Preparing Systems Engineers of Tomorrow

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Abstract – The US Bureau of Labor Statistics has documented a definite and remarkable shift in jobs away from emphasis on programming and logic design towards emphasis on systems, applications, and management. We need to reorient our curriculum and our students to develop systems design skills in these students. An engineering product designed in a vacuum without appropriate stakeholder input may fail in the marketplace. Engineering students lack real-life skills and motivation to interact with stakeholders in other domains and to develop relevant commercial products for them.. We believe that a top-down system design flow, built around UML (Unified Modeling Language), can provide a well-charted pathway for students to develop these skills with less anguish. We offered such six different projects for our students in a course on software-hardware codesign and helped them to incrementally develop their system designs, using UML. We will present our results in the paper.

Keywords: UML, System Design, Model Driven Architecture (MDA), Co-Design

BACKGROUND

An engineering product designed in a vacuum without appropriate stakeholder input may fail in the marketplace. Despite ABET's guidance to the contrary, both professors and students in engineering lack the real-life skills and motivation to develop commercially relevant products. Many working engineers are content to focus on engineering issues, such as coding, logic design, and testing. Unfortunately, such pure engineering jobs can be automated, out-sourced, and migrated to technicians, as they are well-defined and really not that challenging anymore – witness the availability of low cost components and the popularity of component-based design, in software and hardware. More unfortunately, the same engineering professional might consider management and systems engineering below his/her intellectual and engineering capabilities. However, as per the US Bureau of Labor Statistics, the net employment increase over the next decade (2006 to 2016) in many computer occupations with focus on systems software, applications, and management will be 40 %, with a median annual salary of about $89K [1]. This may be compared with annual growths of -4% and 4% for computer programmers and computer hardware engineers, respectively, with respective median annual salaries of $65.5 K and $88.5K. This clearly dictates a shift away from the emphasis on programming and logic design towards systems, applications, and management.

METHOD

We recently revamped our course on software-hardware codesign to emphasize a top-down flow with UML version 2.0. Key to this was the availability of a well written book on UML (unified modeling language) with a good case study of a wireless handheld computer system [2]. UML is a visual modeling language that enables system designers to express their designs in a standard easy-to-understand way, and communicate these ideas effectively with different stake holders such as the customer, the business manager, and the engineers involved in hardware and software implementation. System design involves communication among people and miscommunication can cause design errors that can cause re-designs, design compromises, and/or field failures, after the product has been prototyped. These are costly mistakes and impact engineering design productivity substantially. An error inadvertently introduced at the requirements level is equivalent to 130 errors introduced at the prototype integration stage, in terms of engineering effort involved to fix it [3]. Such concerns have brought about the development of UML. UML is a collection of diagrammatic views that together provide a model of the system. One does not need all the UML diagrams, to describe a system. UML 2.0, the current standard, has 13 types of diagrams that may be

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divided into three types: 6 are useful for representing structure; 3 others are useful to describe behavior and the remaining four others are useful for depicting interactions. Typically, one uses class, object, package, and deployment diagrams from the structure diagram set; activity, use case, and state machine diagrams from the behavior diagram set; and sequence diagram from the interaction set.

The book details a case study of a wireless unit that serves to connect various workers at a restaurant to primarily provide the diner a satisfying experience of dining out. However, it also helps to enhance the productivity of the restaurant workers and reduce their stress. The system design flow is intended for object oriented systems and follows the process of Requirements Gathering, Analysis, Design, Development, and Deployment. The book covers the first 3 stages; the last two stages are implementation stages that may be addressed with .NET from Microsoft. The stage of Requirements Gathering involves the discovery of the business processes (by interviewing the domain experts and summarizing the process with activity diagrams), domain analysis (identification of classes, their attributes, and operations – the first cut), identification of cooperating systems (a deployment diagram is the product), and discovery of system requirements where all the stakeholders meet to identify high level areas of system functionality (a package diagram is the result, with each package representing a set of use cases that are to be implemented to achieve that system functionality). This is followed by the Analysis stage, which involves the following steps: flesh out use cases, refine class diagrams, identify states in the objects (with a state diagram), define interactions among objects (with a sequence diagram), and integrate with cooperating systems. The next stage of Design involves: object diagram refinement, development of component diagrams, planning for deployment, development of the user interface, and design tests. This is followed by the stages of Development (and testing) of code and Deployment (hardware integration and testing). We covered the book's case study in detail in the class. To ensure that the students had specific goals and applied the concepts in parallel, we identified projects and provided assignments that paralleled the case study.

We derived inspiration from our industry collaborations/ innovations to identify 6 potential team projects for the students: personalized graduation ceremony, self-blood pressure management kit; university class scheduling; sound interface to PC for Pre-K and Kindergarten children; file tracking in a law firm; and poll worker aid. The projects addressed the following: meet stakeholders (typically 3 to 5) in that domain to develop activity diagrams; identify class diagrams and associations (from nouns and verbs of the activity diagrams); conceptualize use cases; chart sequence diagrams and state diagrams; and design the user interface. To bring attention to the business aspect, we have added one more step: integrate an on-line business interface that is Ad-driven. The process is completed by evolving a pseudocode/XML/Java/SystemC description of the skeleton code that clearly identifies the components, their interaction, and their internal behavior. Code development and component integration can be finished quickly after that.

RESULTS

All the students have completed assignments 1 (on domain analysis with activity diagrams, evolution of class diagrams, refinement to develop system boundaries, identification of user interface classes and refinement of class diagrams, and listing of the use case details with the refined class diagram) and assignment 2 (on development of sequence charts and state diagrams). Assignment 3 will be completed soon and it will cover the following: listing of the skeleton code with pseudocode and identification of the user interface details. We will present the results at the conference. We will also make three of these student designs (self blood pressure management kit, university class scheduling, and file tracking in a law firm) available at our website ((www.csi.fau.edu) as technical reports. We expect to implement one of these (self-blood pressure management kit) in .NET with web services. This will also be posted at the website and presented at the conference. All the designs involve multiple types of users with their own unique interfaces. Thus, the self-blood pressure management kit has interfaces for the patient, doctor, pharmacist, and the dietician. The group will help the patient manage his blood pressure with different interventions and with few side effects, as appropriate.

DISCUSSION

Some of the groups tried to bypass the step of interviewing domain experts. This resulted in use cases such as expecting a 4 year child to launch his own lesson from the PC (a teacher or a parent should have set it up for the child); and expecting a poll worker to wait to hand over the ballot box to the transporter (we told the team that

automation also meant less manual supervision). Sequence diagrams use arrows to point to the object being invoked and the arrow should be labeled with that object's operation being invoked. Some students did not appreciate the concept and labeled the arrows with respect to the source of the arrow. This may be more intuitive, but does not help in helping the code developer implement the code using object oriented design. In sequence diagrams, time moves down; so, one follows the sequence from top to bottom to understand the flow of control. The students showed sequences going in opposite directions. By having students make presentations to the class and pointing out these errors politely, we believe, the group progressed as a whole.

UML is a big step forward. On the other hand, UML is not intuitive, because it spreads the information across many diagrams, making it difficult to track the system design and to gain an intuitive feel. We have started exploring OPM (Object Process Methodology) which combines objects and processes in the same diagram which can be hierarchically refined [4]. It provides the diagram in both visual and textual format, thus facilitating brainstorming and automatic code generation (at least at the level of skeleton code). Its biggest advantage may be at the level of requirements capture to extract the process flow from domain experts. One may wish to add this to model class diagrams obtained after the initial step of the use of UML's activity diagrams (to brainstorm with domain experts). Result will be a specifications document that can be translated automatically. We plan to explore its inclusion as it is very intuitive and students may find it useful to better integrate their thought process.

We have had to hold several face-to-face meetings with the teams to get students to make progress. We found the teams to be uniformly distributed among motivated, reluctant, and disinterested. This is understandable, because the top-down design process requires time and effort up front to get the user requirements and engineering specifications right. Our own experience shows that both manager and engineers feel that they are not being productive during this period. However, without this methodical approach, there is significant effort involved in development and integration. Net result is that the methodical top-down approach actually reduces the development period and increases commercial success of the developed product.

A few success stories will convince the future generations of graduates to take this process seriously. With that in view, we expect to evolve collaboration with the college of business to involve their BBA and MBA students in taking these specific projects forward as their business ventures. For that, we would have to implement the design and test it. We plan to integrate .NET in next semester's course, albeit with simpler class projects that can be taken all the way from UML to implementation with .NET. An unified approach to go from concept to commercialization will hopefully prove useful and worthwhile.

CONCLUSION

We have evolved a course that uses UML for top-down system design. There were six unique team projects that the students worked on. We expect to implement a few of them with .NET. Subsequent course offerings will integrate both UML and .NET so the students can fully appreciate the consequences of the decisions they made at the requirements level, and also to provide them with a sense of accomplishment by demonstrating their real implementations.

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