

# MIGRATION TO AN A ON-LINE LABORATORY IN MECHANICAL ENGINEERING. THE CASE OF A CAM-FOLLOWER DESIGN PRACTICE

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The European Higher Education Area (EHEA) has led to a change in the way the subjects are taught. One of the more important aspects of the EHEA is to support the autonomous study of the students. Taking into account this new approach, the virtual laboratory of the subject Mechanisms of the Aeronautical studies at the Technical University of Madrid is being migrated to an on-line scheme.

This virtual laboratory consists of two practices: the design of cam-follower mechanisms and the design of trains of gears. Both practices are software applications that, in the current situation, need to be installed on each computer and the students carry out the practice at the computer classroom of the school under the supervision of a teacher.

During this year the design of cam-follower mechanisms practice has been moved to a web application using Java and the Google Development Toolkit. In this practice the students have to design and study the running of a cam to perform a specific displacement diagram with a selected follower taking into account that the mechanism must be able to work properly at high speed regime. The practice has maintained its objectives in the new platform but to take advantage of the new methodology and try to avoid the inconveniences that the previous version had shown. Once the new practice has been ready, a pilot study has been carried out to compare both approaches: on-line and in-lab.

This paper shows the adaptation of the cam and follower practice to an on-line methodology. Both practices are described and the changes that have been done to the initial one are shown. They are compared and the weak and strong points of each one are analyzed. Finally we explain the pilot study carried out, the students' impression and the results obtained.

Keywords: On-line laboratory, mechanisms, mechanics, virtual laboratory, EHEA.

## 1 INTRODUCTION

The European Higher Education Area (EHEA) has led to a new paradigm of teaching and learning. Teacher-centered knowledge-based teaching, resulting from memorization, turns into a more democratic and balanced model where the students and teacher are closer and where personal contact is more prolonged and with more benefit for both. In this new model, the students are responsible at a different level, their work becomes more independent, autonomous and creative. To achieve this goal it is necessary to give the students the tools and knowledge they need to learn the academic subjects instead of telling them what exactly they have to do. This study of the subject has to be done in an autonomous way, outside classroom hours, so it is very important to provide the students the tools they need to take advantage of all the information they receive from the teacher. Laboratory practices are a very useful tool for the students to consolidate the knowledge they have acquired at class. In situ laboratory seems to be the ideal way to perform a practice and get used with an instrument but, actually, it seldom happens. Very frequently there are a lot of students and they only can dedicate limited time to each practice. Also, instrumental practices are often quite limited and they cannot be compared to reality. This, and other, reasons made the virtual practices a very interesting option. Virtual practices have the obvious inconvenience that the students are not manipulating a real machine but a computer simulation. On the other side nowadays computer simulations can be very near to reality and can take into

account factors difficult to obtain in the laboratory room (i.e. dangerous issues, environmental aspects, etc). Unfortunately both methodologies needs an in situ realization of the practice (whether they are a laboratory or a computer classroom), with the resulting problems of the number of students and the need of remain at the lab or computer classroom (the number of computers with the simulation practice installed are generally more than the instrumental practices but they are also limited). This problem can be solved with a design of an on-line practice, in other words, a simulation that can be executed in a server from any computer via Internet, using a web service. This option allows the students to do the practice at home, quietly and taking all the time they need to do it, learn from it and even do some tests and develop their creativity. The Technical University of Madrid has chosen this last option as the preferred one and encourage its teachers to implement on-line practices in their subjects.

The subject "Mechanism" is taught at the Aeronautical studies of the Technical University of Madrid, it deals with the working and design of machines and mechanisms from a mechanical point of view. This subject offers a detail study of the more common mechanisms like bearings, gears, brakes, clutches or cam-followers mechanisms. The teaching of the subjects alternates master classes with problem classes and laboratory sessions. Due to high number of students, the necessity of using computers for the design of the mechanisms and the impossibility of making the mechanisms in the school workshop, the practices at the laboratory sessions are simulations practices.

The subject has two different practices: Design of different sort of straight-cut gears wheels (Tren) and design a cam-follower mechanism to generate a concrete movement (Leva). Each practice have a specific software made by the teachers of the subject, this software is an application that must be installed at each computer that is going to use it. Now it is only installed at the computer classrooms of the school.

Due to the limitations of this software we are working to migrate both practices to a client-server technology. The current paper shows the migration of the Leva practice. We will follow the following steps:

- The original software will be show, paying special attention to its advantages and disadvantages
- The new software design will be explain. This desing tries to avoid the disadvantages of the previous one maintaining its advantages.
- The performance of the new software will be analysed, from a teacher an a student point of view.

## **2 THE Tk-Leva APPLICATION**

The current Leva practice softaware aplication (Tk-Leva) is directed to the higher education centers with mechanical studies. It has been developed at the Escuela Universitaria de Ingeniería Técnica Aeronáutica de la Universidad Politécnica de Madrid (Spain) with the main objective of helping, during the study of the cam-follower mechanisms, the comprehension of:

1. The obtaining of the cam profile of differents sorts of cams.
2. The importance of the design parameters.
3. The working of a cam-follower mechanism.
4. The analysis of the displacement diagram

The necessity of the Tk-Leva application came up with the demand of a useful and flexible tool that generates easily images and graphs of cam-followers mechanisms to facilitate the students comprehension of the subject. The program allows the students to design a concrete cam-follower mechanism through: 1) the analysis of the displacement diagram, 2) analysis of the main parameters of the cam and its profile. From the programmers point of view the software has three different parts: a) the internal calculus, b) the graphical representation and c) graphical interface (written in the programming language tk) that allow the user to communicate with the application and visualize the results.

This application helps the students to understand the relation between the displacement diagram, the velocity and acceleration of the follower. It also has many other functions like showing the curvature radius of the cam. But, above all, it helps the students to have a overall picture of the design of a cam-follower mechanism. Thanks to the program the students is able to understand the complexity of expressions involved in the achievement of the cam profile whose meaning is very difficult to imagine just from the mathematical expressions. In concrete we have observed the following advantages of the use of the program:

1. Regarding the displacement diagram: the importance of the continuity of the derivatives of the displacement diagram is much easier to understand when the students sees them in a graph. The discontinuities are very easy to visualize, so the students can notice its importance. The effects of the sudden changes in the velocity and acceleration are, also, very easy to see.
2. Regarding the obtaining of the cam profile: The graphical process is hardworking and very tedious to do by hand or in the blackboard, however the application can automatically generate the cam profile and provides an animation of the mechanism. The students can change design parameters like follower type, base radius, etc. very easily and see the changes at the cam-follower performance.
3. The calculus algorithms are very efficient and the application can generate a cam-follower mechanism on the fly (doing the process by hand would take hours). So the students can see what he has done wrong and correct it.
4. The application allows the students to manipulate parameters which expressions are very complex and avoids the difficulty of analyzing that functions. This also makes easier to understand all the approximations done in the theoretical calculus and evaluate its validity.
5. The program allows the students a more independent work. They are able to check the goodness of their design and improve it without requiring any help. They can also change parameters on the fly and see what happens.

The main disadvantages detected during the years of using Tk-Leva are:

1. The practices must be done in the computer classrooms of the school. The demand of this facilities is very high –and it is expected to be increasing, so the students can only take advantage of the software 3 hours each semester. This time only allows the students to do a concrete design but no to try alternatives on the fly which is –in the teachers opinion, the best way to learn how to design cam-follower mechanisms. Other consequence of this limitation is that the practice is scheduled before the subject begins and sometimes it is not possible to synchronize it with the theoretical classes.
2. The teacher cannot use Tk-Leva in the classroom as they are only installed in the computer classrooms.

- The application stores all the information of the practice locally and it only can be recalled from that PC. So it is very difficult for the teacher to know the work of each students and evaluate it.

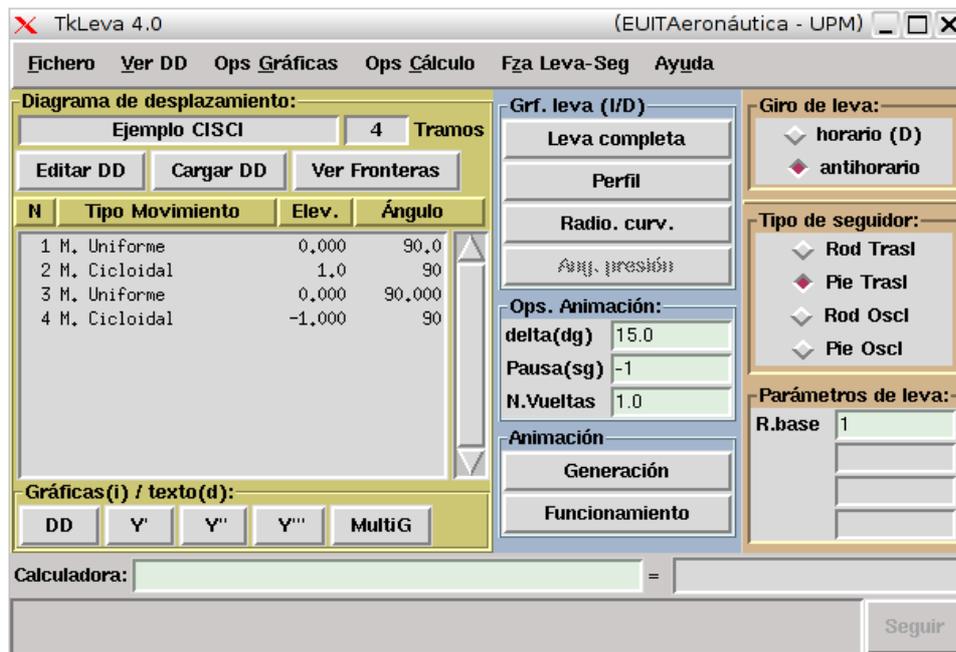


Figure 1. Visual interface of the Tk-Leva.

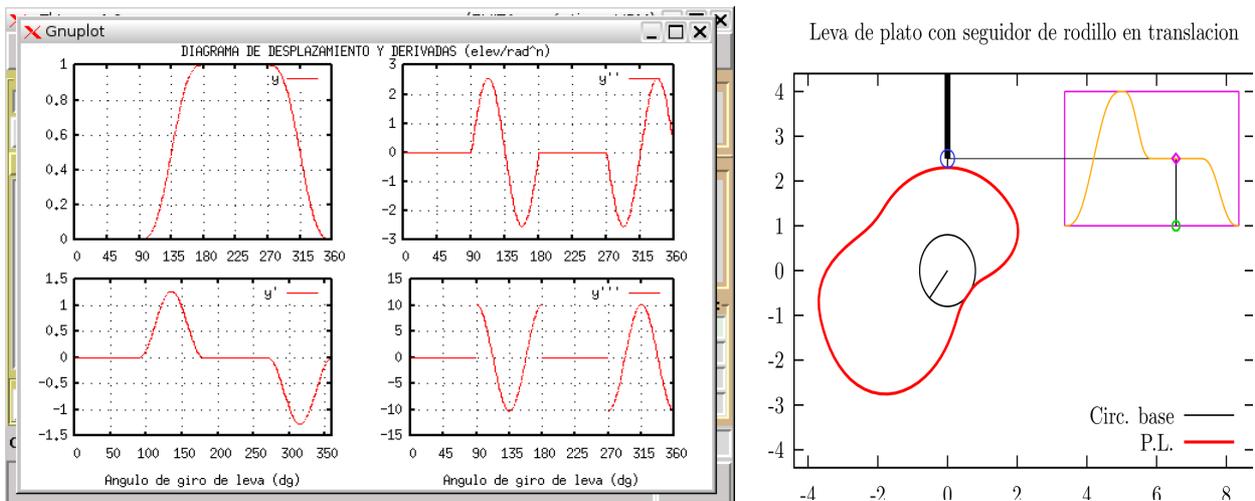


Figure 2. Diagram displacement and its derivatives and cam profile

### 3 THE NEW LEVA APPLICATION

The new Leva application (LevaWeb) has been designed with the requirement of maintaining the functionality of the previous one, however we have treated to provide a more intuitive way to show them. We have decided to maintain all the calculus libraries due to its powerfulness and efficiency. With this requirements we have developed a new software that can be run from an Internet browser. So with a proper identification the students will be able to run the program everywhere and use it while studying the subject. The teacher will also be able to use it in the classrooms to help the students to understand the theoretical framework of a cam-follower mechanism.

To program LevaWeb software we have chosen and client-server platform. In concrete we have chosen Java because it is a good language, very powerful and makes the software easy to upgrade in a future. Java is object oriented (one can quickly understand code that has been written

by other person), garbage collected and strongly-typed. Also we need the code to work properly into the server-side and the client-side, we have decided to work with the Google web toolkit (GWT), because GWT lets you to write both parts of your web application, the client-side and the server-side, in just one language: Java. GWT compiles the client-side Java code to Javascript / HTML 5 / CSS code, the standard web languages that any modern browser can understand. On the other hand, the server-side is just a library of Java servlet classes which are compiled to Java bytecode, and can be then executed by any web server that runs Java, for instance Apache Tomcat. Besides GWT provides a framework of powerful Java classes that are useful for many purposes, like for handling the asynchronous client-server communication process and for building rich HTML / CSS user interfaces. We've used the Eclipse IDE as the source code editor, and Apache Subversion as the revision control system. GWT, Eclipse and Subversion are all free, open-source tools.

Finally, using this technology we have built a new application with a intuitive interface, visually more attractive to the students and maintaining most of the capabilities of the previous version. Up to now, there are some characteristics not yet included like the spring constraint between the cam and the follower and the animation of a cam-follower. However they are expected to be included in the application during the following months.

We have also included an user registration and validation system so that each user works in a different session and can save and recall their work. This new functionality is very important because it allows the students to continue working with a concrete design at different times and different PCs without having to start all the design from scratch again. It also allows the students to save the practice and send it to the teacher and lets the teacher to know the progress of each students and be able to evaluate it.

The software is being tested in a server of the school and only the students of the subject mechanisms can access to it. We plan to finish the debugging of the software during this semester and will move the software to a production server so that the software can be accesible to all the university community.

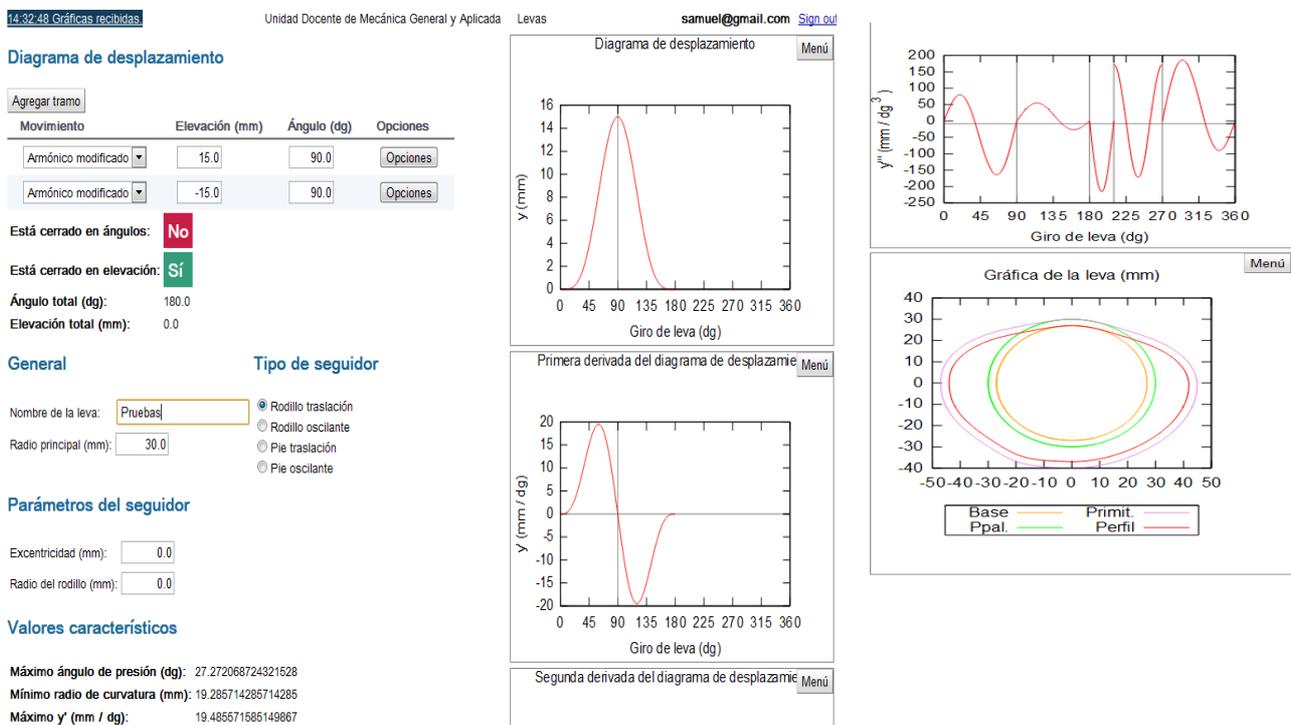


Figure 3: Visual appearance of LevaWeb, displacement diagrams and leva profile.

## 4 FIRST IMPRESSIONS OF THE NEW APPLICATION

The new application was presented to the students last semester. We showed the students both versions (Tk-Leva and LevaWeb). During the practice session at the computer classroom the students were able to choose between both versions and they can also use the new one out of class.

We have took advantage to this simultaneous contact to know the students and teachers impressions.

### 4.1 Students satisfaction

A survey has been carried out to know the opinion of the students on the utility of the application in relation with the previous local application. In the survey the students are asked about the preference between Tk-Leva and LevaWeb. This questions were addressed only to students who used both applications. The results are summarized in Table 1. The perception of the students is that both versions of the application have similar utility, documentation and storage of data (although, actually, Tk-Leva is much better documented and has a more compete storage of the the projects) and they see Tk-Leva as more powerful application, as in fact it is (as mentioned before not all the capabilities of Tk-Leva are already implemented in LevaWeb). In the rest of answers: usability, appearance and overall preference, the mean is quite neutral but the mode shows a clear preference for the web version in the majority of the students.

Question	Mode	Mean	Stnd. Dev.	Answers
Usability	1	2,4	1,4	55
Documentation	3	2,6	1,3	55
Funcionality	4	3,3	1,3	54
Utility	3	3,0	1,2	55
Data Storage	3	2,6	1,3	54
Appearance and aesthetics	1	2,6	1,3	54
Overall preference	1	2,7	1,4	52

Table1: Students preference between Tk-Leva and LevaWeb. 1 indicates neat preference for LevaWeb and 5 neat preference for Tk-Leva.

### 4.2 Teachers satisfaction

Also, teachers where asked to compare both application and give their opinion. Their initial feeling was that LevaWeb is more versatile and should make autonomous work easier, as students are not binded to the laboratory but. Instead, they may work in the computer classroom or even at home. Nevertheless, after the experience, their opinion was less positive. Released from the schedule bindings, the work of the students dramatically dropped. Often, after a brief understanding of the duty they should do, the students leave the laboratory promising to finish at home although, in most cases, they don't work any more. In contrast, when the local Tk-Leva was used, most of the students fulfill their deal and also, some of them work the exercises in great depth.

## 5 CONCLUSION

A new software application for the cam-follower practice has been implemented. This application allows the students to work with it out of the classrooms and have most of the functions of the previous one. LevaWeb has been tested by the students and teachers and both think that it is working fine. The new application has a more attractive appearance and a better usability but it has not all the functionality of the previous one. So LevaWeb is a good tool to use it at the laboratory and in classes and it can substitute Tk-Leva when all the options of this new were implemented in the new software.

However LevaWeb was also designed to be used by the students by themselves. We have noticed that, although the application could perfectly be used by the students out of the classes, they do not use it. The main intention of the on-line application was to promote the autonomous learning. So, to obligate to on-site sessions, doesn't seem a good solution. Instead, a different approach is needed. Until now, the laboratory was assessed by an objective test designed to measure the profit of the practical sessions. Probably, a "project" approach in which an open problem must be solved would be more motivating for the students. But these activities tend to be more time-consuming for the students (and for the teachers).

At present, there seems to be no more choice: to bind the students to the laboratory in order to ensure their commitment (in this case, the on-line version is pointless) or to set a complex time-consuming deal to assess the progress, instead of the objective test.

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