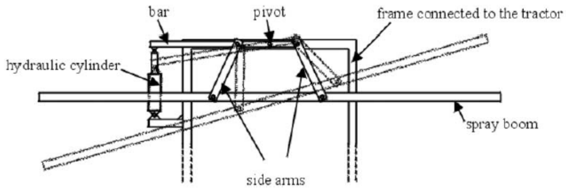
D. Tasks:

Derive the analytical mathematical model for passive suspension systems: pendulum and trapezium based suspensions.

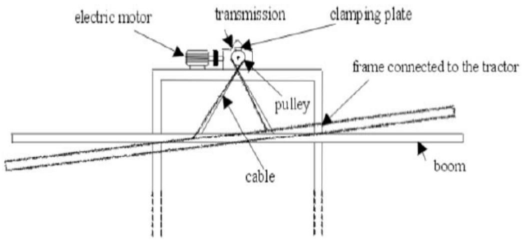
Analyse the following active suspensions systems (Fig. 2). From the modelling procedure studied during theoretical class, establish the mathematical model of one of them. Results will be explained to the rest of the class. Propose your own conclusion after the oral presentations.



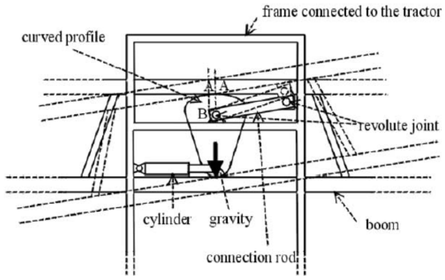
Active pendulum suspension



Active trapezium suspension



Cable suspension



Suspension based on following a curved profile

Figure 2. Four types of active suspension systems. [4]

3.4 Activity in Agriculture Machinery

A. Title: Boom suspension influence on spray distribution (1.5 ECTS)

B. Materials

In this activity students are provided with the needed machinery: spray boom and tractor; which is driven by an expert person. Other materials for field measurements: sensors and acquire systems (from Agricultural Applied Electronics), balances, chronometers, milestones, recipients, hydro-sensible paper...

C. Introduction

In this subject machinery of crop production is studied: design, elements, performance and field measurements. Pest control equipment is one of the main contents in this topic.

The effects of boom height, boom speed, suspension system and nozzle type on dynamic spray have to be analyzed. Several researches proposed procedures and instrumentation to measure vibration inputs to the boom, boom acceleration response, boom height and sprayer position along a field track with the aim of relating boom dynamics to field spray deposits [5]. Students are required to carry out field measurements with commercial spray booms.

D. Tasks:

Calculate the vertical distance between different points of the spray boom and the soil for different inclination angles (Table 3).

Table 3. Vertical distance (cm) between several points of the spray boom and the soil.

Inclination angle (º)	Distance to the centre of the spray boom (m)				
	-21	-9	0	9	21
0.5			0.0		
1			0.0		
2			0.0		

Identify the type of suspension systems in the spray booms studied.

Install accelerometers, ultrasound sensors, potentiometers... and the corresponding data loggers on the boom.

Carry out the field measurements in order to determine the dynamic behaviour of the machine and the homogeneity of the distribution.

3.5 Activity in Process Simulation and Optimization

A. Title: Study of a controller for the self-levelling system for stabilizing a spray machine (1.5 ECTS)

B. Materials

Students are provided with scientific bibliography [3] and the needed hardware and software (Matlab and Simulink [7]) to develop the controllers.

C. Introduction

We want to design a controller to automatically add damping to the suspension and keep the boom parallel to the soil

D. Tasks

Using the mathematical model derived in Activity in Mechanics and Mechanisms develop a simulation model for that suspension system

Study of different control strategies to achieve a stable system

Implementation on a small-scale real spraying machine built in Robotics

3.6 Activity in Robotics

A. Title: Design, construction and programming of a vehicle with a "spray boom" and a suspensions system (3 ECTS)

B. Materials

The subject uses Lego Mindstorm as a training tool with Lejos (JAVA for lego) as programming language along whole year supervision.

C. Introduction

Robotics in Agriculture has been a new subject this year (7.5 ECTS); this subject has been designed in the framework of the innovative educational path, within the aim of providing a practical scenario for multidisciplinary contents and abilities.

During the first semester the students face a week program with problem-based education, starting with the design and building of basic mechanisms like gear boxes, manipulators and vehicles, and also learning how to deal with object oriented languages and available Lego libraries. During the second semester the students are requested to develop a complete robot with the ability of performing general as well as agricultural specific tasks. Exhibitions and oral presentations are programmed along the course. For next edition some groups of students will be required to focus their project on "spray boom".

D. Tasks

Develop a complete robot with the ability of working in a dwarf tree forest, with a structure simulating a "spray boom" and with one of the suspension systems studied at Mechanics and Mechanisms.

4 REFERENCES

[1] Anthonis, J.; Audenaert, J.; Ramon, H.; 2005. Design Optimisation for the Vertical Suspension of a Crop Sprayer Boom. Biosystems Engineering 90 (2): 153–160.

[2] CIGR Handbook of Agricultural Engineering Volume VI: Information Technology. 2006

[3] Deprez, K.; Anthonis, J.; Ramon, H.; Van Bressel, H. 2002. Development of a slow active suspension for stabilizing the roll of spray booms, part 2: controller design. Biosystems Engineering 81(3), 273-279

[4] Deprez, K.; Anthonis, J.; Ramon, H.; 2003. System for vertical boom corrections on hilly fields. Journal of Sound and Vibration 266: 613–624.

[5] Jeon, H.Y.; Womac, A.R.; Wilkerson J.B.; 2004. Sprayer boom instrumentation for field use. Transactions of the ASAE 47(3): 659-666.

[6] Recio, B.; Morato, M.C.; Castellanos, M.T.; Garcia, J.L.; Garcia-Mouton, E.; 2008.Computational Engineering in Systems Applications.183-187. WSEAS Press

[7] Simulink (2007). Version R2007b. The MathWorks. USA