WEB-BASED CBR (CASE-BASED REASONING) AS A TOOL WITH THE APPLICATION TO TOOLING SELECTION

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Abstract
Over the past few years, manufacturing companies have had to deal with an increasing demand for feature-rich products at low costs. The pressures exerted on their existing manufacturing processes have lead manufacturers to investigate Internet-based solutions, in order to cope with growing competition. The decentralisation phenomenon also came up as a reason to implement networked-application, which has been the starting point for Internet/Intranet–based systems. Today, the availability of powerful and low cost 3D tools, database backend systems, along with web-based technologies, provides interesting opportunities to the manufacturing community, with solutions directly implementable at the core of their businesses and organisations.

In this paper a web-based engineering approach is presented to developing a design support system using CBR technology for helping in the decision-making process when choosing cutting tools. The system aims to provide on-line intelligent support for determining the most suitable configuration for turning operations, based on initial parameters and requirements for the cutting operation. The system also features a user-driven 3D turning simulator which allows testing the chosen insert for several turning operations. The system aims to be a useful e-manufacturing tool being able to quickly and responsively provide tooling data in a highly interactive way.

Keywords: Case-Based Reasoning, Web-based turning processes and operations, tooling selection, 3D interactivity for manufacturing.

1. INTRODUCTION
Machining and manufacturing technologies are one of the backbone technologies for today's entire industry. Machining, as a shape-producing method is the most universally used, in which a power-driven device causes material to be removed. Cutting speed, feed rate, depth of cut, the tool design parameters, the tool path and the work-piece fixture are just some of decision variables that have to be considered in order to pick the right tooling configuration [1]. Once a suitable machining operation or a sequence of machining operations is selected, the cutting tools and cutting conditions for each of the operations have to be chosen. The tooling and the cutting conditions will have a significant influence on the cycle time, the tool wear/life and the material-removal rate as well as on the quality of the surface finish and dimensional accuracy [2]. Finding the right combination of machine tool and optimum cutting tool to machine a part is therefore critical and can often be a time-consuming and costly activity. To achieve this, the most common procedure is generally to refer to cutting tool manufacturers' catalogues, in order to select the right tool holder/insert combination. Although these catalogues are still distributed in paper-based format, they have recently started to appear in electronic versions, as static browsable documents available either from a CD-ROM or lately via the World Wide Web [3]. Some attempts have also been made to ease this selection process through the use of intelligent systems, which have been developed as part of CAPP (Computer Aided Process Planning) applications, or more recently integrated to some "top of the range" CAD/CAM (Computer Aided Design/Manufacturing) packages.

Dereli and Filiz [4] have proposed an approach using Genetic Algorithms (Gas), which mathematically determines from the 3D features of a mechanical part the best tooling arrangement to optimise the tooling set. McMullen et al. [5] have focused on optimising production sequences by limiting the number of tooling replacements. Their approach is concerned with finding relevant tooling sequences while trying to maintain tool-wear uniformity through correlation and heuristic methods. Habel and Slodky [6] have developed expert system modules to be integrated to a CAPP application to intelligently select tooling configurations by taking into account as many factors as possible. Similarly CAD/CAM packages have recently started to integrate flexible tooling management features by accessing tool catalogues or interfacing with external tool database.

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From the examples above and based on a vast literature survey, it seems that so far, intelligent approaches have mainly been used to optimise the retrieval of tooling configurations from catalogues and databases. However, although most mechanical and machining aspects have been taken into account within the previous approaches, the human decision factor involved in choosing a particular configuration has almost been ignored. The shop-floor technicians and engineers who perform directly all machining operations have acquired an extremely valuable experience on machining conditions and parameters, which include tooling configurations. This ever growing knowledge should therefore be made available for retrieval and reuse, as similar machining conditions are likely to be encountered again by either the same person, by another person in the shop-floor, or by another operator machining in similar conditions in a totally different location. Therefore, to compete effectively and more importantly to keep control of their intellectual capital, companies must implement such kind of solutions, which will enable them to interactively and efficiently communicate information related to their manufacturing processes within their own infrastructures. These solutions must be implemented on the Internet, as this communication medium offers scalability, easier implementation, and compatibility across diverse computer platforms and devices and thus reduce incremental infrastructure investments. Coupled with the field of Artificial Intelligence for handling the knowledge capture, organisation and retrieval, Web-based intelligent systems are the key to increase productivity via the delivery of technical information and intellectual capital in a highly responsive, secure, accurate and geographically dispersed manner. The intelligent part of handling all the data is made possible through an approach using Case-Based Reasoning theory. In 1997, Pomerol [6] provided a pertinent comparison of expert systems techniques for the decision-making field. In particular, he gave a thoughtful explanation of the reasons for the human to make decisions, and proposed Case-Based Reasoning as one of the most suitable reasoning models to support decision theory. The next sections will therefore describe in more detail the novel approach of implementing a web-based CBR support system for helping decision-makings for tooling configurations in turning operations. In addition to this, the system also features a new way of using Web-based 3D for industrial purposes through the real-time visualisation and simulation of tooling configurations in a language generic framework.

2. WEB-BASED CBR FOR E-MANUFACTURING

Case-Based Reasoning (CBR) is a general paradigm for problem solving based on the recall and reuse of specific experiences [8]. Also CBR is an approach to incremental, sustained learning, since a new experience is retained each time a problem has been solved. Because one of the main aspects underlying CBR theory is learning from experience, it requires a well worked out set of methods in order to extract relevant knowledge from the experience, integrate a case into an existing knowledge structure, and index the case for later matching with similar cases. In general, the key issues to formulate the CBR theory include:

- Situation assessment/retrieval
- Case application and evaluation
- Case adaptation
- Storage

Initially, the CBR idea was intended to be a cognitive model of human problem solving. However, it soon became obvious that it is also a very promising approach for developing intelligent knowledge-based systems. Today, after over 25 years of CBR research and development, CBR has become a mature software technology for several application areas. Many of these applications are in the area of engineering domains and deal with tasks such as diagnosis, decision support, design, or planning. The approach presented in this paper intends to propose the use of Web-based graphically-enhanced CBR applications for manufacturing purposes. The system developed acts as a tool the decision-makings when choosing a tooling configuration for turning operations. Its availability via the World Wide Web makes it an extremely powerful tool as described through the following points:

- The Web-based system is generated entirely dynamically as and when requested by a user.
- The system can be accessed by anybody, anywhere and at anytime.
- The system can grow freely and securely over the time.
- The system is based on a 3-tiers architecture, thus enabling to separate the user interface, the processing unit, and the storage unit, and therefore allowing modularity, customisation, security and efficiency through distributed computing.
- The system involves only a minimum financial investment as the entire application can be generated, hosted and executed using extremely efficient and reliable open-source technologies freely available.
- The Web-based system benefits from a wide and ever-growing variety of medias, ranging from dynamic text and pictures to high-end, real-time, entirely interactive 3D scenes.

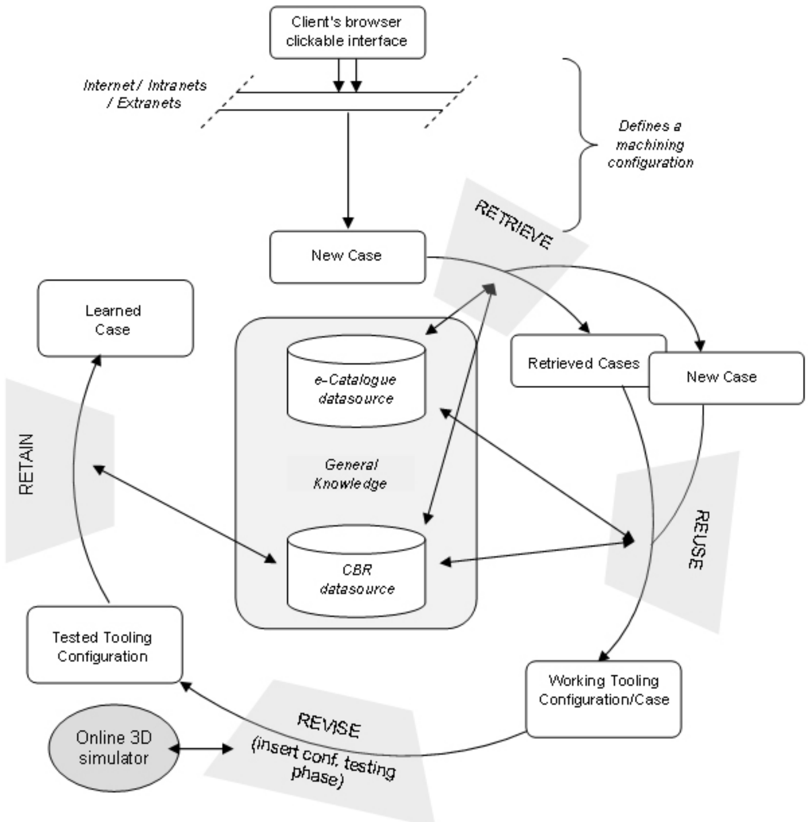


Figure 1 - Adapted CBR approach for the Web-based system

The Web-based CBR application developed is articulated around a newly organised e-catalogue of ISO turning inserts and tools built from WidiaValenite's original paper-based tooling catalogue. The vast number of possible "insert-tool" configurations available nowadays for a particular machining condition is at the origin of applying the system to this type of manufacturing equipment. The system therefore enables the user to perform "standard" e-catalogues searches for a particular machining configuration, and retrieves all matching competing tooling configuration solutions. In addition to this first output result, the CBR module generates a list of existing matching cases according to this same particular machining configuration, leaving then the choice to the user to either pick an existing case or one of the proposed results. Whatever the choice, the user can now reuse a configuration, and can, if available, access information left by previous users on that configuration. The defined configuration is now ready for being tested via a web-based real-time 3D simulator or even and when possible on a lathe in a real shop-floor. The tested configuration's parameters can finally be added to the system and retained in the CBR data source for further reuse. Figure 1 illustrates the adapted CBR approach above for the development of the proposed tooling selection system.

Furthermore, Aamodt et al.'s Human-Based CBR model is also applied in the system development by integration with CBR and Web-based intelligence programming. Firstly, the web-based CBR system enables to retrieve in an organised order the best tooling configurations as they have been added as cases by previous users. Secondly, within each of all the available configuration solutions, it is also possible to reuse knowledge on machining conditions which have proven successful and added by previous users. Using the Web as a medium to vehicle this intellectual capital under the form of manufacturing cases is therefore to ensure immediacy, accuracy and availability in getting the information independently of the user's location.

3. SYSTEM DEVELOPMENT AND IMPLEMENTATION

The approach for designing the system has been based on some considerations for its future usage. One of the main driving criteria was that the system should be equally accessible and understandable by several types of users, ranging from shop-floor workers/operators to design, manufacturing and sales engineers, perhaps even customers. Another aspect was that the system should offer the two basic options, such as either perform a thorough search using AI, or a simple search for a reference as in the original electronic catalogue. Also, in the eventuality of having such a system implemented in a professional working environment, the application should provide some sort of security in terms of user access. Finally, the author decided that as Widia Valenite is an international group, the language of the web-based application should be taken into account, and therefore integrated as an important factor in the final system. Based on the above parameters, an architecture for the application has been designed as in Figure 2.

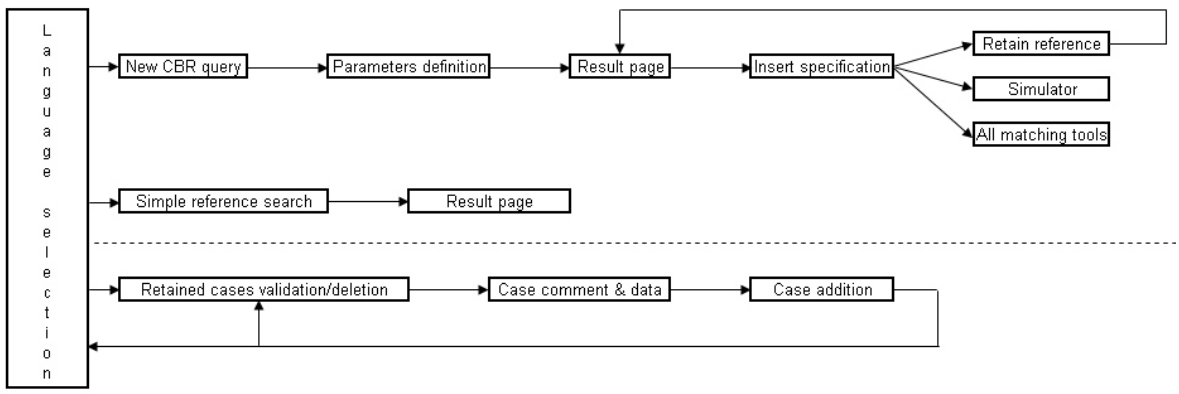


Figure 2 – A proposed system architecture

The two loops above the dotted line represent the two options of the system, such as a CBR search and a catalogue search respectively. The third loop is dynamically integrated to the system, according the first CBR loop's outcome. Further precisions on this mechanism will be added in following section.

3.1. The CBR search loop

This represents the main loop of the web-based application during which the user performs a search on a tooling configuration for a given problem. After a successful login, a session is opened on the server and is bound to the application, and lasts until the client's web browser is closed. As a session can only be created from the login page, this will prevent users trying to access any page of the system by providing the correct URL. So after having selected a language to browse the web-application with, the user is presented a first page allowing him to perform either a CBR search or a simple catalogue search as depicted in Figure 3 below.

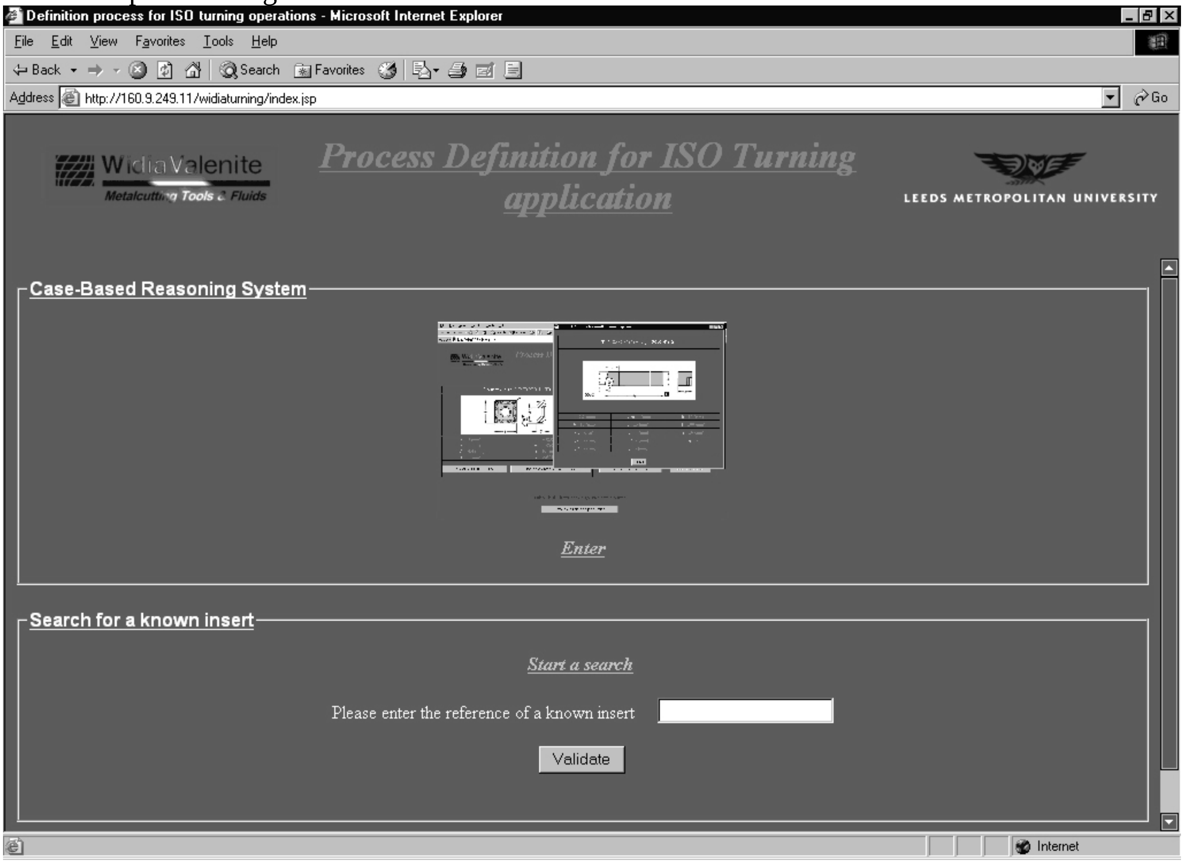


Figure 3 – CBR/Catalogue selection page

Having chosen the CBR search option, the user is directed to the initial step in which two search parameters have to be provided. In order to demonstrate the principle of such an application, only two entry parameters are requested in this example, but this could easily be extended to any number or type of entry parameter. This would result in a more complicated and time-consuming search with more complicated search rules, but the principle would remain identical. The first parameter to provide is the type of turning operation, which can either be for internal or external turning. The user can either make a selection from a drop-down list, or use the graphical selection via two extra pages. The second parameter to provide is the material type. Again, as almost any type of user is supposed to be able to utilise this system, the material type definition is done by classification selection. This way any material should belong to one of the proposed standard classes.

Once the user has made a valid selection for both parameters and submitted the request, the system loads a result page. Behind the scenes several database queries are executed in order to retrieve two lists of insert reference: the exhaustive list and the CBR list (RETRIEVAL phase). The exhaustive list consists of a scan of the entire datasource in order to retrieve all the insert references that match the two entry parameters provided. The CBR list only exists if some previous cases have already been added, matching again the two entry parameters provided. The user has then the choice to either pick a reference which has been validated in the past (REUSE phase), or to opt for another reference in the exhaustive list. This result page is presented as in Figure 4, with the exhaustive list on the left-side and the CBR one on the right-side.

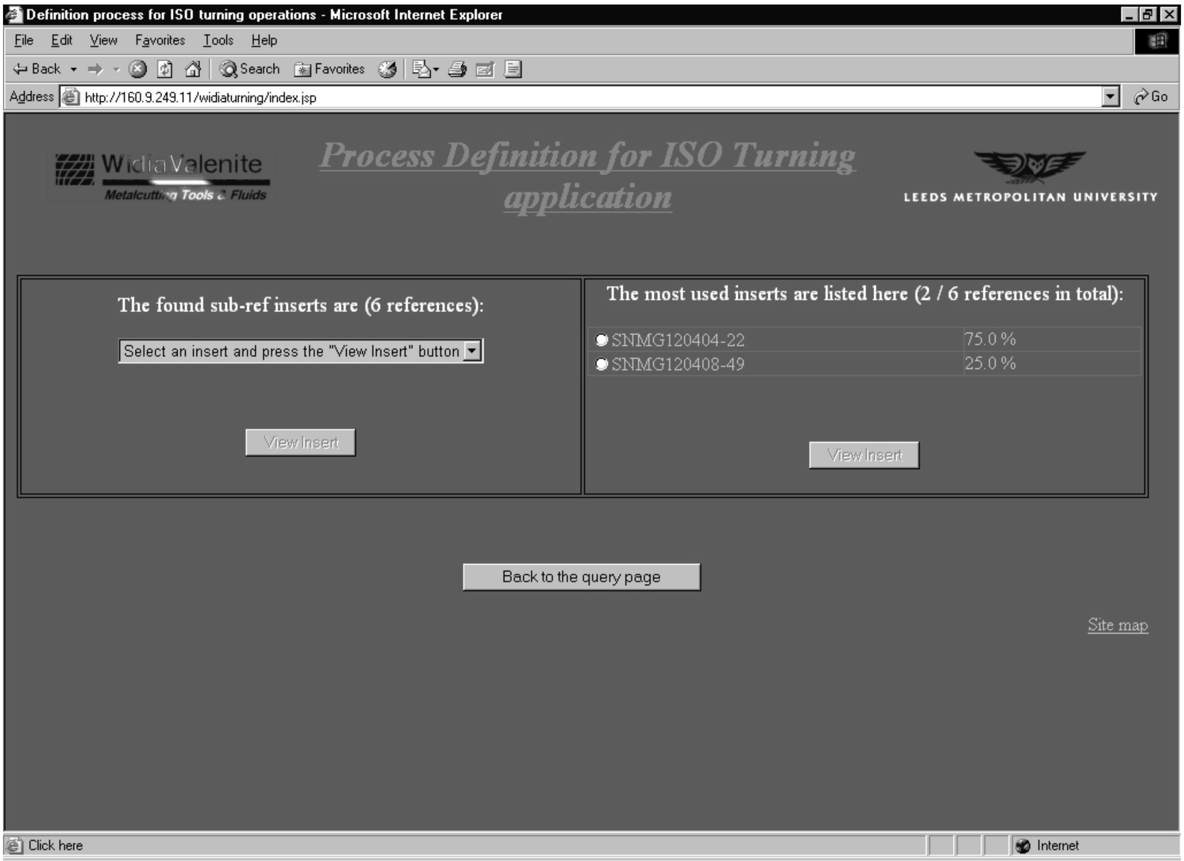


Figure 4 – Result page

As described in Figure 5, after having chosen a reference from one of the two previous lists, the user has now access to various types of data about the insert. A 2D schematic drawing is presented as well as the dimensions of the insert. The page features also the tools matching the entry parameters and able to hold the insert. Finally, if the reference belongs to the CBR list, then comments from previous users are accessible. For further clarification, more information is accessible through different windows, which contain (starting clockwise in Figure 5):

- 2D matching tool definition and dimensions
- fully-interactive turning simulator (to be further described)
- exhaustive list of matching tooling with the selected insert
- a 3D representation of the tooling equipment selected

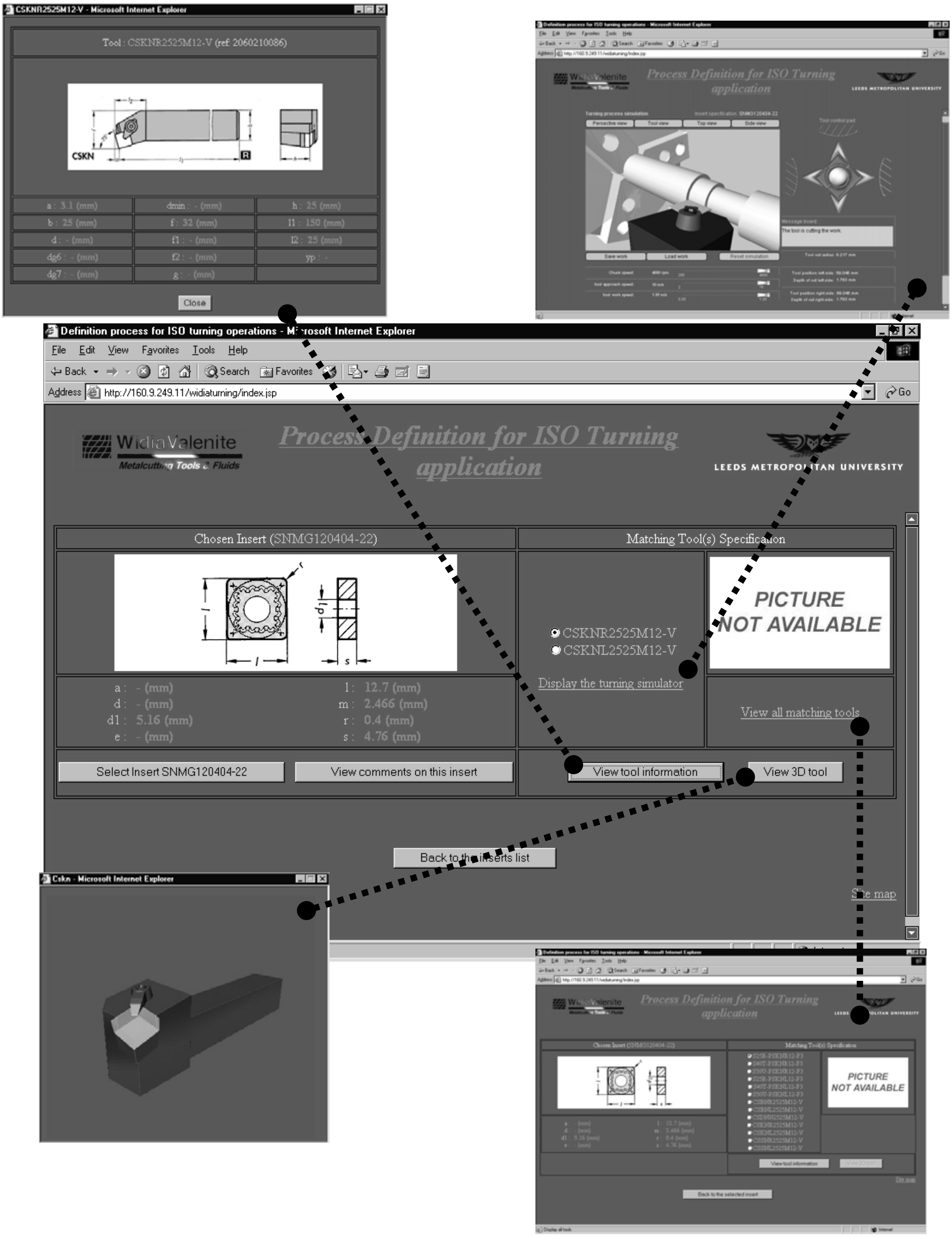


Figure 5 – Insert's related information page

Being now aware of the type of insert that can perform a machine operation based on the two entry parameters provided, the user can now retain the insert for further testing. Having recognised that in a working environment, a user would not leave the web-based system on for testing the insert in deciding whether or not to create a new case, a more suitable process has been considered. Inspired from e-commerce web applications, it has been decided to create a “cart” of chosen inserts for future validation or deletion. This sensible approach enables the user to select an insert for testing and process to the validation during a future login.

After validating the selection, the user is redirected back to the page displaying the two lists of inserts matching the entry parameters. This enables further investigation on the proposed references, and maybe other inserts selection for further testing. In this case, when reaching the same selection step, the user would be given information on the selection made previously, as shown in the following Figure 6.

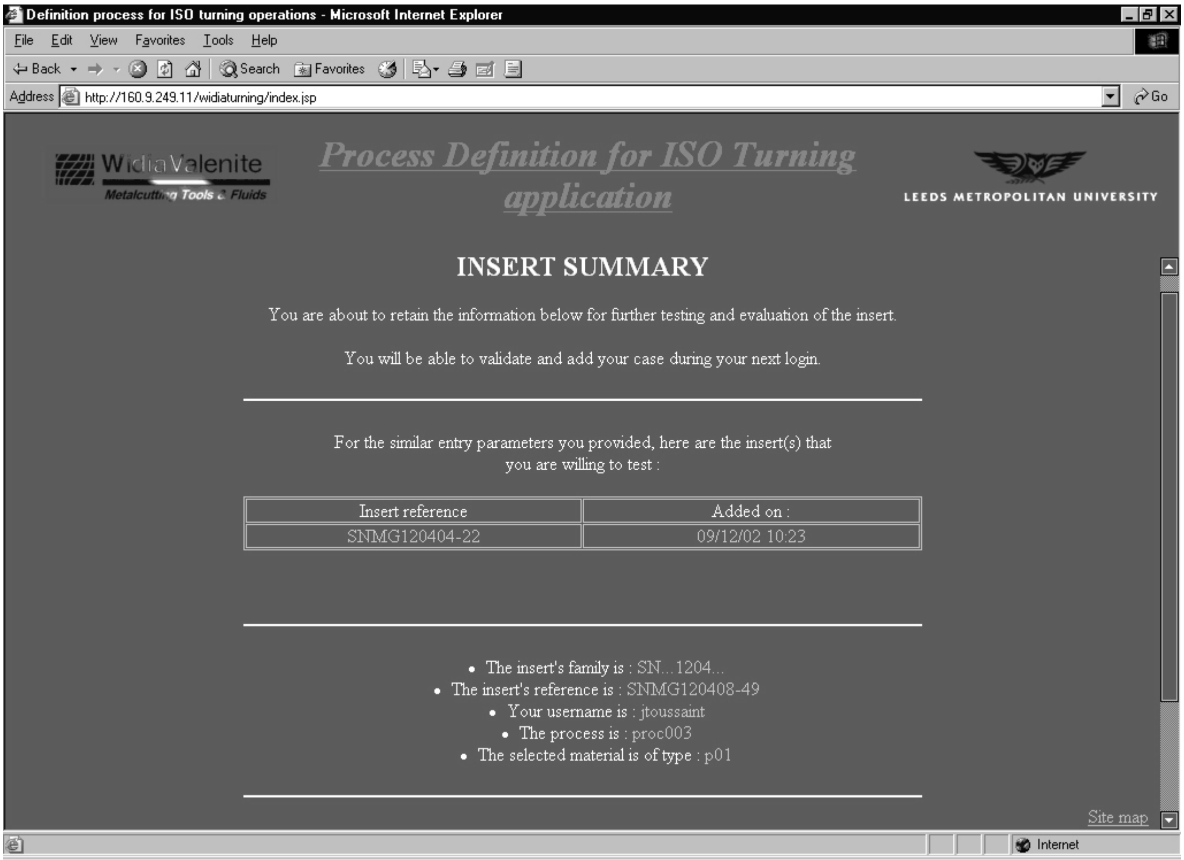
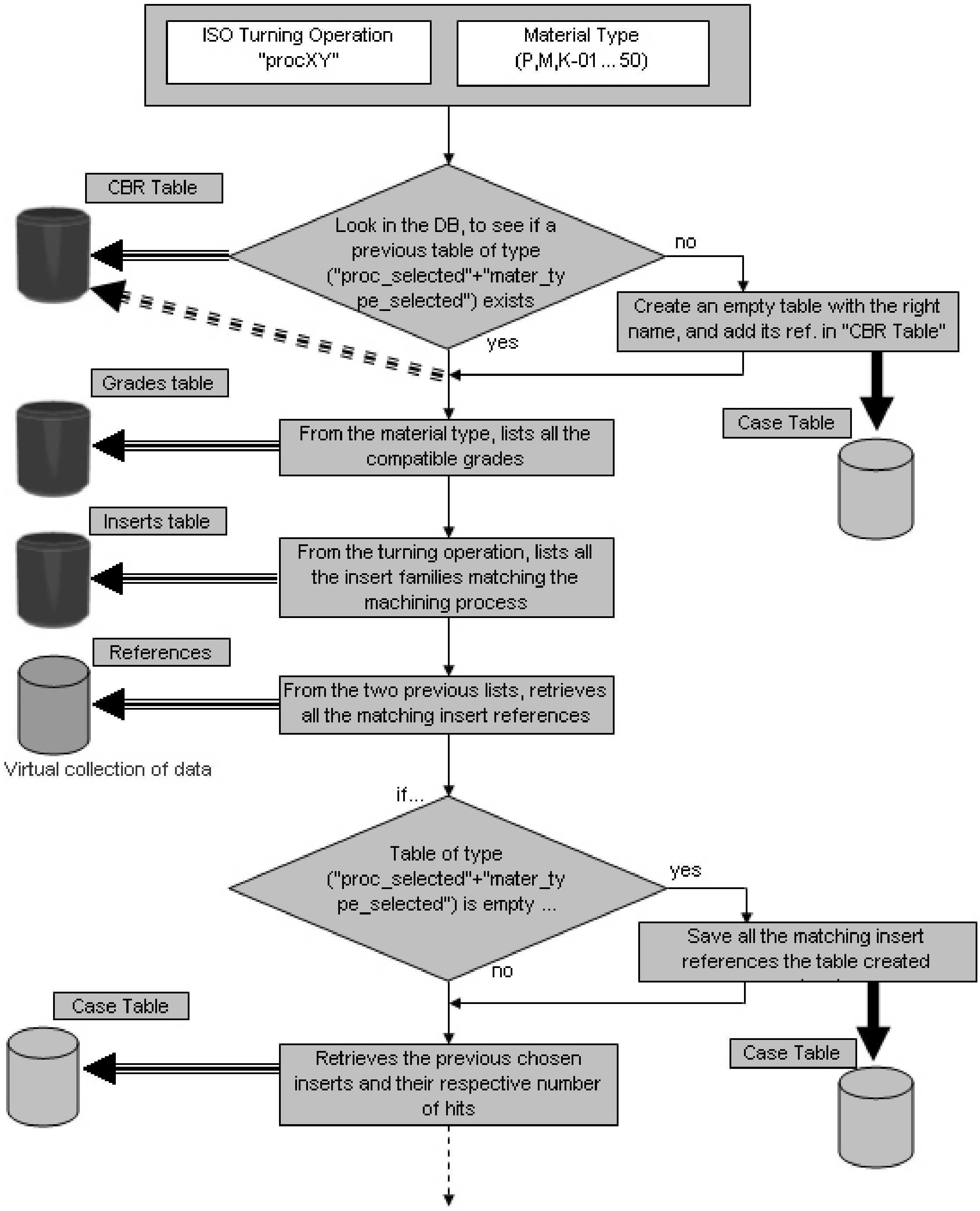


Figure 6 – Selection page with previously retained reference

At this point the user is supposed to have successfully found insert references and matching tooling information for the entry parameters provided. The user has been given the choice to either make a selection from the entire vendor’s list or from a possible CBR list created dynamically by previous system usage. In any case, the “tooling cart” now contains references to be tested, that the user will be able to access for validation or deletion during the next system access, as further explained in the next section. A summary of the process starting at the original parameters entry to the insert selection is presented as in Figure 7 below.


ISO Turning Operation "procXY"
Material Type (P,M,K-01 ... 50)
CBR Table
Look in the DB, to see if a previous table of type ("proc_selected"+"mater_type_selected") exists
no
Create an empty table with the right name, and add its ref. in "CBR Table"
yes
Case Table
Grades table
From the material type, lists all the compatible grades
Inserts table
From the turning operation, lists all the insert families matching the machining process
References
From the two previous lists, retrieves all the matching insert references
Virtual collection of data
if...
Table of type ("proc_selected"+"mater_type_selected") is empty ...
yes
Save all the matching insert references the table created
no
Case Table
Retrieves the previous chosen inserts and their respective number of hits
Case Table

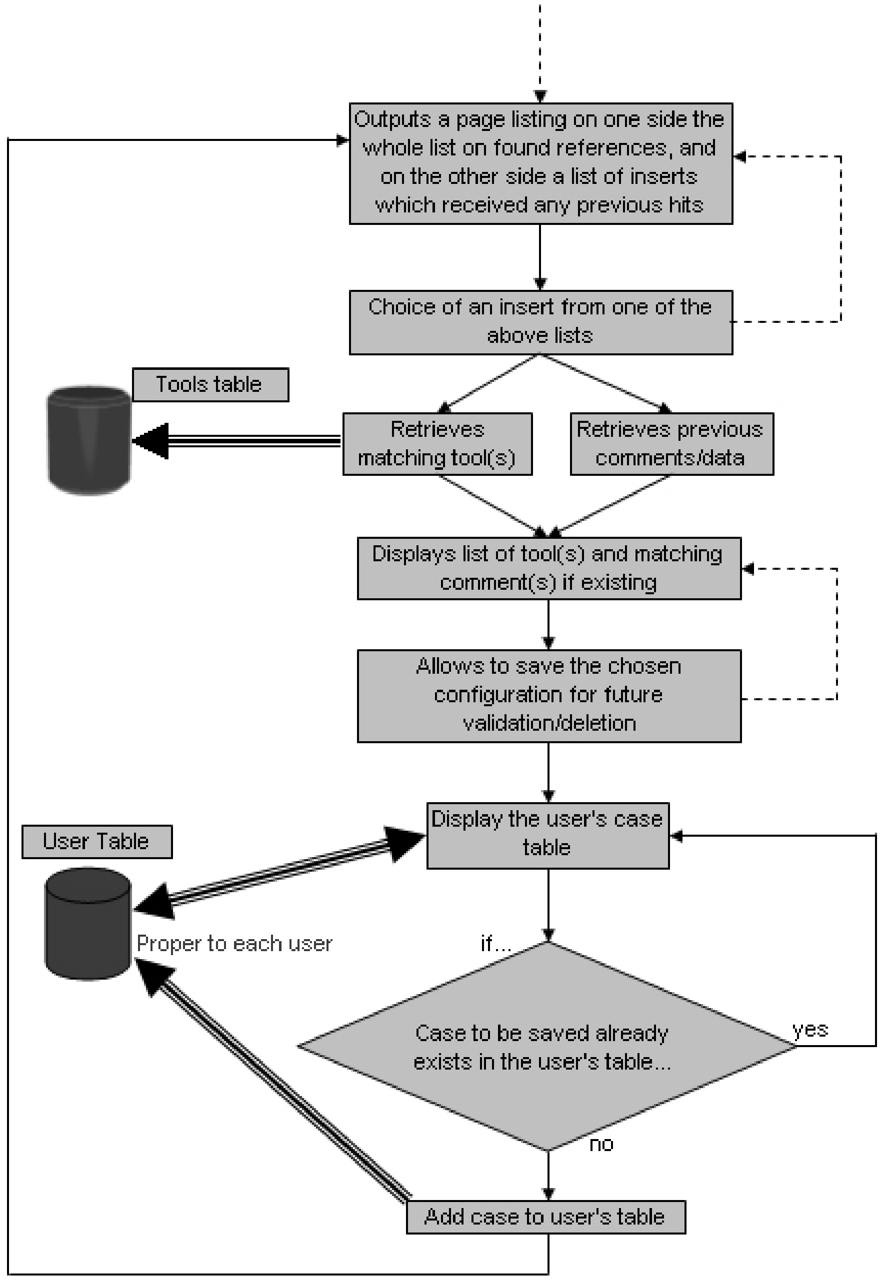


Figure 7 – Process representation in block diagram

3.2. CBR validation/deletion loop

During a next login, the system will enable the user to access the insert reference(s) retained previously. The initial page has had a new accessible menu created dynamically as represented in Figure 8.

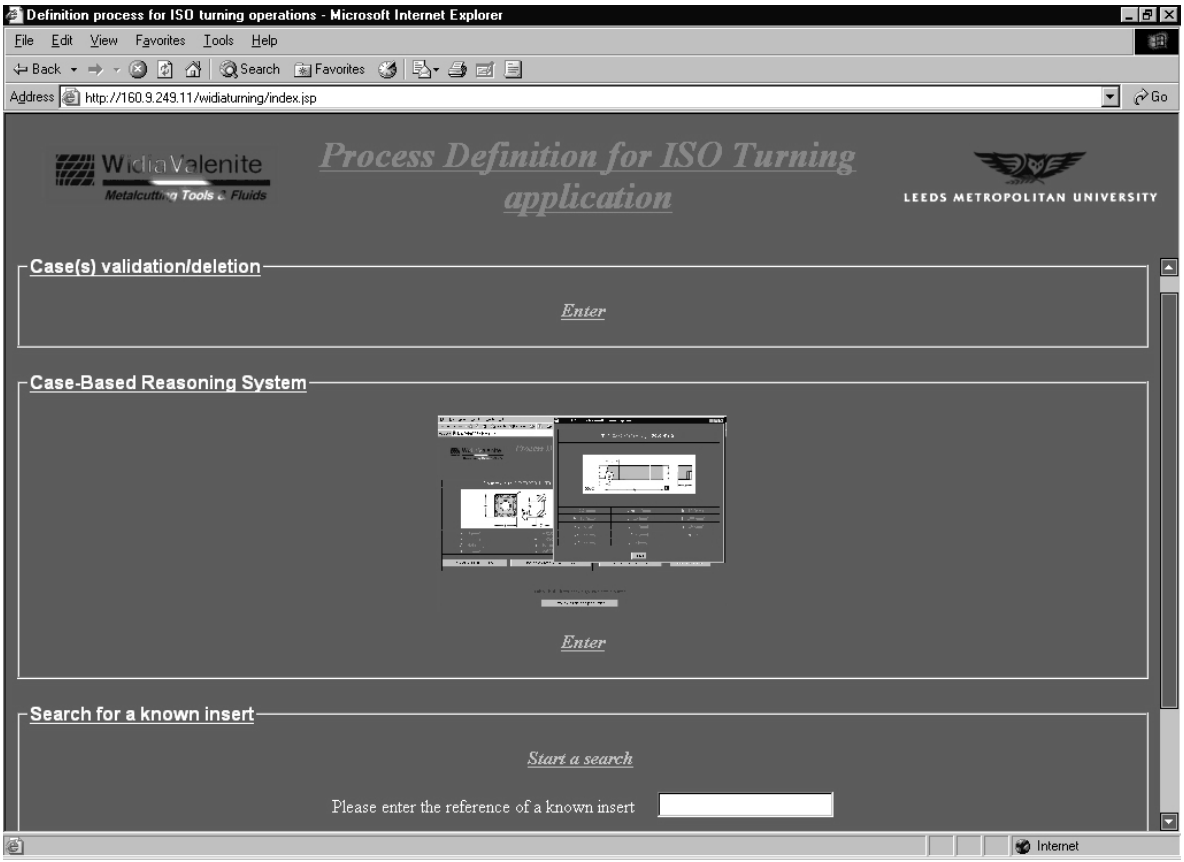


Figure 8 – Initial page featuring new menu

Entering the case validation/deletion loop, the user is presented with all the inserts previously selected. All the references have been sorted in a table, reminding the user of the time and date of selection, as well as the process and material type the query was submitted with. This can be depicted as in Figure 9.

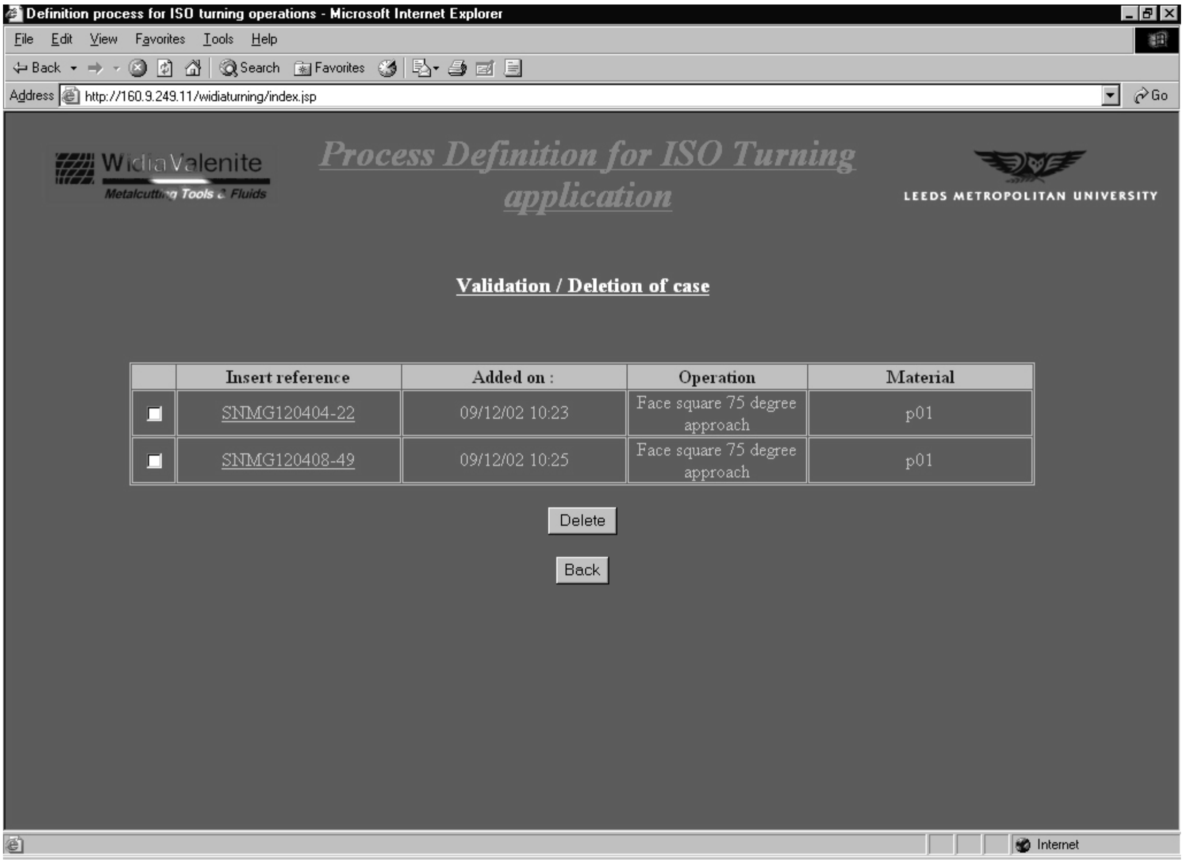


Figure 9 – Summary of previously selected references

The user now faces two choices: either to delete a reference as it is not suitable with the machining operation performed, or to validate the case. This last option enables the user to share the successful use of the selected reference by adding a case to the general datasource. At this point, many scenarios could have been possible, depending on what type of information has to be provided by the user for adding a case. For demonstration purposes, the author designed the system for saving a comment on the machining operations, as well as three machining parameters: the tool feed, the work speed, and the average depth of cut respectively (REVISE phase). An example of this page is shown in Figure 10.

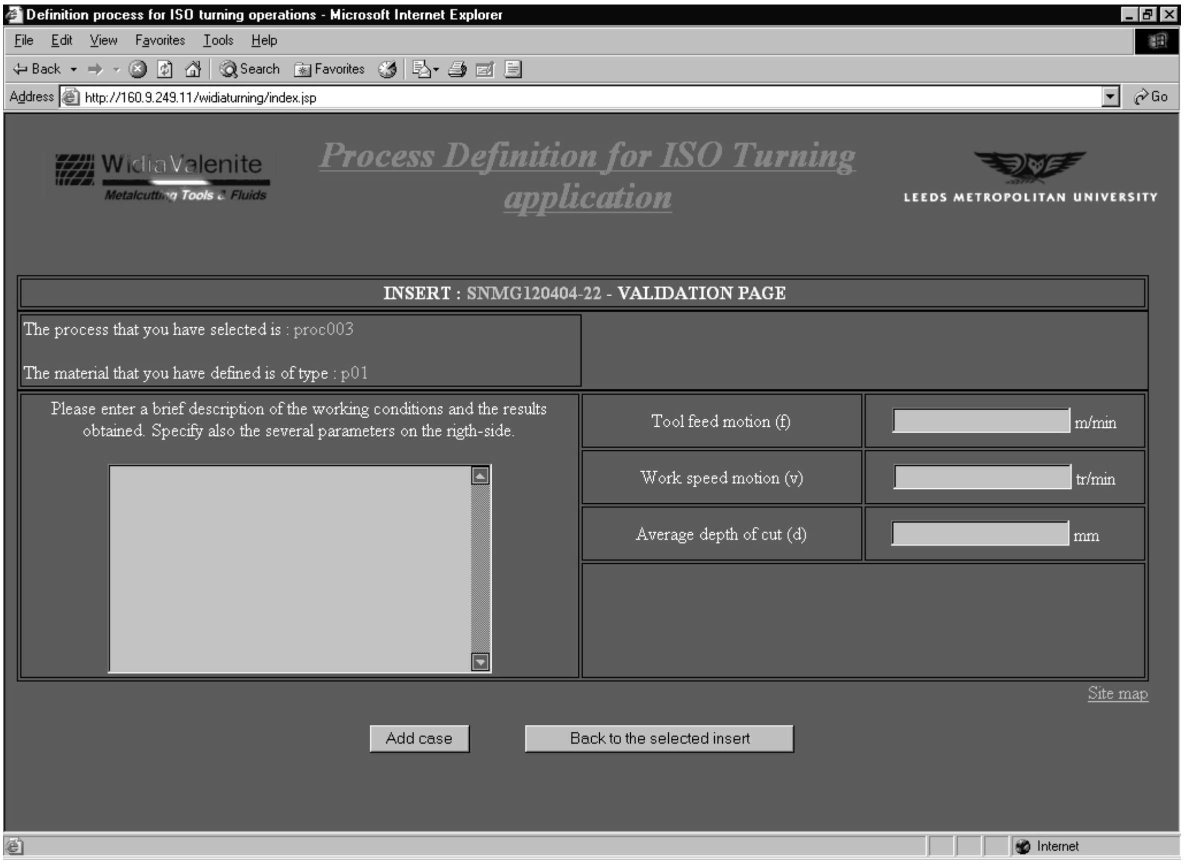


Figure 10 – Input page for case validation

Providing that the user has filled in correctly all the required fields, a summary of the case to be added is displayed prior to validation. This is the last step of the entire CBR process, before adding the case to the general knowledge (RETAIN phase). The way the web-application has been designed, it enables to retrieve, to reuse, to revise and to retain cases in a very agile and responsive manner. A summary of the validation/deletion process can be depicted as in Figure 11.

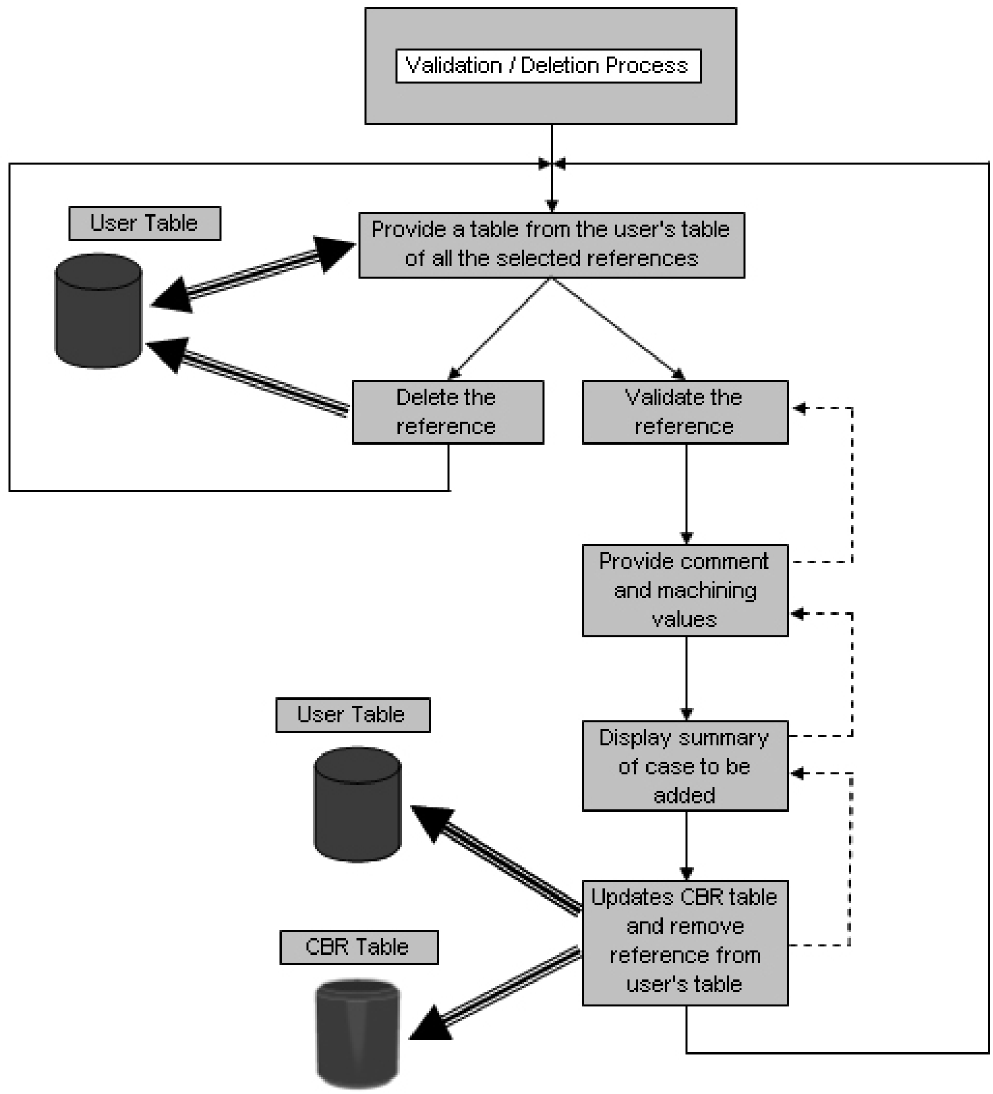


Figure 11 – Validation/Deletion process

In addition to provide a fully working example of implementing web-based CBR application for manufacturing purposes, the system also integrates advanced features such as language selection and 3D simulation in a highly dynamic manner. These two aspects are to be further explained in the following section.

3.3. Genericity through language selection

One of the greatest advantages of using the Internet for providing tools and applications lies in the power of delivering dynamically generated information across geographically dispersed locations. These dispersed locations could be within the same enterprise on the same site or on different sites, and could also be across different organisations located in different countries. In addition to this, the system might have to be accessed by a vast diversity of people, some of who might not have strong language skills. Being able to vehicle the information as well as being able to translate it easily and effortlessly would appeal to the biggest number and would encourage them to use it. Therefore because of these reasons and as the same datasource might be shared among international participants, this led the author to implement language genericity within the application.

Such a system that integrates a generic language feature could be extremely valuable in matters of communication and application maintenance. This would remove the need of maintaining "cloned" web-applications, therefore avoiding information redundancy, and use the Internet's dynamicity potential at its maximum level. In order to facilitate the integration of such a feature, its implementation has to be done during the first stages of the system's design. The principle is that instead of inserting text as it should be as in most of today's application, a reference is made to sentences in a datasource. This datasource is actually a chronological dictionary of sentences as they are used throughout the web-based application. The use of sentences instead of single words was strongly supported by the fact that technical expressions in different languages are not very likely to be literal translation. Based on this idea and after login into the system, the user is prompted to choose a preferred language to browse the web-based application. This will have an automatic and dynamic effect on the language being displayed for titles, text, buttons, helps, etc. An example of the difference of translation on the same item is shown in Figure 12.

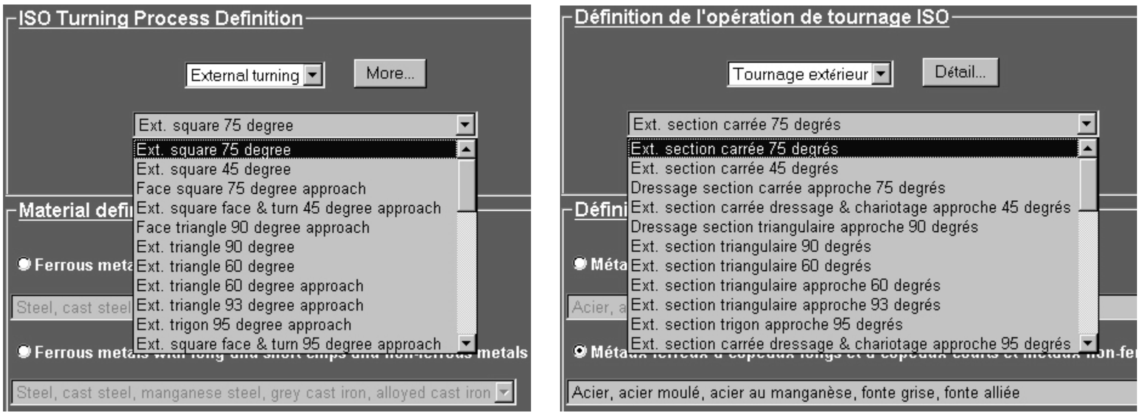


Figure 12 – Example of real-time translation

During the design phase of the web-application, the language genericity feature appeared to be very convenient, as it enabled to translate the entire application from English to French in a matter of minutes. Finally it seems very surprising that despite the low investment in matters of time, equipment, and knowledge it requires, this features does not seem to appear on most of today's web-based systems.

3.4. Modelisation of a responsive 3D turning simulator

As previously mentioned, the CBR search loop enables the access to a real-time responsive 3D simulator for turning operations. The original idea for this simulator was to offer the user a chance to virtually test the selected insert, through a simulation of turning operations. Ideally, the user would be able to perform any random movement within the simulator, without having to follow any predefined machining path. After carrying out a survey among today's 3D technologies, the author chose Macromedia Director 8.5 and its advanced programming language: Lingo. An evaluation of this technology is provided in Toussaint and Cheng's [10] publication. The design of the 3D simulator involved some heavy programming as it features some characteristics itemised as follows:

- The 3D scene is web-based oriented. This means that the whole object is as small as possible (200 KB), in order to be acceptable regarding to today's download times standards.
- The 3D scene is built as a heterogeneous environment. This means that the application is only initialised from programming code (which is quick to load), and then loads only the elements required for the user (such as the tools for example).
- The 3D scene is not dependent of the page it is embedded into. Prior to displaying the 3D object in the web page, dynamic information is passed to it. This information is typically tool geometries, readily translated sentences, tool properties (tangencies, etc), etc.
- The 3D scene is entirely analytically controlled. This means that all the intersections, tool movements, will be detected mathematically and only then represented graphically. Similarly, all the user's graphical actions via the pointer are captured analytically, computed and then reproduced back on the screen.

After designing and developing the simulator based on the above parameter, it has been decided to stay consistent regarding the user interface layout. A screenshot of the simulator is depicted in the following Figure 13.

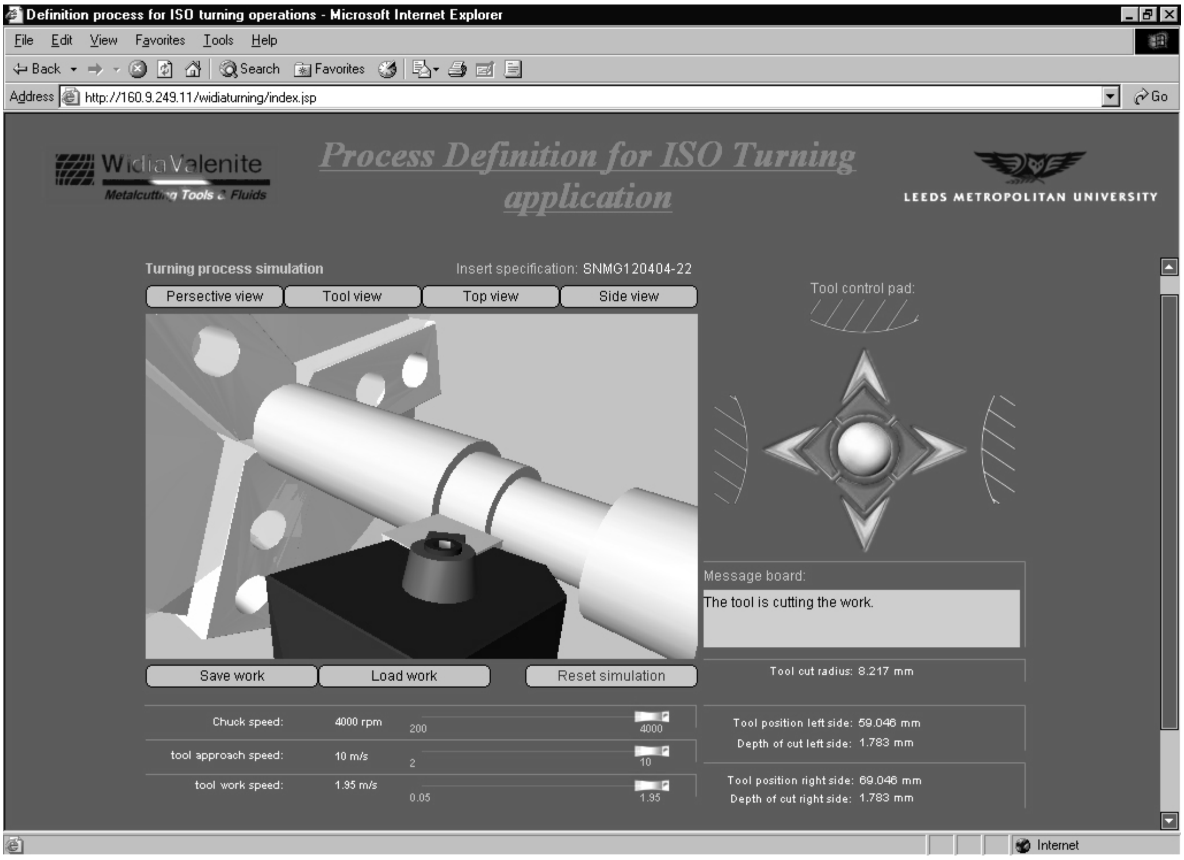


Figure 13 – Screenshot of the 3D turning simulator

From this view and via the control pad, the user is allowed to perform virtual machining operations using the insert reference previously chosen. In addition to enabling different viewpoints, the application also assists the user by providing him with textual feedback of the operation currently performed (e.g. the tool is tangent to the work, the tool is cutting the work, etc.). Finally, all the positions displayed in the 3D scene are analytically calculated and therefore ultimately accurate, without depending on the client's computer hardware. This enables to provide a truly realistic experience to the user as all the measured actions, will be exactly reproduced on screen. Using different technologies, such as VRML in particular, Ong et al. [11] as well as Qiu et al. [12] recently attempted to use VR for the CNC milling process. Despite offering different computation functionalities than the simulator presented previously, it seems that they have been limited in the graphical interactivity because of their choice of 3D technology. The risk is that potential users might be reluctant to navigate with the interface they designed, resulting in small usage of the application for daily simulation purposes.

4. DISCUSSIONS

This paper presents an approach to implementing a Web-based CBR system for supporting decision-making in the intelligent selection of tooling selection. The approach explores how to intelligently record, store and retrieve technical intellectual capital via the WWW for manufacturing purposes. In addition to providing real-time access to technical knowledge, the Internet provides also a set of new multimedia technologies, which can be adapted and can offer great potential throughout the manufacturing industry at all levels of each organisation. Through an application example, this paper presents the integration of the field of Case-Based Reasoning with Internet technologies as a way to greatly enhanced existing e-catalogues and turned them into intelligent, distributed and language generic applications. Although the approach has mainly focused on tooling equipment, the authors believe that a similar implementation framework and methods could be applied to other engineering products. By offering a high level of customisation and scalability, Intelligent Web-based systems are a very promising solution for companies wanting to view, manage and protect their technical knowledge assets in today's knowledge-driven competing market [9].

5. ACKNOWLEDGEMENTS

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