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A Interactive 3D Multimedia Problem-based Library for Manufacturing Engineering Technology Education with Internet Support

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Abstract

The advanced design and manufacturing/ assembly industry is increasingly operating on a globally integrated, Internet-based collaborative model of design, production and support in which OEMs (Original Equipment Manufacturers) assemble products out of components and objects (both hardware and software) by a network of distributed suppliers. This distributed client-server digital enterprise collaboration and creation model is enabled by the Internet, company intranets and consortium based extranets.

In order to fulfill this need, we have created an object / component-oriented methodology and architecture, that is analytical, quantitative, and open-source computational. This paper introduces the methodology, to some extent the object/ component knowledge documentation architecture and offers examples of this industry /academia sponsored R&D effort. As our validation results, and the over thirty supporting enterprises clearly indicate, our 3D web-enabled, interactive multimedia solution can be applied to satisfy a large variety of engineering technology knowledge documentation and learning, as well as hi-tech product and process marketing needs. For education, the created CBL Library is an effective method for outcome-oriented problem solving and assessment because it forces both the student as well as the tutor to focus, and then create new wealth, and encourage outcome-oriented educational practices and follow US ABET (Accreditation Board of Engineering and Technology in the USA), and European educational principles.

Introduction

The eTransition process leads towards waste reduction, innovation and prosperity at all levels of the modern enterprise, including not just machines, and traditional engineering processes and resources, but biomedical engineering, medical sciences and human resources. This is because the integrated, collaborative opportunities of product and process design, information technology and management, must be performed by a highly skilled, collaborating, eager, and continuously learning workforce. This effort needs sound methodology and a firm architecture for documenting, educating, distributing and managing manufacturing technology knowledge, the critical resource of any company, college and university with a future.

In order to fulfill this need, we have created an object / component-oriented methodology and architecture that is analytical, quantitative, and open-source computational. Then we have implemented over thirty open source, 3D browser readable, interactive multimedia, web-enabled library cases, covering a wide range of engineering technology, design, manufacturing, IT, management, and biomedical engineering topics.

Each case in this library first looks at the real-world customer requirement, then experts offer one or more solution(s) by explaining real-world solutions, working with real machines, or processes, or systems, and / or engineering management tasks, and then discuss further development, service, maintenance, integration, connectivity and many other issues with several feedback loops, sound methods, and practical examples. During the discussion, as well as at the end each 3D multimedia eBook case the library offers plenty of discussion and improvement opportunities, as well as open-source computational solutions and active code templates for real or virtual teams to test and validate their own logic, and data.

Our approach mirrors real-world issues as closely as possible in an open source, networked virtual classroom, i.e. on the students' laptop screens by using various techniques, most importantly the Virtual Product Demo with 3D objects that the students can explore, disassemble and then re-assemble in a matter of seconds, 3DVR interactive objects and 360 degree panoramic virtual tours, and high quality accurate videos containing interviews with product/process experts and time and motion accurate machine / process / technology / system demonstrations, as well as active code to perform analytical calculations and simulate real-world experiences.

The Methodology and Validated Application Examples

In our PBL library we follow an object-oriented design, therefore our architecture includes case-based library programs that are self-contained, reusable objects built of components. Often these objects and components are text, high quality digital video, animation, 3DVR and animated 360 degree panoramas. They are open source, web-enabled, delivered on the web, or in some cases in CD-ROM, or DVD (to overcome transfer rate and in some countries expensive web-access bottlenecks) or fast company intranets for continuous professional development purposes.

The ways we present challenges are very similar to the way professional engineers solve problems. This is because we first look at the real-world customer requirement, then we offer one or more solutions by explaining real-world machines, or processes, or various manufacturing, design and other technologies, or systems, or management tasks and then we discuss further development, service, maintenance, integration, connectivity and many other issues. Notice that we do NOT follow the traditional linear, but rather the modern concurrent, object oriented approach to integrated product / process design.

In terms of delivering our cases we follow the Virtual Product Demo concept, in that we virtually take the learner with us to factories, R&D studios, exhibitions and professional laboratories and give them interesting demos explained by real-world experts with challenging problems to solve. In all cases we show them high quality, interactive videos and often 3D objects and panoramas so that they can interrogate them and even participate in digital, virtual factory tours. (Note, although this approach does NOT replace real, working laboratories for the class, it nevertheless takes the learners into high-quality labs, that are often not in many universities reach, therefore offer unique experiences for the students, as well as for the faculty.)

In terms of challenging to learn and investigate the illustrated case further we give several direct URL (web) contacts, e-mail addresses so that the learner can get in touch with key contacts and start to collaborate. We focus our questions and address exciting technology, engineering, management, and computing science/ IT (Information Technology) issues. This approach helps distance learners as well as educators to work with the material in real-world classroom and / or virtually web-networked teams, and explore the appropriate mix of challenging problems with their learners ([1], [2], [3], [4] and [5]).

Specifically, our methodology suggests the following activities, or processes with continuous quality and requirement feedback-loops ([6], and [10] to [13]):

1. Research and analyze the needs, for all key processes and technologies presented, and / or researched by the learners as a response to the presented technologies, and then
2. Develop a comprehensive (preferably object oriented) system model, in terms of what technologies can be applied to solve a certain challenge. Then
3. Create a pilot system, a real, or virtual prototype that you can realistically implement, validate, refine, then
4. Create the full system as specified by your customer(s)/ sponsor(s) and then
5. Validate/ test, support, maintain and educate all parties involved.

In more detail, the process by which the learners can achieve the above outlined and expected results can be as follows ([6] to [8], [9], and [14] to [18]):

1. Requirements analysis: This phase, with the aid of one of our analytical software tools, included in the case library, helps to figure out what technologies are required. Furthermore it helps to answer the following questions: What does the customer want? How can we satisfy this need at the highest quality and minimum cost? What are the engineering technology

solutions for satisfying customer needs? How does our competition do in terms of satisfying the same technology needs?

2. Object oriented system analysis. (This is the 'as is' system scenario, describing what technologies are currently employed at the site under analysis.)
3. Object oriented system design. (This is the 'to be' system scenario, exploring alternative, new, often better technologies.)
4. Optional small scale test phase implementation feedback loop of the most important aspects and processes. (This is basically a technology prototype to be demonstrated to selected customers.)
5. System design refinement feedback loop. (Based on feedback the team should refine and improve their design / system.)
6. Full test phase implementation feedback loop to all key aspects and processes of the chosen technology.
7. System design completion.
8. Implementation and system integration of the new technology with the existing technologies in the site.
9. Final documentation (Prepare the documentation on the way preferably using interactive multimedia and on-line Internet technology. This will help to satisfy customers as well as save expenses when the documentation needs updating).
10. Subject to contract, continuous system maintenance and support.
11. System administration support and optional formal education at all levels to all involved. (Again, the interactive multimedia Internet based documentation could be the same as the distance learning resource material; saving significant time and cost.)
12. The identification of future R&D and other collaborative / sales opportunities.

Our cases are object-oriented and self-contained; nevertheless, they can be integrated or grouped into different classes of objects in a lean and flexible way, just as a modern software program, or a modern manufacturing / assembly system technology can be integrated into different environments.

This reusability enables learners as well as instructors and managers to 'plug-and-play' our cases in ways they choose rather than the way the author meant it. The methodology we follow enables basic knowledge transfer enabled with 3DVR interactive multimedia. It is highly interactive, collaborative and enables large groups as well as individuals to gain the same knowledge effectively. Although this method is not for everybody because the problems as well as the solutions are interdisciplinary, often open-ended and can get complex, in all cases our solution will enhance, support and enable a wide range of interactions with real-world challenges.

The benefits of introducing problems for students to solve using cases in a browser-readable 3DVR interactive multimedia format are manifold. The entire learning process becomes more student- versus lecture- or tutor-centered. Students can learn by exploring versus being told, and can have as many goes at solving a problem, or exploring an idea, taking as much time as desired or is available. Mistakes made can be corrected without penalties. Multimedia tools, or a subset of such technology and a variety of media, are available during the learning process.

Self-assessment is possible. This means that students become more self-critical as they participate directly in their own learning process. The format eliminates "hidden curriculum" and self-assessment questions.

Team, group and class assessment is integrated into every module of our programs (supported by active code spreadsheets, often with embedded 3D objects, video-clips and animations) that the students can interrogate to understand either the question(s) or the answers better. Furthermore, in our assessment programs graphs are shown illustrating individual vs. group / class benchmark assessment results. This is very useful, in particular for distance learning students, because they feel that they are equal members of the class. (Note, that in all of our cases traditional, as well as e-mail, web-collaborative, telephone and personal-appointment-based tutorial support is available if required.)

The entire education process is more suited to satisfy individual needs. Since failure is not exposed in Open Learning situations, fear is not part of the learning and testing process. Students teach themselves, work on their own and the educator's role changes towards a facilitator, consultant and guide, rather than the sole information provider as in the past ([3], and [6] to [8]).

Following our methodology education does not become boring, because the routine part of the material is taught by the students themselves, by means of the interactive 3DVR multimedia technology, and because the exciting or difficult parts can be reinforced by the instructor. This means, that the entire education process is more suited to satisfy individual needs from 'batch size 1 to many' at the same high quality.

To illustrate some aspects of our interactive, 3D browser readable eLearning architecture, in **Figure 1**, we present a typical screen segment of a case, in which we introduce rapid prototyping technologies, filmed in a multi-million dollar laboratory. The unique feature of this virtual technology-oriented laboratory tour is that the subject area experts explain the processes by means of text, videos, 3D interactive multimedia objects and even active code, all of which can be explored in the order and depth the student individually decides at the time of viewing / reading the eBook.

As can be seen, the left hand side of the screen is usually hyper-linked text and small icons prompting student actions, with the fundamental text content. In the right hand side of the screen, we offer active code, animation clips, interactive videos in 2D and 3D, 3D objects, 360 degree panoramas, virtual facility tours, and others, that enhance the learning process, and together with the text, images and other media re-enforce the subject area.

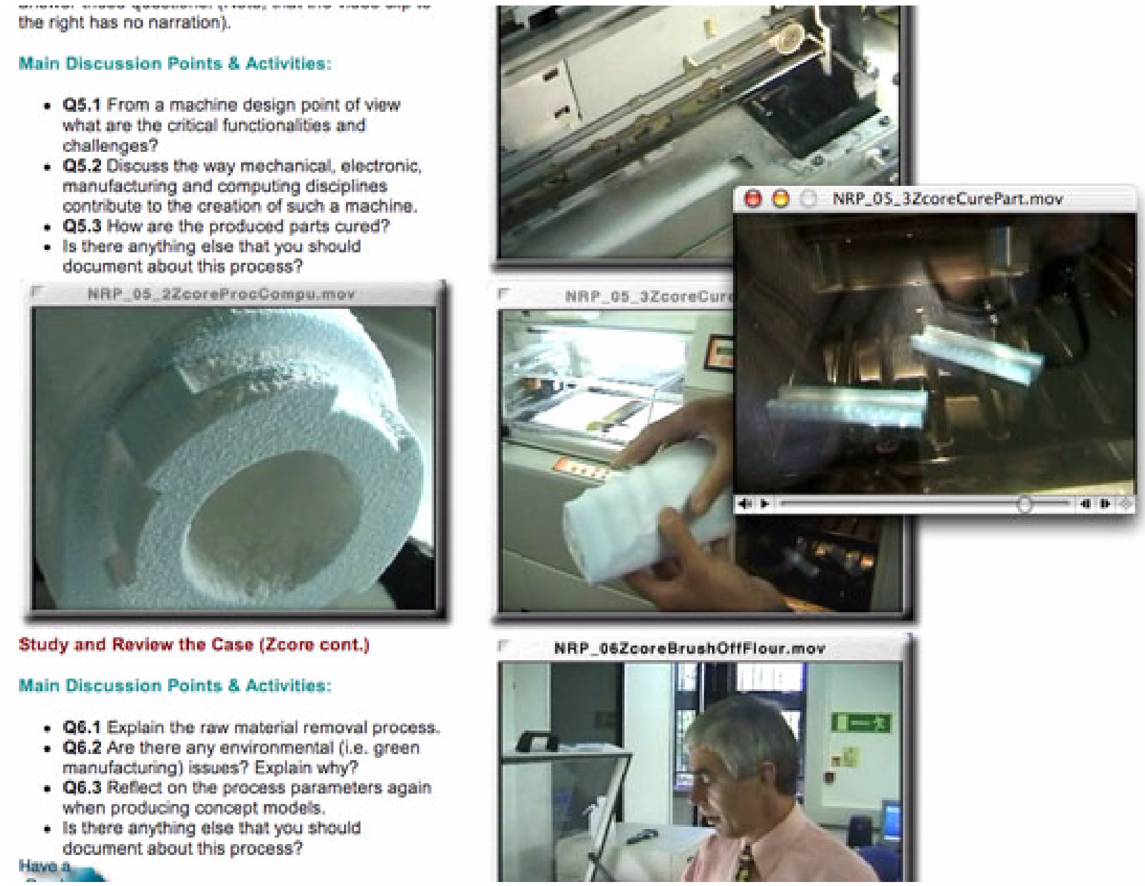

Figure 1. A Typical screen segment of our interactive 3D multimedia screens in the Case Based Learning Library. (Please note, that due to the constraints of the layout of this paper, we had to reduce the size, as well as the quality of our full screen, high quality screen-prints. Please visit http://www.cimwareukandusa.com, and then click on the Case Library icon to view these screen-prints in high quality).

Figure 2 (below) illustrates further screen segments, that show how students can actively manipulate real-world virtual 3D objects, and explore them according to their own interest. (Note, that according to our experience, this approach keeps the students interested in the subject they learn, because they can actively interact with the computer, showing them exciting 3D interactive animations, and active code they can run with their own data, all under their control. Please note, that our original screens are in high quality, full screen and full color graphics, that we had to reduce in size and quality to fit the format requirements of this paper. Please visit http://www.cimwareukandusa.com, and then click on the Case Library icon to view these screen-prints in high quality).

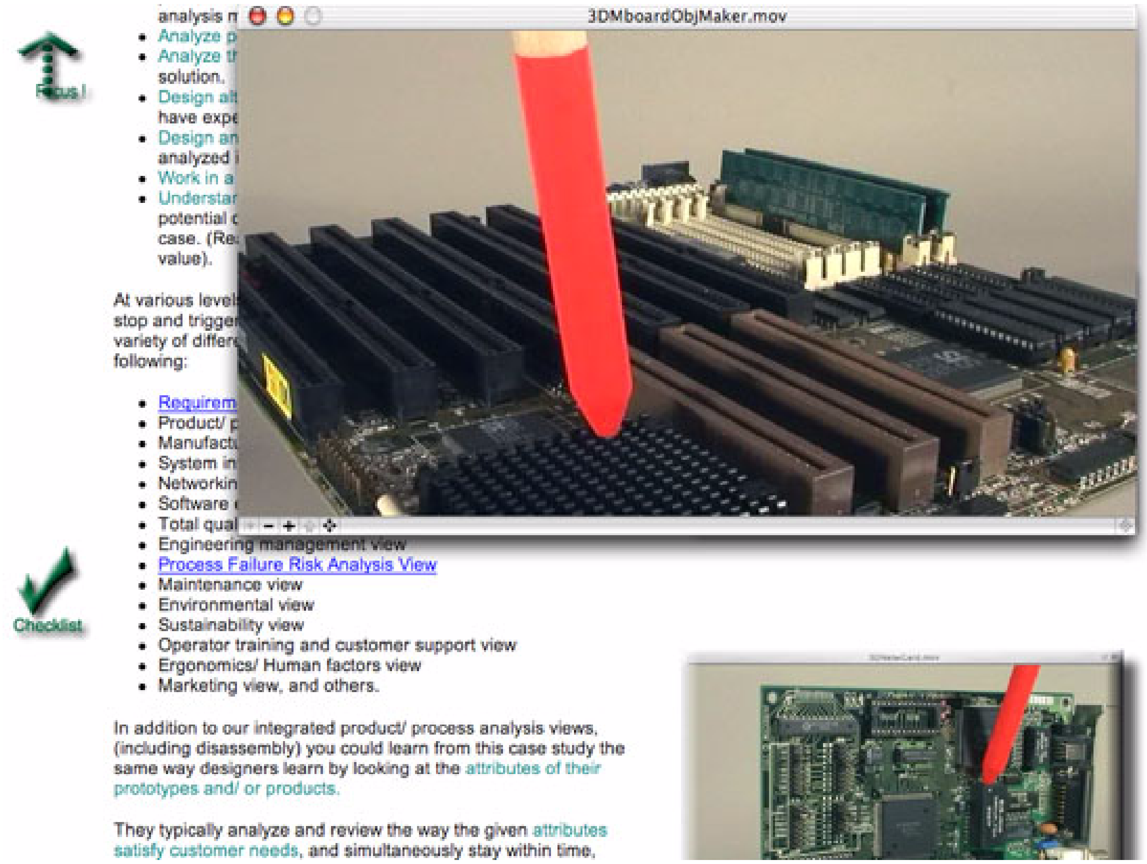

Figure 2 illustrates an interactive 3D virtual reality object, that enables students to explore an-in-depth view of the discussed subject area, in case a disassembly technology demonstration. (Please note, that our original screens are in high quality, full screen and full color graphics, that we had to reduce in size and quality to fit the format requirements of this paper.)

Summary and Conclusions

Our 3D multimedia learning material have been validated and tested in several industry and university (live and virtual) classes, involving hundreds of undergraduate and graduate students at NJIT in Industrial Engineering, Mechanical Engineering, Computing Science and Information Technology, as well as on a wider US and international basis, at Dundee University in Scotland, at Nottingham in the UK, at Imperial College in London, at Old Dominion in the USA, at the University of Michigan, in Ann Arbor, in Sweden, in Hungary, in Mexico, in Hong Kong, in Singapore, in Switzerland, at Kyoto and Kobe Universities in Japan, and at many other institutions and companies world-wide. We are pleased to report that our methods, and several 3D multimedia resources have been adopted for university and company intranets for eLearning. Due to the open-source, analytical and computational, web-browser readable nature of our approach, each object / module is customizable, extendible and editable. This popular feature allows students and faculty to become simultaneously authors as well as readers. (In order to maintain integrity and quality, obviously, the core documents are maintained permanently only by the document owners.)

The most important design feature of our object oriented system architecture is that there is only one core, reusable electronic document, built of 3D web-objects, and active code, that has to be authored and maintained. This enables a wide variety of users /viewers to occasionally become authors (via the appropriate security gates and web-technology) feeding useful knowledge into the content of the object and component oriented architecture.

This work is the result of several years of on-going research. It started in 1977-78 when Paul G Ranky has developed an FMS (Flexible Manufacturing System) object-oriented database and then later, in 1984 by Ranky at Nottingham and Siemens-Plessey in the UK, and then in 1992 when together with Mick F. Ranky, supported by CIMware Ltd., http://www.cimwareukandusa.com and FESTO Ltd. an interactive multimedia CD-ROM was developed as an electronic support system for servo-pneumatic positioning, as well as part of another project for bio-medical engineering with Prof. T. Pato in Berne, Switzerland. In 1997 Paul G. Ranky and Mick F. Ranky developed a 3D browser readable, virtual computer disassembly method, supported by industry, that has led to several other R&D grants (including major DOD grants for NJIT) and publications, including the 3D Multimedia Case Based Library (1995 to date).

Since then the topic as well as the architecture has evolved into a robust, object-oriented knowledge management architecture with 3D web-objects, supported by several companies and institutions, including FESTO Inc. USA, GenRad, Inc., The Nottingham Innovative Manufacturing Center, IMI, Ford, Rolls Royce, Ratheon, PSE&G, GibbsCAM, GenRad, Cincinnati Machines, Fanuc Robotics, MCI-WorldCom, IBM, Okuma, BMW, Motorola, Sony, GE Fanuc, Yamazaki Mazak, Bosch and many others. Our efforts have been validated and strongly supported most importantly by our undergraduate and graduate engineering, engineering management and computing students at NJIT, and elsewhere in the world, who have worked through different versions of our objects and helped us shaping it to its current, still evolving, nevertheless already mature and very robust truly multi-platform (meaning Apple Mac, OS 9 and OS X, PC Win 98, 2000, NT, XP, Linux and Unix compatible) format.

We would like to thank for the continuous support of our students, the companies and organizations, and pleased to report that our efforts are moving on with an increasingly positive energy flow in all of us involved.

Live Software Demonstration

During the presentation of this paper at the conference there will be several live software demonstrations, illustrating the novel interactive 3D multimedia, as well as the active code and video-clips, that a printed paper can never truly illustrate. Furthermore during discussions further, in-depth software demonstrations will be given, and questions will be answered during the conference using off-line, and optionally wireless Internet access (based on availability).

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