A Multi-layer Based Architecture for the Development of an Open Source CAD/CAM Integration Virtual Platform for the Training of Professional Skills in Engineering Students

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Abstract- This article proposes a n-layer architecture, with a web client as a front-end, for the development of a virtual platform for process simulation on CNC machines. This Open-Source platform includes a CAD-CAM interface drawing primitives, and then used to furnish a CNC program that triggers a touch-screen virtual simulator. The objectives of this project are two fold. First, an educational component that foster new alternatives for the CAD-CAM/CNC learning process in undergrad & grade schools and technical and technological institutes emphasizing in the development of critical skills, discussion and collaborative work. The second objective puts together a research & technological component that will take the state of the art in CAD-CAM integration to a new level with the development of optimal algorithms and virtual platforms, on-line availability, that will pave the way for the long-term goal of this project, that is, to have a visible and active graduate school in Ecuador and a world wide Open-Innovation community in the area of CAD-CAM integration and operation of CNC machinery. The virtual platform, developed as a part of this study delivers: (1) improved training process of students, (2) creates a multidisciplinary team and a collaborative work space that will push the new generation of students to face future technological challenges, (3) implement industry standards for CAD/CAM, (4) a platform for the development of industrial applications. A prototype of this system was developed and implemented in a network of universities and technological institutes in Ecuador.

The CAD/CAM systems plays an important role in the Engineering System for the industry. In the academic area, this Open-Source platform permit to develop in the student a series skill that are the basis for their professional performance. This article also shows how the proposed open source CAD/CAM integration virtual platform support for the development of these skills as a tool for three-dimensional modeling and engineering analysis.

***Keywords*:** CAD-CAM integration, Virtual platforms, CNC machines, Skills.

1. Introduction

Manufacturing is a transformation process by which raw materials are converted into finished products with a market value, by a combination of labor, machinery, special tools and energy. Tools and machinery play a key role in the technological development of the world to the point that the rate of development of machine tools is an indicator of industrial development.

Complexity in the manufacturing process and increasing market demand for lower prices and stock led to the development of CNC (i.e. Computer Numerical Control). CNC is a manufacturing automation (i.e. programmable) method that delivers important factors such as accuracy, speed, flexibility, operational reliability and increased industrial safety during the manufacturing process. By using this coded instructions, all actions of a machine or mechanism are controlled by a sequence of operations and movements (path tool, depth of cut, change tools, etc.) previously established by the programmer (Rao, 2010). CNC code is based on the EIA 267-C standard and became as a standard itself for the integration of CAD, CAM and CAE on high performance computing environments.

Now a day, commercial mechanical CAD/CAM packages provide a rather low level of interaction with user needs (Rao, 2010). On the other hand, the Open Source Development Model open up dominant

proprietary software and brings collaborative work and community needs to the scene to strengthen the capabilities of current available CAD-CAM/CNC integration tools.

Several efforts are currently conducted towards the development of more efficient integration platforms on Open Environments (Chang et al., 2006). However, technologies and methodologies for software development on Internet (Groover, 2007) are also an active area of research and development that brings new programming paradigms, code portability and flexibility with numerous applications in other fields. Within this context, a fundamental question arises and is answered in this project:

Is it possible to use a multi-layered platform to integrate CAD/CAM procedures and deliver a more efficient and accessible application under the concept of Open Innovation?

The answer to this question is, step by step, given throughout this paper. A web access CAD viewer for interacting with the users through Internet, a production environment with tools to support the development of CAM models that interface with a CNC code generator is available as standalone application but also in a corporate computational platform (i.e. CEDIA multimedia center) to spread the educational impact of this project.

2. Software Architecture for CAD/CAM Integration
2.1. The n-layer Architecture

The CAD/CAM web application is designed on Java Servlet technology. It has two web clients: (1) administration module, and (2) user module. The module for administration allows for security administration, maintenance catalogues control, etc. The user module constitutes the user interface; it is of the "Client Rich" type since high performance for user interaction, and graphics handling is required. The application is built on three layers described as follows (Figure 1):

(1) Front-End. The front-end encompasses all the user interface of this application. It can be divided in the following components.
- **Views:** Web pages in JSP with tag libraries from Spring MVC that display user forms.
- **Controllers:** Controllers from SpringMVC that receive and process the user requests.
- **Models:** These are objects from the domain model.

(2) Business Logic. Collect all the complex processes that compose the application.
- **Service Layer: Controllers:** Implement and execute all processes that belong to the business logic. It is also in charge of all the interactions with the Model Domain.
- **Model Domain Layer:** It contains all the components that encompass the conceptual structure of the applications. It utilizes traditions JaveBeans technology.

(3) Data. Implements the Data Model and the access to the data. It is built over ORM Hibernate.
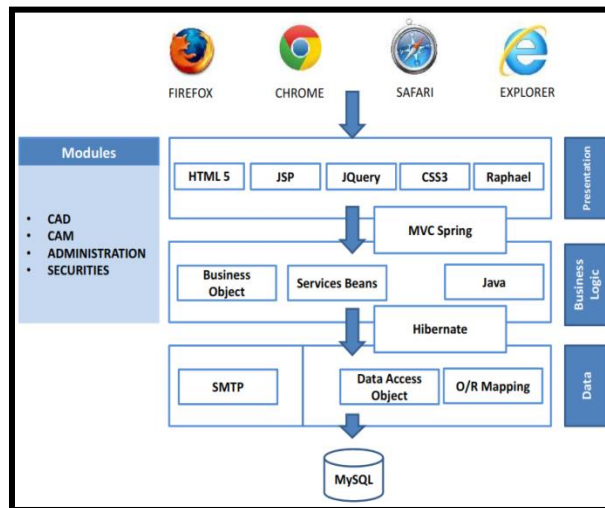

Fig. 1. A n-layered architecture with web client for the development of a CAD/CAM Open Source platform.

2.2 Application Components

Figure 2 shows the functionality and component of the CAD/CAM application. The links reflect the interactions between the different modules that compose the application. The application consists of three modules: (1) Security, (2) CAD, and (3) CAM, all of them access the data model designed for this application.

- **Module 1 (CAD):** It implements the business logic related to the generation of geometric entities or primitives that represent the target object for the manufacturing process. The CAD (Computer Aided Design), allows the designer to describe the geometry of parts, integrated circuits, assemblies, etc.
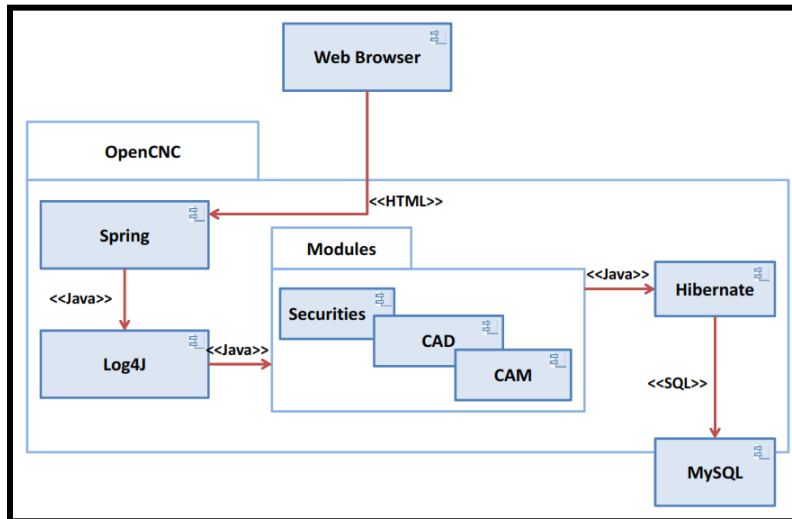

Fig. 2 Application framework.

- **Module 2 (CAM):** It implements all the CAM operation specified by the user. It ends up with the generation of the CNC program that will serve as an input for the Virtual Simulator. The term CAM (Computer Aided Manufacturing) can be defined as the use of computerized systems for planning, management and control of the operations of a manufacturing plant by direct or indirect interface between the computer system and production resources.
- **Module 3 (Security/Administration):** It handles the security administration for the system.
- **Module 4 (Hibernate/MySQL):** It facilitates the mapping between the application object model and the relational data base.

3. Using the Virtual Platform for the Development of Skills

An accurate definition of skills is: "From the epistemological approach of complex thinking, skills are thought of as processes that construct, reconstruct and reinforce people, in order to understand, analyze and solve different tasks and problems of working environments, with reflective consciousness, autonomy and creativity, looking for the productivity, growth of the organization from own personal fulfillment, rationally using environmental resources and taking into account the complexity and uncertainty of the situation" (Nicolescu et al., 2005).

The whole skills model establishes three levels, basic skills, generic and specific; the range goes from the general to the particular wide. Core competencies are the essential intellectual abilities for learning a profession; in them are the cognitive, technical and methodological skills, many of which are acquired in previous levels of education (e.g. mathematical proper use of oral language, and writing). Generic skills are the common basis of profession or refer to the specific situations of professional practice that require complex answers. Finally, specific skills are the particular base of professional practice and are linked to specific performance conditions.

From the skills based approach, the subjects must focus on what businesses need, but education at

the University should not focus just training to businesses, also have responsibilities towards the formation of university skills training researchers and entrepreneurs. Therefore, it is necessary to reformulate the powers that form in the engineering courses that use CAD / CAM systems as support platforms to form in students additional skills to companies who require you, allow them to future implementation innovative concepts in business, and encourage entrepreneurial attitudes with high technological content, allowing the market to introduce new products or services.

Therefore, when micro curriculum design should consider include different from those found in the analysis of the social skills, the proposed open source CAD/CAM integration virtual platform allows students to develop other skills that will be useful in your future, not only as a tool operators drawing for companies, but also to produce graduates with skills investigative and enterprise.
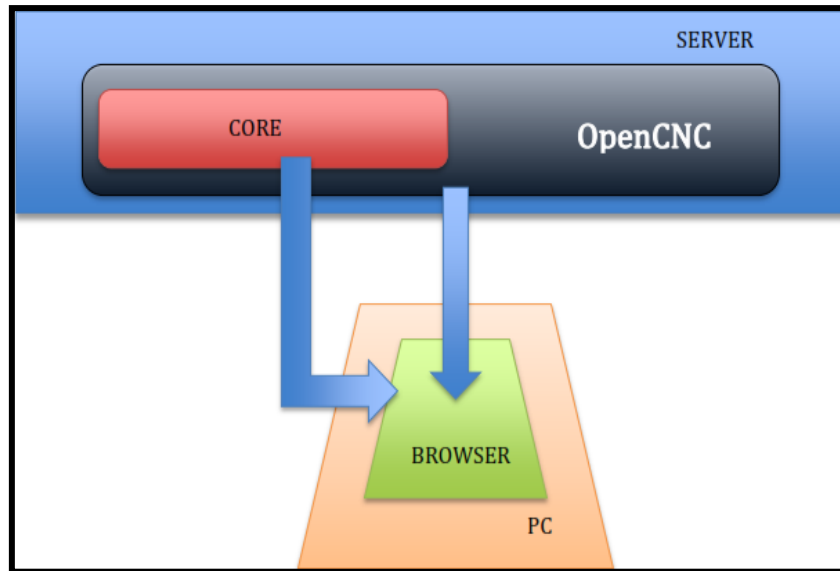

Fig. 3 Benefits of the Open-Source platform.

The "core" of the Open-Source platform is available for downloading (Figure 3); architects, engineers, designers and common people can use and modify the code, therefore all versions can adjust to everyone needs. The principal goal is to generate and improve creativity. The product is for leaders because any person can create an industry (i.e 3D printers, CNC machines). The entire project can be done in South America, so the price and time invested will be the lowest due to the software just needs to be implement in any machine; also we should consider that South America economy is growing so it is important to show that with this software we can also create new technology concerning to CAD/CAM and open source

The software cannot be use just in the mechanic industry; it can also be useful in media industry as a tool to develop creativity and achieve new goals.

The open source CAD/CAM integration virtual platform application has been of invaluable help, because it has allowed all students the same opportunity to develop the skills displayed before. With the proposed open source CAD/CAM integration virtual platform has allowed a real democratization of knowledge and the development of cognitive skills (allowing obtaining knowledge of a much easier way) , of action (allowing learning by doing very quickly and see materialized ideas easily) and attitudinal (to learn in a fun way and with high levels of motivation).

4. Results and Discussion

An integrated CAD -CAM platform is available in an Open Environment. Based on primitives used to describe the geometry of an object, a CNC program can be generated. The program is then used as an input for the virtual simulator implemented on a touch-screen system to let the user visualize the operation of CNC machines and tools. This virtual laboratory has been successfully implemented in Ecuadorian universities and technological institutes to facilitate the training on manufacturing processes of students and professionals.

In addition, the platform is being used by a group of researchers as a base line for further developments related to high performance computing, and artificial intelligence algorithms for CAD-CAM integration. A Network of researchers, instructors, graduate and undergraduate students in New Manufacturing Technologies that integrates interdisciplinary research can be regarded as an important output of this research project.

The high cost of CNC tools and machines is an obstacle for educational institutions of developing countries to include this type of equipment in the training process of students. Virtual simulators and laboratories, like the one implemented in this project, generate a profound impact in the learning process of mechanical engineers and technicians of these countries. In addition to that, the industrialization process and technological dependence of developing countries can be shortened with these type of Open Source and Open Innovation environments.

The introduction of the proposed open source CAD/CAM integration virtual platform has allowed the development of additional skills to use as a dimensional modeling tool for obtaining a manufacturing drawings or requirements for companies, but also to produce graduates with skills investigative and enterprise.

Acknowledgments

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