Impact of Motorola's Vision on Florida Atlantic University's Engineering Curriculum

Submitted by

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Abstract:

This paper presents our university's efforts in translating public research results from a Motorola funded project into academic innovations. Motorola funded the university during 2003-2008 at $1.1 M to develop ways to radically increase engineering design productivity. The research resulted in best practices and a blueprint for that. It also helped develop project based courses on state-of-the-art topics, specifically on the development of Apps for the smart phone, robotics, and the semantic web. Separation of concerns and sequencing of courses allowed us to develop and offer courses at high school, undergraduate and graduate student levels. Several faculty members and about 450 students from various colleges and local schools were involved in the development of Apps in these courses. Our process led to state-of-the-art team projects that were successfully completed in a methodical, efficient, timely, and reliable manner. This paper provides the methodology used and the lessons learned.

Background:

Motorola's iDEN Mobile Devices (now Motorola Mobility) funded us during the past decade to develop a methodology to radically increase their engineering design productivity. The second author of this paper was a Motorola Senior Fellow and the CTO at this Motorola plant at that point. The project, envisioned by him, and entitled as "One Pass to Production" (OPP), had the stated goal of a new product design cycle of 24 hours, as compared to 24 months, the then norm in the high tech world. Motorola's internal evaluation at project completion concluded that our approaches could reduce the time period to 3 months, an improvement of 6 to 8 fold [1]. This paper will document our effort to incorporate those principles in a different context, viz., teaching project oriented courses. ABET encourages team projects in the engineering curriculum to expose students to real world engineering problems and perspectives. However, such courses tend to have multiple challenges for professors and students alike, resulting in poor results. Our process leads to state-of-the-art team projects that are successfully completed to the satisfaction of all the stakeholders. For more information, please see corresponding course websites [2, 3 & 4].

Methods:

On Technology Mapping to Academics: Engineering design productivity is significantly enhanced by Model Driven Architecture (MDA), Design Reuse, Adoption of Standards, Separation of Concerns & Concurrency, and Open Source Tools & Languages. Application of these principles to academic team projects can be simple and intuitive, and excellent results can be achieved fairly quickly. First, we address each of these dimensions, as it relates to a specific course sequence, on Android smart phone app development. We have separated the technology concept and the corresponding academic adoption in the details given below:

- *Technology Concept*: MDA facilitates abstract modeling to actual implementation in well-defined and organized stages. *Academic Adaption*: The students use story boarding to document use cases and the MVC (model-view-control) pattern to develop their technical screen mockups. MVC is the predominant way to develop smart phone and other GUI (graphical user interface)-based applications, so the App is user friendly and useful in a real world context. However, this also helps the students to think about the strategy of 'divide and conquer' in developing their App.
- *Technology Concept:* Design Reuse benefits the designer in multiple ways. This allows the designer to think about higher level functionality that uses these existing (pre-designed and implemented) modules. *Academic Adaption:* For example, Android provides APIs (application programming interfaces) for Bluetooth, a standard hardware element in smart phones. We also develop our own Android components (with help from graduate students). We also make available App code from previous semesters, so students can quickly pick up the best practices. Further, the Android on-line community is dynamic, vibrant, and very community oriented. We also contribute to this with our own website which is well visited [2].
- *Technology Concept:* Adoption of Standards has to be forward looking for it to be successful. This also requires analysis of future trends. *Academic Adaption:* Our analysis showed that Android would capture a large market share (at present, it has already cornered more than 50% of the smart phone market. When we started our courses, back in fall 2009, Apple's iPhone was the dominant platform by far). We decided against the use of the iPhone, since it has a steep learning curve, uses proprietary technology, and requires its own hardware. Android, however, is based on Java and XML, popular and well accepted languages. It can also be downloaded free and used in the popular and open-source Eclipse IDE (integrated development environment) on PCs with Windows and other operating systems. Software emulation is easy and complete. A smart phone (the physical hardware) can be interfaced to the PC via the USB link and integrated, so the Apps could be downloaded directly to the phone and test run. All this means that Android App prototypes can be developed fairly quickly. Apple, however, should be

credited for being the bold trend setters that made all this happen. Our students, once they develop an App for Android, find it easy to migrate to the iOS platform and support it as well.

- *Technology Concept:* Separation of Concerns is achieved via concurrent development of reusable component libraries, platforms, and prototypes. *Academic Adaption:* In our case, graduate students focus on developing Android software components, because of their intellectual maturity and professionalism; the undergraduate students develop App platforms, because of their technical savvy and energy; and the high school students develop marketable Apps because of their creativity and social connectedness. Each of the later artifacts or deliverables requires the earlier ones for their successful completion. Thus, the graduate students develop components in the fall semester, with the undergraduate students developing the platforms in the spring semester, and the high school students transforming these platforms into marketable Apps during the summer semester (in a three week course). Both undergraduate engineering and high school students work in teams of three. In each of these teams, one student each focuses on functionality (with focus on programming), aesthetics (with focus on graphics, animation, and multi-media), and project coordination (with focus on system design, integration & testing, team management, documentation, etc.,). The high school student teams develop marketable Apps, unlike undergraduate engineering students, who develop well-engineered platforms that the high school students can mix and match to achieve their goals. The high school students' work is thus made easier from a technical perspective; however, they still need to use their creativity and aesthetics to transform these platforms into marketable Apps. To facilitate this, we involve a graphics professor (3rd co-author) to advise the students on graphics, aesthetics, story-boarding, and marketing video preparation. The anthropology professor (4th co-author) was first involved while developing social game App platforms (at the undergraduate level) and has now a larger role in understanding team dynamics and developing guidelines to improve productivity and reduce team conflicts.
- *Technology Concept:* The academic community is split on the use of open source (as against proprietary) tools and languages. We have opted for the open source environment for the following reasons: Open source environment allows students to examine the code and architecture, incorporate their own innovative ideas, learn the flow faster (with the help of the community), and become productive sooner. Security, usability, and integration with other tools are enhanced by the constant involvement of an interested community. Proprietary tools, in our experience, become increasingly complex as paying customers demand more functionality. This leads to a steep learning curve for beginners. Also, cost of acquisition will be a concern for university students. *Academic Adaption:* Android, Java, XML, and Eclipse provide open source tools and languages. Their large on-line communities facilitated immensely our flow. We also added our own Android support site and student blog sites. We encourage students to learn from each other via their blog sites. The course grading is not curved, so the students are more willing to help each other. Our site has full documentation of all the earlier Apps, presentations, reports, and marketing videos, so the current groups taking such a course would have enough examples to learn from. Such transparency to underlying flow and implementation details allows for a faster learning curve, innovation, multiple perspectives, and reduced cost to all. These are the norm for innovation and high productivity in every field that has embraced these principles. Examples of such fields are electronic chip design and PCR (polymerase chain reaction) DNA sequencing.

We have used this methodology to develop course sequences for App development in three domains: Android smart phone, robotics, and semantic web. The Android environment is the most developed of the three.

The Flow: Our overarching goal here in all this has been to educate students from high school level to graduate level in various advanced areas of high tech, in a synergistic manner that is cognizant of their strengths and needs, while realizing a pipeline of engineering products that are potentially marketable. We included undergraduate teaching assistants during the summer semester to enhance communication with the high school students. To ensure that the students complete projects on-time, we provide 5 project assignments to pace them (worth 15% of the final grade), at both undergraduate and high school level. These were on the following topics: Storyboarding; Technical mock-ups; Java and XML modules' development; App integration and testing; and the App Portfolio completion (presentation slides, marketing video, App folder, a five page report, and the team blog site). At the end of the semester, a group of judges with professional background in engineering and graphics review the projects via a 20 minute presentations from each of the teams. They are scored on a set of 10 App dimensions (uniqueness; ease of user interface and experience; graphics attractiveness/appeal/quality; mobile performance considerations, such as battery life, code size, and geo-sensitivity; complexity of programming algorithms; audio effects; teaching/educational factor; business acumen (business model, advertising, etc); security considerations; ease of updates for fixes, new features, etc.). Judges' evaluation has a weightage of 25% for the final grade. To ensure that all the teammates are trained, we complete the course material in the first half of the semester with a comprehensive exam (worth 20% of the final grade) on Android, Java, and XML by the middle of the semester. The second half of the semester is focused on the project. This separation of concerns helps the students focus better and deliver. Submission of complete documentation (presentation slides, App project folder, marketing video, completed blog site, and a conference paper) yield the students 40% of the final grade.

Results:

Android Course Sequence: This is a flow that has worked well for us in all the three domains, viz., in smart phone, robotics, and semantic web App development. We have successfully repeated this cycle on Android App development two years in a row, during 2010 and 2011 [5]. During 2012, we experimented with variations to make the course accessible to more students. A total of 450 students at all levels, including working professionals, have been trained. We have 26 marketable Apps on fun games, social impact games, and medical needs. Our web site documents progress in this field and our contributions to the Android community [2]. We expect to put some of these Apps soon on the market. More than 145K visits have been recorded for this site. Most of the student teams had their own blog sites. Links for all these may be found listed at our website [2].

Details of our courses offered during the 2012 academic year are detailed below.

- During the spring 2012 semester, we involved students and professors from non-engineering disciplines as well, at the undergraduate level, to encourage even truer real world experience in project work. About eighty students from four disciplines (engineering, arts, business, and anthropology) teamed up to develop seven health-related mobile applications as part of a new interdisciplinary course [6]. The undergraduate student teams were taught and advised by four faculty members, one each from these disciplines. Thus while the engineering students focused on the functionality, the graphics majors addressed the aesthetics, with the business students addressing the market analysis, and the anthropology students providing guidance on team dynamics. The seven apps are well documented at student blog sites.

- During the summer 2012 semester, we offered all the three courses because of the popularity of the field. Blog site links for these students' work are listed at the android website [2]. All the tools cited below are open source and can be easily located on the Internet.
  - Two undergraduate eLearning courses were offered by two of us, professors in engineering and arts. The 29 undergraduate students from engineering and arts formed nine teams and developed Apps. Seven of the nine Apps were completed.
  - The high school students' course now incorporates Android's App Inventor, which provides a simper mechanism (much like the Lego interface) to build Apps. The students developed simpler Apps using both the App Inventor and Java, and compared the two on certain performance metrics (power dissipation, code size, and usability). Six of the eight teams achieved good results and further details may be found at our site.
  - The graduate engineering course on Android components is now more sophisticated. The students (19) used EMF (Eclipse Modeling Framework) to automate most of the code generation and develop plug-in compatible component. Results are documented at our site.

Courses on Robotics and the Semantic Web: We have adopted a similar approach to the robotics and semantic web domains as well. Please visit their respective websites [3 & 4]. The former involves the development of low cost robots to draw geometric art and eventually play multiplayer floor games (based on board games such as Tic-Tac-Toe and Chess), while the latter involves intelligent reuse of information on the web. Reuse and Open Source tools make the process predictable and productive. With regard to robotics, graduate and undergraduate engineering students helped develop, during fall 2011 and spring 2012 [7], a low cost robotic platform and a set of algorithms. We used the Open Source Arduino environment and off-the-shelf hardware components to build and program the robots. During spring 2012, seventeen high school students (in five teams) rebuilt these robots and explored ways to reduce cost further. They used the robots to draw geometric shapes on large canvases of about 1 m x 1 m [7, 8, & 9]. Their presentation videos may be found through their blog site links listed at our robotics web site [3]. Our current robot can be built for under $100, paving the way for wider usage in formal and informal academic settings.

The semantic web app domain is the least developed at present. A graduate course has been offered twice in an attempt to build an integrated flow and a set of Apps. The Apps here are built with several open source tools (such as Jena for semantic web framework, Protégé for ontology, Lucene for text analysis, and Nutch for web crawling) , standards (such as RDF and OWL, for building an ontology), and languages (Java and XML). Since much of the useful data and information reside on the web, and they can be extensive and voluminous, one needs intelligent and semantic web approaches to retrieve, analyze, and present only relevant information. Google and Yahoo have built their businesses on such intelligent web techniques. Semantic web extends the concept by using pre-defined ontologies to aid in this process. There is significant potential for personalizing the searches and retrieving only the required information. This may be compared with Google searches with hundreds of hits many of which totally unrelated to our search needs. We now have developed an integrated flow that is ready to be used in an undergraduate course to develop App platforms. The graduate students' work is documented at our semantic web site [4]. We used this flow, along with Eclipse based tools, to develop an App to help patients with Type II diabetes [10].

Business Incubation: Some students have even leveraged their learning to start small businesses. A total of 5 small businesses were formed. One of them won a second prize in the small business competition held at our university in 2011. Another one has had two Android Apps receive top recognition in recent conferences/code-A-thons hosted by Google and AT&T. A third one, recently formed, has already attracted VC (venture capital) funding. Two others applied for federal (SBIR) funding and did not succeed. One of these has since then developed collaboration with our university for developing university-wide Apps. There is more work to be done to achieve consistent success in this arena.

Discussion:

All this effort started with one premise, that we can apply lessons learned from our industrial collaboration to significantly enhance the academic environment, as pertinent to state-of-the-art team oriented projects. Here are some potentially useful outcomes:

- From a productivity perspective, high school students (with entry level skills) achieved in 3 weeks during summers what typical undergraduate engineering students achieve during a regular 15 week semester course, thus realizing a potential productivity improvement of about tenfold.
- We actively recruited students from 9 local high schools, emphasizing the inclusion of groups under-represented in engineering. We created an environment that is conducive to team work and creativity that led to remarkable results. This matches well with the national goal to increase interest in STEM disciplines in our new generation.
- Our Computer Engineering program is aided since these team projects meet most, if not all, of the ABET Accreditation Criteria 3. The philosophy behind these criteria has practical implications as well – the students will be better trained to work in teams, follow a methodical approach, solve technical and management problems, and address an advanced topic in their project.
- We now have shown that a four way collaboration across four colleges of engineering, arts, business, and anthropology is feasible, and that we can extend it to eLearning. Thus, we believe that we will be able to include students and faculty members from other colleges and departments. It is entirely conceivable, for example, to define a focus on applications related to nursing, climate change, etc., and offer a course on that. This will bring together professors from these disciplines with those in engineering and arts, leading to possible collaborative research, papers, and grants.
- Our graduate students focus on further enhancing the productivity by building software and hardware components. This requires them to explore a certain topic in depth, learn advanced tools (for auto code generation, plug in compatibility, testing, etc.,), and develop a solution. This should help them to gain in confidence, and address better research and professional challenges
- Business college faculty and students are now involved, thus paving the way for a formalized manner to form student-led small businesses. We have seen some success in that

direction already. The college of business has now embraced our flow and is expected to develop courses to benefit from this. They believe that this will increase the student enrollment in the college of business, and lead to many small businesses.

- We have a collection of marketable Apps. The university administrators have now given us approvals to market Apps through the university. However, while we waited, the technology has moved on. We now have more Android versions and phone screen sizes to support. This requires effort, but we are on track. Revenue generated will help us improve courses and innovate further.

Conclusions:

The open source tools and exciting technology trends provide a unique opportunity to embed realistic and state-of-the-art team projects into the engineering curriculum. We used lessons learned from an industry project on radically increasing engineering design productivity to facilitate this. We show how one can teach and train students from the high school level to the graduate level, with grade and age appropriate material and challenges. This has the potential to leverage many of the resources of a brick and mortar university campus to enhance teaching and research across disciplines, and increase funding and entrepreneurial activities.

Bibliographic Information:

1. CSI center's research site, http://www.csi.fau.edu/dashboard.action
2. Android App and course site, http://android.fau.edu/
3. Robotics App and course site, http://robotics.fau.edu/
4. Semantic Web App and course site, http://semanticweb.fau.edu/
5. Shankar, R., McAfee, F., Harris, M., Carvalho, G., and Silva, N., STEM Education with Innovation and Entrepreneurship, *ASEE Mid-Atlantic Regional Conference*, Philadelphia, PA, October 2011.
6. Mobihalthnews, http://mobihealthnews.com/17939/florida-atlantic-students-focus-on-android-health-apps/ , published July 17, 2012
7. Shankar, R., Gundel, J., Ploger, D., Nemeth, A., and Hecht, S., Robotic Art for STEM, *2012 Florida Conference on Recent Advances in Robotics*, Boca Raton, FL, May 2012
8. Shankar, R., Ploger, D., Masory, O., and McAfee, F., Robotic Games for STEM Education, *ASEE Mid-Atlantic Regional Conference*, Philadelphia, PA, October 2011.
9. Ploger, D., Shankar, R., Nemeth, A., and Hecht, S., Exporting Engineering Technology Practice to Enhance Pre-college Mathematics Learning, *ASEE Gulf South West Annual Conference*, El Paso, TX, April 2012.
10. Islam, S., Freytag, G., and Shankar, R., Intelligent Health Information System to Empower Patients with Chronic Diseases, *IRI-HI (Information Reuse and Integration in Health Informatics) conference*, Las Vegas, NV, August 2012.

Biographical Information:

Ravi Shankar, PhD, MBA, PE, Fellow (AHA), is a professor in the Department of Computer and Electrical Engineering and Computer Science (CEECS). He is also the director of a college-wide center on systems integration (www.csi.fau.edu). His current research is focused on semantic web and engineering design productivity. He has taught several courses recently with focus on Android smart phones, robotics, and semantic web. All these areas have had a strong STEM component and involved students from local high schools, undergraduate students from engineering and other disciplines, and graduate students in engineering. More information may be found at android.fau.edu, robotics.fau.edu, and semanticweb.fau.edu. He has 5 US patents. The university has received $1M in royalties from commercialization of his research. He was recently funded by Motorola's iDEN Cell Phone Division with a $1.1 M grant (over 6 years) to radically improve engineering design productivity.

Jaime Borras, MSEE, is CEO and Founder of Wireless Silicon Groups, Inc., Miramar, FL. The company's strategic mission is to rapidly create new Smartphone product platforms based on the most advanced mobile components to satisfy emerging computer trends while optimizing performance, providing longer battery life and improving security. Mr. Borras, prior to founding his own company, held several senior positions at Motorola Inc., Plantation, FL, during 1974-2008. His latest position was as Motorola Senior Fellow after being corporate VP and CTO, for iDEN Mobile Devices within Motorola. He has been issued 43 US patents and has had over 50 technical publications and speaking engagements. Mr. Borras, while CTO of Motorola funded the OPP (One Pass to Production) project at Florida Atlantic University at a total of $1.1 M during 2003-2008.

Fran McAfee, MFA, is an Associate Professor in the School of Multimedia and Communication Studies in the College of Arts and Letters at Florida Atlantic University, Ft. Lauderdale, FL. He and Dr. Shankar have co-taught courses to high school and undergraduate students on smart phone App development, since spring 2010. He has worked with colleagues in Ocean Engineering by creating computer animation to depict concepts of technology under development. This helped the engineering team to secure major funding from the State of FL. More recently, he and Dr. Shankar have started working on building an animation component library.

Michael Harris, PhD, is an Associate Professor and Chair of the Anthropology Department within the College of Arts and Letters. He has worked with Prof. McAfee and Dr. Shankar in developing multi-disciplinary courses on Android Smart Phone Apps. Students from anthropology, arts, business, and engineering worked together in teams during spring 2012 to develop these Apps. The Anthropology students studied the team dynamics and evolved guidelines to help the teams focus on the end goal.

Don Ploger, PhD, is an Associate Professor with the College of Education. He and Dr. Shankar have worked together in developing Robotics courses for high school students. Dr. Ploger brings two important perspectives to this collaborative research. First, from an engineering education perspective, he emphasizes the importance of communicating essential knowledge to non-engineers. The second perspective comes from the mathematics education research literature. There is a well-established paradox: students often fail to apply familiar methods when they attempt to solve novel problems. Coordinating these perspectives has facilitated the collaboration across disciplines

Oren Masory, PhD, is a Professor in the Ocean and Mechanical Engineering (OME) department in the College of Engineering and Computer Science (COECS). He was the Director of the Robotics Center within the engineering college. He has contributed substantially to the refinement of the curriculum of Capstone projects of undergraduate engineering students. His research interests include robotics, automation, machine tools controls, assistive technology, accident reconstruction and safety

Ravi Behara, PhD, is an Associate Professor with the Information Technology and Operations Management (ITOM) in the College of Business at Florida Atlantic University, Boca Raton, FL. His current research interests include computer simulation, unstructured data (Text) analysis, and social network analysis applied to problems in innovation management, customer/patient satisfaction and healthcare operations.