This paper presents an application based on digital enterprise technologies to support both the business globalization and service providing in small and medium sized companies highly focused in production competences. The requirements and functionalities are discussed and the application to support the work environment, communication and remote access to information and in-site knowledge is overviewed. The application was designed considering the current work procedures in tooling industry and it allows tool makers staff, in their usual workstation, to interact with their in-site colleagues, clients or any partner at distant places and discuss technical problems, accessing and having available all the required information.

1. INTRODUCTION

Tool-makers have been facing a huge challenge. They must provide an extended quality service to their clients at a more and more reduced price and in a smaller and smaller timeframe. In this environment, teamwork within tool-makers staff and cooperation between tool-makers and clients (most of the time in different geographical locations) are vital to think ahead and to eliminate inefficiencies in the work progress related to delays in communication between the right interlocutors and in accessing relevant information and knowledge (seeking and retrieval) for in-time decision making.

Although each tool is a unique device produced in a one-of-a-kind manufacturing system, its production involves a common set of steps that happen concurrently rather than sequentially. From the request for a quotation (the traditional first step) to the tool trial out on production machines (the traditional final step) the building of a tool requires design and production technologies involving a high capital investment and a qualified labour force in which the tacit technological knowledge, highly dependent on a learning by doing process, is resident [1].

It is largely accepted that tool makers must accommodate new business strategies based on a closed interaction with their clients [1], frequently the tool user company,
providing added value engineering services associated to the tool life cycle [2] and targeted to the market real needs. Nevertheless, this new approach represents by itself a huge challenge. It requires a permanent interaction with a significant number of clients all over the world and even with partners and subcontractors at different levels in the value chain of the final products. The establishment of those relations requires a more permanent presence at the final parts fabricator site to assist the tool during its in-production phase, particularly in the tool trial out, maintenance procedures and troubleshooting events, and to identify new requirements and business opportunities in accordance to the clients’ real needs. Since tool makers are small and medium size companies, this permanent presence represents a significant effort [3], which can be viewed at two levels. The immediate one is the significant financial effort, frequently difficult to support. The second one is related to the fact that this presence is relevant only if it is based on high level qualified human resources, which are scarce assets even at tool making plant.

The objective of the research work presented in this paper is to design and implement an innovative distributed and mobile engineering platform, based on information and communication technologies, which offers a more natural and user friendly approach to manage active and dynamic tool folders, allowing clients and field engineers to access tool-related information and tool related knowledge in several output modalities (e.g. audio, text, 2D/3D models, video, etc.). If such a platform is available the interface with clients and partners at their site or elsewhere can be made by personnel at lower levels of their learning curves maintaining the efficiency and the quality of the assistance as all the tool history data, tool maker knowledge and competences are available in real time in the background.

2. WORK PROCEDURES IN TOOLING COMPANIES

In order to support the definition of the Mobile Engineering functionalities and architecture, the first step of the work developed was to achieve a clear understanding of the current internal working procedures of a tool making company. This task was accomplished in Portuguese tooling industry and was supported on a formal questionnaire structured in the following topics: information and communication flow; work procedures; information systems currently used; most relevant problems and constrains regarding communication and information access.

Regarding the communication practices, tooling companies started in the recent past to use advanced tools as communication forms. The telephone, fax and the working meetings at prod are becoming less important with the growing use of informatics and communication technologies. The exchanges of e-mails are current and video-conference in general is emerging as a way to discuss projects within a virtual meeting. Although these technologies are owned by the most tool makers, a great barrier to their efficient use still remains, due mainly to the innumerable incompatibilities with client systems and to the current need to shift from the current workstation to a specific workplace where the communication devices are available.

The process of producing a new tool starts with a contact from a potential client requesting a quotation proposal (Figure 1). Tool makers have a set of more or less stable clients, with whom they are used to work with. This scenario facilitates the communication between the intervening parts. The first contact to the client is made
by telephone, fax or e-mail and the needed information to define the project requirements is transmitted by e-mail (even if it is not the most reliable tool for confidential information) or FTP servers (for large packages and/or for strictly confidential information). Having this information, usually the geometrical models and the technological information about the final product and the client production facilities, the tool maker can send a proposal document having a quotation, a delivery time and a technical overview of the proposed tool engineering solution.

If the client approves the provided proposal, the tool maker starts working on a preliminary project and on the work plan. The preliminary project can suffer several alterations and internal/external approvals, within a constrained timeframe, involving the tool maker and its client staffs. When the tool preliminary project is approved, it becomes the starting point for the development of the detail project where the tool is completely specified. Again the client has to acknowledge the rightness of the tool detail project to produce its product. The tool material list is build and the orders to the suppliers are emitted to buy the needed materials. From this point on, the tool project manager coordinates all the decision making processes and handles all the generated information/documentation about the project. He also makes the bridge between the client, the toolmaker commercial, development and shop floor departments while the tool is not delivered to the client. A huge amount of information is managed and organized, making his job greatly dependent on his working capacity and coordination qualities. Indeed, the project manager spends a large percentage of his working time controlling the information and often the team management and the control of the work progress are neglected. The tool trial is the production end stage. Once more, the project manager establishes the link with the client, following-up the trials. Frequently, re-work or

---

**Figure 1 – Major actions on a tool development project (process iterations are not represented but currently occur at any stage)**

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ask for tool proposal based on part geometrical and technical specifications</td>
</tr>
<tr>
<td>2.</td>
<td>Proposal defining quotation + delivery time + technical overview</td>
</tr>
<tr>
<td>3.</td>
<td>Client approves the proposal</td>
</tr>
<tr>
<td>4.</td>
<td>Preliminary tool project and definition of global work plan</td>
</tr>
<tr>
<td>5.</td>
<td>Ask for preliminary project approval</td>
</tr>
<tr>
<td>6.</td>
<td>Client approves the preliminary project</td>
</tr>
<tr>
<td>7.</td>
<td>Tool design and tool production (subcontractors may be involved)</td>
</tr>
<tr>
<td>8.</td>
<td>Feedback regarding technical solutions and work progress</td>
</tr>
<tr>
<td>9.</td>
<td>Tool trial-out</td>
</tr>
<tr>
<td>10.</td>
<td>Delivery of the final tool and technical documentation</td>
</tr>
<tr>
<td>11.</td>
<td>Tool trial-out in production conditions</td>
</tr>
<tr>
<td>12.</td>
<td>Assistance in trial-out</td>
</tr>
<tr>
<td>13.</td>
<td>Follow up of the tool performance</td>
</tr>
<tr>
<td>14.</td>
<td>Possible maintenance/repairing/modifications on the tool</td>
</tr>
</tbody>
</table>

---

*An application for globalization of toolmaking companies*
fine adjustments are needed to guarantee the tool good functioning and/or to improve its performance. Finally, the tool and a set of tool related documents (CAD models, engineering analysis, quality plans, certificates …) are sent to the client.

Nowadays, post-sale support is increasingly a differentiating factor among tool makers. Following-up the tool in the client’s plant and the fulfilment of subsequent demands related to the maintenance support or even performance improvement are already current practices in the sector and are decisive factors regarding the establishment of long-term partnerships with clients. Telephone calls are usual the way to maintain the contact and follow the tool performance. However, even being expensive and representing a significant staff effort, when dealing with important clients, visits to the client site are done to stress the interest and the support from the tool maker.

During the development process the tool maker has to cope with a great amount of technical information about the final product and its materials, the tool design process, the design of auxiliary components and systems and the tool manufacturing process. They face a colossus job of keeping all the information and documentation organized, quickly accessible, wherever and whenever it is needed, and updated with the numerous modifications and iterations that happen all along the tool development process.

Although, PDM (Product Data Management) and PLM (Product Lifecycle Management) systems have been available for some years, such systems are not used in the tooling sector. The philosophy of PDM systems [4], with a long and unfriendly implementation process, compatibility problems and a rigid customized work-flow, does not support the degree of agility that the small tooling companies require to adapt to dynamic requirements within a short response time. Their unpredictability is quite difficult to structure in a PDM system, designed for large organizations with highly structured work procedures. In fact, some tool makers have access to advanced tools for communication and product information management, but two technical barriers still prevail. The first one is the small adequacy of the available systems, conceived for large companies dealing with mass production or large industrial projects, to the specificity of this industry. The second one is related to some technical incompatibility between different clients and tool maker’s hardware and software systems.

3. MOBILE ENGINEERING CONCEPT

Despite the still common vision that the office or the factory is the place where the work is performed, nowadays many people work “off-site” in other environments. For instance, they can be in the clients or supplier’s site, in the factory floor, in a hotel or even at home. The competitiveness of tooling companies in a global market requires from each company the agility to search for new business opportunities and to deal with dynamic client requirements and potential needs in order to establish a permanent relationship. In such context, tool makers must promote their engineering and technical staff mobility (e.g. tool designers; project managers and other specialized workers), providing them a work environment that allows the access in real time to tool projects information, the access to internal and external knowledge and the facility to have communication between workers in order to share the
An application for globalization of toolmaking companies

knowledge between the senior and junior staff. The concept behind the Mobile Engineering project is an effort to answer the staff mobility requirements mentioned above.

The Mobile Engineering platform is the materialization of the Mobile Engineering concept (Figure 2). It integrates different Information and Communication Technologies (ICT) based systems to provide the access to the tooling company information and knowledge repository, to support competitive decision making processes and efficient after-sales engineering services, in a context where the workplace can be anywhere.

The success of such platform depends on the fulfilment of a set of functional requirements:
- Integrated IT environment compatible with the toolmaker working procedures;
- Central repository of information and explicit knowledge with the capability to store and organize in a hierarchical fashion all project documentation;
- Remote access to the central repository resident in the tooling company;
- Capability to work off-line if an internet connection is not available or has a low band width;
- Support for video and voice meetings among project participants;
- Support for virtual conferences involving shared visualization, manipulation and edition of digital geometric models;
- Security/integrity of the repository data by reliable and secure communications (authentication, encryption, integrity) and permission access control;
- Low implementation cost, simple administration and maintenance requirements and user-friendly interfaces with quick learning curves.

4. PLATFORM ARCHITETURE

The architecture of the Mobile Engineering platform contains four main blocks: Smart Field Manuals (SFM), CAD Annotation, Voice/Video Tools and the Commercial-of-the-Shelf (COTS) production software systems (Figure 3). Each block has a counterpart on the user computer, called Mobile User Workspace, and on the tool maker back office, called the Mobile Engineering Central Services, which represents the central repository that is part of the Mobile Engineering concept.
The COTS Production software block represents the set of software applications used in the tool development process. Besides engineering software like CAD, CAE and CAM systems, this block also represents non-engineering software like word processing, spreadsheets, etc.. The files generated by the COTS production Software are the main subject of the tasks done by the Smart Field Manual and CAD Annotation blocks.

The Voice/Video system block is the application that allows the mobile users to communicate between themselves by voice or video using an internet connection. Since there are many communication applications freely available with excellent quality, an analysis of such applications was done in order to find out the most adequate one. Skype2 was selected as it is a free product, already used by some tool makers, has communication quality and is easy to install and operate.

The CAD annotation block provides to the tool engineers a flexible and simple system for visualization, edition and textual annotation on 3D geometric models in a mobile and shared environment. With this system the participants on a tool project can exchange ideas having as a starting point the tool 3D model, reducing the time needed to find the best solution for a geometrical/technological/engineering problem. Simultaneous with the CAD Annotation block, the Voice/Video system block can be used to improve the communication between the participants.

The Smart Field Manual (SFM) block creates and manages the central project documentation repository from the Mobile Engineering Concept. The projects documentation is organized in a set of Smart Field Manuals. A Smart Field Manual is the collection of all documents generated all along the tool life cycle (design, production, assembly and trial outs, delivery, operating conditions, maintenance). By a document it is meant a digital file, like a text file, a CAD or CAM file produced by the COTS Production Software block or by the CAD Annotation block. With the projects digital artefacts organized in SFMs, the tool makers have in a unique and secure location all the information related to all their projects, which facilitates the reuse of the past projects data in the development of new ones.

An SFM file besides its content (produced by a COTS) has also indexing information (like name, client, comment,…) describing its content. The content of an SFM file can have multiple versions to accommodate the evolution of the tool project. To support concurrent project development a new version of the content can
only be added by a user if no other user is also working on the same SFM file (check-in/check-out operations).

To organize the SFM Files there is the possibility to place them in a SFM Directory. SFM Directories can be organized in a tree structure. Each SFM Directory has also indexing information describing its content. SFMs, SFM Files and SFM Directories have a permission list which tells what users can view, delete or edit its contents.

The architecture of the SFM block follows the client/server pattern where the communication is done via web services. The client application is called the SFM Desktop and the server application is called the SFM Services. The SFM Desktop can work connected or disconnected from the SFM Services. To support the mobility and assuming that a connection to the tool maker back office may be unavailable or have an inadequate bandwidth to support an efficient access to large files, the SFM block provides an offline working mode where the content of SFMs can still be viewed and accessed disconnected from the central repository. The SFM Desktop is depicted in Figure 4.

Figure 4 – Smart Field Manual Desktop screen-shoot

The client is divided in three main areas. The top area lists the SFMs from the central repository to which the user has access when working in on-line mode or the ones available when working in off-line mode. The bottom area, displays the content of the selected SFM from the top area. The right area gives a quick overview about the indexing information of the SFM, SFM Directory or SFM File selected on the other two areas. The content of the SFM list and the content of each SFM are directly related with the permission rules applied to the user.

For a SFM to become available offline it is necessary to apply to it the Subscribe operation while the SFM Desktop is on the on-line working mode. During the SFM Desktop off-line mode the SFM can be consulted and the content of the SFM Files can be changed by applying new versions to them. Once the SFM desktop is back to the on-line working mode, it is possible to update the SFM on the central repository with the new versions added to its SFM Files.

The SFM Services are located on the Mobile Engineering Central Services. Conceptually they are organized in six components:
• Content Storage Area: Abstracts the computer file system, where the SFM Files contents (and versions) are stored and retrieved;
• User Directory: Definition of users and what operations they can do on the SFM Desktop;
• Content Authorization Service: Rules what SFM, SFM Directories or SFM Files a user can view, edit, delete;
• Content Management: Implements the edit, view, delete operations on a SFM, SFM File and SFM Directory
• Replication Management: In cooperation with the Content Management synchronizes the SFMs content when shifting from the on-line working mode to the off-line working mode and vice-versa.
• Communication Services: Provides the web services communication facilities between the SFM clients and the other SFM services components.

The development of the SFM Desktop and Services was based on Java open source projects. The products used were: Axis, Hibernate, PostgreSQL, Apache Tomcat, Apache Axis, HSQLDB and the Java Web Start Facility.

5. CONCLUSIONS

More than ever tool makers assume themselves as service providers with partners and clients are all over the world. But, to establish new businesses with far away clients and maintain long term partnerships and effective collaboration with them are perceived as huge barriers, difficult to deal within a scarce resources environment. The mobile engineering platform presented in this paper is an infrastructure that is being developed to provide close assistance to clients in distant places and to give an easy access to information and to in-site knowledge wherever it is needed. Besides the remote access to the information repository, it provides each workstation with a collaboration environment where virtual meetings, integrating information access, CAD conference and video/voice communication can take place.

The human component in the implementation of communication and information management systems is quite difficult to unravel. Tooling companies have qualified technicians with a great capacity to assimilate new technologies and work methodologies. However, they are highly focused on production competences and organization and information management issues are regarded as secondary and less relevant. If they are confronted with something new in this field, during the learning curve a rejection should be expected. So, all these new systems are being integrated gradually in a demonstrator company, in small task forces and pilot projects, to evaluate benefits and improvement potential and to eliminate possible rejections.

5.1 Acknowledgments

This research work has been sponsored by the EC through the 6th Framework Integrated Project – EuroTooling21.
6. REFERENCES


