Session 2542

A Novel 3D Internet-based Multimedia Method for Teaching and Learning About Engineering Management Requirements Analysis

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Introduction

The objective of this research was to create a case-based / problem-based teaching and learning curriculum, supported by an advanced 3D web-enabled case library, focusing on needs, or in other words requirements analysis.

Our solution enables students to explore requirements, following an analytical approach. We demonstrate our method as applied to engineering management, design and manufacturing engineering, biomedical engineering, computer systems and networking subjects with the aid of a generic architecture, that includes 3D web-browser readable multimedia, text, images, interactive videos, 2D and 3D animations, active code for calculations, and even self-assessment tools.

The developed and validated cases besides traditional teaching and learning methods, and laboratory activities, use browser-readable interactive 2D and 3D objects, animation, videos, 3D objects of real components, virtual 3D disassembly methods of objects, and simulated (virtual) factory tours that the students can explore and study. Our educational and computational requirements analysis, risk analysis, assessment, and other methods introduce a novel approach to developing and running undergraduate and graduate courses in this subject area for face-to-face, honors and distance learning modes.

In this paper we introduce the principles of our educational methods and solutions, and explain and demonstrate (during our live presentation) a series of case-based learning modules (eBooks) that encourage analytical requirements analysis in the engineering management context, and offers reusable interactive multimedia development, team-oriented learning and problem-solving with real-world challenges.

Our efforts are supported by over 30 academic and industrial partners, assuring the diversity, the relevance and the quality of this rapidly growing library and teaching /

learning method.

Requirements Analysis in the Engineering Management Context

Requirements analysis is considered to be one of the most important features of any engineering management project because if done professionally, it helps to specify and then research / develop appropriate features, processes that customers need / want.

In this particular paper we focus on our generic methodology, and illustrate some engineering management applications ([1], [2] and [3]).

Our generic Component Oriented Requirements Analysis (CORA), represents a systematic, customizable method developed by Ranky for customers to identify their needs, and then offer them (software and other) engineering solutions that satisfy their requirements within a competitive environment. Furthermore, the method is successfully applied in design, manufacturing, industrial, software, IT, and even biomedical-engineering and related engineering management fields.

CORA is a generic Team Oriented Problem Solving (TOPS), method, aimed at minimizing dissatisfaction, and financial loss due to poor communication and management. CORA is applied during the electronic support system planning stages of a process, and then updated on a regular basis to document changes in requirements and /or engineering solutions ([4] and [5]).

CORA is an iterative technique that promotes systematic engineering team thinking when a new process and / or product or system requirement is developed. The CORA Team's core mission is to study the customer and the future user base very carefully, and then extract, collect, analyze and reason over customer requirements using our spreadsheets.

As a generic, object-oriented engineering management problem solving method, as with all cases in our library of cases, we are committed to the following approach:

- Analyze the needs and the requirements, the demonstrated processes, methods and systems they try to, or have to satisfy.
- Analyze the actual methods presented. Find the core methodologies, the mathematical models, the underlying engineering (and/or other) science foundation.
- Analyze the technologies involved. (How is science turned into a practical solution/ engineering and/or computing technology?)
- Analyze and review the actual processes and the way the process flow is integrated. (Follow an object-oriented process analysis method, e.g. from concept to product.)
- Analyze potential alternative solutions.
- Analyze the benefits and the disadvantages of each process/ solution.
- Design alternative methods, processes based on what you have experienced/ seen,

and learned.

- Design an integrated system, based on what you have analyzed in this case. (Preferably use web-based, open source tools and knowledge documentation systems, because this will encourage every member of the team to participate, as well develop the methods further, so that they become ‘living documents’.)
- Work in a multi-disciplinary team and exchange ideas, because this way the engineering management team will become stronger, and their decisions better.
- Understand the boundaries as well as the tremendous potential of new ideas and developments by working on this case. (Realize that in order to survive and win, you must add value.)

The above challenges are presented to students using 3D interactive virtual environments of real-world challenges (see Figures 1 and 2). (Note, that the virtual approach here helps to bring students to facilities, that would otherwise be impossible to reach, due to cost, time and other constraints.)

Furthermore, the expert guided in-depth discussions, the interactive tours, the text and other 2D and 3D media, the worked out examples, as well as the active code in our cases offered help students to grasp the method, and then use the active code for calculating with their own data.

Some Architectural Design Methods and Solutions

In this library we follow an object oriented design approach, therefore the open systems architecture includes the following key design principles ([6] to [11]).

Case-based library programs are self contained objects built of reusable objects and components. Often, these objects and components are text, high quality images, interactive digital 2D video, 2D and 3D animation, 3DVR (3D virtual reality) and animated 360 degree 3D panoramas.

They are open source, web-enabled, delivered on CD-ROM or DVD (to overcome transfer rate and in some countries expensive web-access bottlenecks) or fast company intranets, the new emerging opportunity for continuous professional development.

The way we present challenges are similar to the way professional engineers, and engineering managers solve problems. This is because we first look at the real-world customer requirement, then offer one or more solutions by explaining real-world machines, or processes, or systems, or management tasks and then discuss further development, service, maintenance, integration, connectivity and many other issues with several feedback loops, and then offer discussion opportunities for real or virtual teams.

In terms of delivering the individual cases in the Library the 3D Virtual Product Demo concept is followed, an innovation on its own, in that learners are taken virtually into real hi-tech factories, R&D studios, exhibitions and laboratories and are given interesting demos and challenges explained by real-world experts who explain one possible solution.

In all cases the library modules show high quality, interactive videos and often 3D objects and 360 degree interactive panoramas so that learners can interrogate objects, take products virtually apart in 3D, enjoy virtual factory or facility tours and even participate/ collaborate actively by e-mail and other Internet methods.

In terms of challenging the learner to learn and investigate the illustrated case(s) further the cases give them several direct URL (web) contacts, e-mail addresses so that they can get in touch with anybody over the web, including any of the authors who have created/ presented the cases.

In several cases, assessment is supported by spreadsheet-based automated tools, that in case of an incorrect answer hyper-links the learner back to a ‘sorter switch’ routine, that offers a variety of revision solutions, so that the missed material can be learned, and the test re-taken.

The assessment questions address exciting engineering, management, and computing science / IT (Information Technology), biomedical engineering, and other issues, and in many cases document best practices. This approach helps distance learners as well as educators to work with the material in real-world classroom and/or virtually web-networked teams.

In direct response to the needs of our industrial and academic sponsors, the cases are object-oriented and self contained, nevertheless can be integrated/ grouped into different classes of objects in a lean and flexible way (the same way as a modern software program, or a modern manufacturing / assembly system can be integrated into different environments). This enables learners as well as tutors and managers to 'plug-and-play' the Library cases in the way they choose to, rather than the way the author meant it. This means that our 'typical' readers are problem solvers, as well as readers and authors at the same time... an interesting challenge for all of us.

The ways we present challenges are very similar to the way professional engineers solve problems. Notice that we do NOT follow the traditional linear, but rather the modern concurrent, object oriented approach to integrated product/ process design ([7], and [8] and [11] to [13]).

Specifically, our methodology suggests the following activities, or processes with continuous quality and requirement feedback-loops:

1. Research and analyze the needs, for all key processes, and then
2. Develop a comprehensive object oriented system model.
3. Create a pilot system, a 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.

Our cases are object-oriented and self-contained; nevertheless can be integrated or grouped into different classes of objects in a lean and flexible way, just as a modern software program can be integrated into different environments. This 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 (three dimensional virtual reality) interactive multimedia. It is highly interactive, collaborative and enables large groups as well as individuals to gain the same knowledge effectively ([1]). 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 ([14] to [17]).

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 ([18] to [23]).

Within our cases self-assessment is possible. This means that students become more self-critical as they participate directly in their own learning process. 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. (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. As a result, the entire education process is more suited to satisfy individual needs from 'batch size 1 to many' at the same high quality ([24] and [25]).

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.

A Component Oriented Requirements Analysis Methodology

Our Component Oriented Requirements Analysis (CORA), represents a systematic, customizable method developed by us to identify customer needs, and then offer (software and other) engineering solutions that satisfy their requirements within a competitive environment. CORA is aimed at minimizing dissatisfaction, and financial loss due to poor communication between line manager and operators, and/or between designers, line managers and operators.

In terms of our methods base, our solution gives an open source, web-enabled environment with a graphical interface and embedded 3D web-objects, that run on literally any multimedia PC / Win, Mac, Linux, Solaris, UNIX, etc. computer in the world. Our code is integrated in four modules, these being: User Requirements, Engineering Solutions, Parameter set, and Benchmarking.

These modules interact via a correlation matrix that has values based on team assessment, and then via various algorithms offer the best possible optimization in terms of

- how we should satisfy our customers' needs,
- what the critical priorities are,
- what the critical parameters are,
- what are the actual values or ranges of values of these parameters,
- how do others satisfy the same needs (i.e. how do our competitors, if any, satisfy our customer requirements),
- what are the absolute and the relative importance values for each ranked requirement,
- what are the critical actions (processes) we should take to satisfy our customers' requirements, and
- others.

CORA is applied during the electronic support system planning stages of a process, and then updated and shown on line-support systems (e.g. LCD screens in front of each operator) on a regular basis to document changes in requirements and /or best practice engineering and engineering management solutions.

As illustrated in **Figure 1**, CORA is a matrix-based method, similar to QFD (Quality Function Deployment) practices, developed for user requirement / need analysis.

As can be seen in Figure 1 the team enters the

1. user requirements in the left hand side of the matrix, including their
2. priority ratings, then the
3. selected engineering solutions (at the top of the matrix) and then the

4. correlation values (1, or 3, or 9) linking requirements and engineering solutions in the actual matrix (middle section of the spreadsheet).

It should be noted, that we enter data into a CORA spreadsheet on a relative scale, therefore standards should be determined by the local CORA Team, as well as by the local, customized standards they follow.

As a result of our team efforts, the CORA software tool calculates absolute and relative importance ratings, and guides the team on where to put critical resources for improving customer satisfaction, quality, and others.

To illustrate some aspects of our interactive, 3D browser readable eLearning architecture, in **Figure 1**, we present a typical screen segment of a specific requirements analysis case, in which we introduce our CORA tool to help engineering managers to decide networked automotive robot requirements, when developing computer controlled welding systems.

Fig2_RankyCORA_NetwRobotsV5.xls

Object / Component Oriented Requirements Analysis Program for Automotive Networked Robots by Paul G. Ranky © 1992-2002

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Engineering / S… Respo… Requirements

mailto:cimware@cimwareukandusa.com?subject=Requirements Analysis Template ver.5

Automotive Line Manager: Customer Requirements (Reflecting component/ object behavior related to customer needs)

S.No	Describe the Requirement	Importance Rating (1-	Fieldbus Network	Profibus Network	DeviceNet Network	Ethernet	Graphical Robot Progr	On-site maint. Suppor	Off-site Maint. Suppor	On-site Redundant Se	Off-site Redundant Se	Link to Factory MRP	Link to Factory TQM	2D videos/ 3D multimedia	Cell-based web Camera	PC-based Robot Controller			
S.No	Describe the Requirement		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Reliability of data transfer for real-time access should be high	5	9	9	9	9				9	3					9			
2	Reliability of reporting process failure to the line manager's computer	4	9	9	9	9										9			
3	Ease of integration into a system (plug and play networking): important!	4	9	9	9	9										9			
4	Ease of robot programming (welding/ assembly)	3				9	9	9								3			
5	Ease of changing robot programs (locally, and via the network)	4	9	9	9	9	9	3	9					9	9	3			
6	Ease of adding new sensors to a robot, or robot cell, or line	3	9	9	9	9										9			
7	Safety of operation: critical!	5	9	9	9	9		9	3	9	3					9			
8	Cost of change/ extension/ system expansion should be low	4	3	3	3	3		9	3	3	3					9			
9	Operator training needs and costs should be low	3					9	9	3							9			
10	Network installation complexity and cost should be low	3	9	9	9	9			3	3						9			
11	Maintenance complexity and cost should be low	5	9	9	9	9				9	3					9			
12	Network management responsibilities should be high	3	3	3	3	9													
13	Network reliability must be high	3	3	3	3	9													
14	The network should report robot production data	5	1	1	1	3						9							
15	The network should report robot process quality data	5											9						
16	Robot tool management should be on the network	3										3							
17	Operators should have multimedia manuals for in-process training	4	3	3	3	3	9							9	9	9			
18	The network should have 'panic' support by simulating alt. solutions	4	3	3	3	3	9									9			
19	The network must be linked to the factory LAN	5	9	9	9	9	9		3	3	1	9	9			9			
20	The system history database should be on the network	5	3	3	3	3			3	3	9	9	9	3	3	9			
	Target Values (List here the parameters that specify engineering solutions accurately. If you don't know the range of the acceptable values, use our Taguchi		27 msec	27 msec	27 msec	27 msec	onized, edia	han 3 s	han 24 hrs	switch	han 30 itch	h every 2 s	h every 2 s	40 pixels er	40 pixels er	inux, , or OSX			

Sheet1 / Sheet2 / Sheet3

Figure 1. A typical screen segments of our interactive CORA tool with 3D multimedia objects in the Case Based Learning Library. (Please note, that due to the size and format limitations of this paper, unfortunately we cannot show the other screens and segments of this eBook program, nevertheless interested readers should look up http://www.cimwareukandusa.com, and then click on the Case Library Icon.)

Figure 2 (below) illustrates further screen segments, that enable students to actively manipulate real-world photo-realistic virtual 3D objects, and explore customer requirements following our analytical approach ([25] to [28]).

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.)

Figure 2 illustrates an interactive 3D virtual reality object that enables students to explore an-in-depth view of the discussed subject area. (Please visit http://www.cimwareukandusa.com, and then click on the Case Library icon to view these screen-prints in full color and high quality).

Summary and Conclusions

Our 3D multimedia learning eBooks have been validated and tested in several industry and university (live and virtual) classes, involving hundreds of undergraduate and graduate students. The institutions and subjects include Industrial Engineering, Mechanical Engineering, Computing Science and Information Technology, as well as on a wider US and international basis, at NJIT, 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, 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.)

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. These include 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, robust multi-platform (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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