IUPUC Spatial Innovation Lab

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ABSTRACT

During the summer of 2016 the IUPUC ME Division envisioned the concept of an "Imagineering Lab" based largely on academic makerspace concepts. Important sub-sections of the Imagineering Lab are its "Actualization Lab" (mechatronics, actuators, sensors, DAQ devices etc.) and a "Spatial Innovation Lab" (SIL) based on developing "dream stations" (computer work stations) equipped with exciting new technology in intuitive 2D and 3D image creation and Virtual Reality (VR) technology. The objective of the SIL is to create a work flow converting intuitively created imagery to animation, engineering simulation and analysis and computer driven manufacturing interfaces. This paper discusses the challenges and methods being used to create a sustainable Spatial Innovation Lab.

INTRODUCTION AND BACKGROUND

The idea of creating our Imagineering Lab occurred during an ME division retreat last summer (2016), in which our small faculty of full time instructors, adjuncts, and industry advisors met to reconcile the challenges of our newly implemented (2011), rapidly growing Columbus ME program. We made a bold decision to ban scheduled classes and labs in our 60'x 90' multipurpose room that had previously had a podium and seating for 20 in the front for traditional lectures and lab equipment and work stations in the back. The problem was that the room was scheduled for traditional lectures and labs from morning to night so that there was no access to the equipment in the back. Further we had no space to do projects or research. By making the room open access to our engineering community we created a makerspace type environment wherein anyone could use the room and the equipment therein at any time. It could be used for traditional labs, projects, studying, meetings or anything else. The only rule we placed on the room was that while anyone could use it at any time, it was always open for anyone else to do whatever they needed at the same time. We then further elected to enhance the Imagineering Lab by using remaining grant funding for the Arvin Computational Analysis and Engineering Simulation Lab (CASEL) to fund new equipment and software to create an Actualization Lab and a Spatial Innovation Lab within the Imagineering Lab environment.

COLUMBUS IN, IUPUC ME, IUCA+D AND THE AMCE

Columbus Indiana, population 44,000 is an extraordinary town. It's the birthplace of Cummins Diesel. Surrounding Bartholomew County tops the US in mechanical engineers per capita. It is listed 6th in top US cities (right behind Washington DC) for architectural quality and innovation by the American Institute of Architects. Indiana leads the nation in per capita manufacturing jobs with the Columbus region being one of Indiana's most dense areas for high-tech manufacturing and product development.

In 2010 IU inaugurated the IU Center for Art and Design (IUCA+D) in Columbus. Also in 2010, in order to meet the strong desires of the community, IUPUC initiated the IUPUC ME Division with the commitment to fully staff and equip the division to be able to provide 100% of the degree requirements for the ABET accredited IUPUI Purdue BSME degree in Columbus. Also in 2010, the Columbus Education Coalition funded with grants from the Lilly Foundation built the Advanced Manufacturing Center of Excellence building (AMCE) on the IUPUC campus which also adjoins the Ivy Tech Community College Campus. In keeping with Columbus' architectural spirit the AMCE was designed by internationally acclaimed architect Cesar Pelli. The AMCE building was designed to house the IUPUC ME division, Purdue Polytechnic MET program, and Ivy Tech. Thus uniquely, 3 strong STEM programs from 3 institutions spanning the spectrum of engineering and technology are housed in the same facility. In the summer of 2016 IUPUC ME conceived the Imagineering Lab. At the same time Columbus IUCA+D received permission to begin a master's program in architecture beginning in the fall of 2018.

Though rapidly growing, IUPUC has only 160 ME students of which about half are in first year pre-engineering. IUPUC itself has about 2200 students and adding Ivy Tech and Purdue Polytechnic adds about 500 additional students to our combined community. IUPUC ME serves the south-central Indiana region so that most of our students commute to campus, some traveling over an hour or more. Virtually all 3rd and 4th year students attain valuable engineering related part time employment. IUPUC ME does not have a graduate program so that as our students become technologically advanced, they graduate, causing rapid turnover of our student knowledge base. What is right for us to become a sustainable center of innovation?

WHAT OUR NEIGHBORS ARE DOING

For the last several years we have been monitoring makers/creative design efforts, visiting facilities and meeting with faculty and staff (including attending ISAM 16 and touring MIT makers facilities). The SIL goal is to encourage creativity and to enable the designer to easily transform idea to design to end product which might be a mechanism, a structure, drawings, an animation, a video, or an interactive virtual reality space, or any combination. What most facilities have in common is a collection of CNC driven fabricators supported by basic machining. The fabrication side is driven by digital design. For design there seems to be two approaches, artistic

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design and engineering design. And while these should be synergistic, most facilities tend to be based on one or the other culturally segregating art and craft from engineering and technology.

Indiana University-Purdue University Indianapolis (IUPUI) Herron School of Art, for example, has it's "Think It Make It Lab". On the design side they have Wacom tablets and 3D scanners and utilize mainly Zbrush, Sculptriss, SketchUp Pro, Photoshop, Rhino, and Corel for software. For fabrication they have mostly 2D CNC fabricators such as a plotter printer, laser engraver, plasma cutter, vinyl cutter. 3D fabricators are a CNC router and plastic 3D printers. Their product tends to be non-structural, non-kinematic assemblies of planar parts and 3D printed individual plastic objects. Occasionally there is some project based overlap with the technical world such as using 3D printing to model dental implants.

Elsewhere at IUPUI the Purdue School of Engineering and Technology supports 3D design and modeling, analysis and simulation. On the output side they have CNC and manual machining capability, and 3D plastic printing. The IUPUI BSME curriculum has a strong course sequence in design and several courses require students to do design related projects. On the technology side, they offer a B.S. in "Computer Graphics Technology" (CGT) that promises to "prepare students for careers with titles including graphic designer, digital animator, technical illustrator, multimedia developer, web developer, and computer game developer" [3].

Also, as we have observed and discovered from our own experience, the design, analysis, simulation, instrumentation, data acquisition, actualization, and controls aspect of an engineering program are beyond the capabilities of traditional institutional IT organizations such as IU's Information Technology Services (UITS) that administers all IU computers and networks for all IU administered campuses including IUPUI and IUPUC. To overcome this difficulty the ME department of Purdue School of Engineering originally received grant money to establish a dedicated engineering server providing engineering students 24/7 remote access to engineering related software which was originally called CNC 24/7. This has morphed into a permanent separate organization that occupies the entire basement of the IUPUI Engineering Technology Building, employs 6 staff members and has altered the CNC to mean "Computer Network Center". Its mission is "provide a full range of services to assist School of Engineering and Technology students, faculty, researchers and staff in their use of technology". It "works closely with University Information Services (UITS) to ensure local computer labs managed by UITS meet the school's needs"[3]. Among its services it lists 77 engineering/research software apps that it supports as well as Unix/Linux support for research needs, and maintains "Advanced Visualization Systems" including Haptic devices, a stereo wall, VR theater, 3D printing, 3D rendering cluster, and 3D scanning. The IUPUI CNC has provided consulting to IUPUC ME, however none of its resources are available to IUPUC.

IUCA+D in Columbus uses Rhino as its main design tool. They have sponsored Rhino workshops in the AMCE which were attended by some of our IUPUC ME students. One ME student used Rhino to win an IU design contest which resulted in her winning design being used to build a decorative archway for the IU homecoming. Now that IUCA+D is officially starting an architecture program we mutually look forwards to IUCA+D and IUPUC ME students working together on community design projects.

The Columbus chamber of commerce has been trying to encourage a community makers space to the extent that it formed an exploratory makers space committee of which the writer is a member. This committee toured regional makers spaces. The most interesting and successful nonacademic makers space that was toured is the LVL1 makerspace in Louisville Kentucky which describes itself as a democratically operated, open, friendly community of "tinkers, makers, engineers, educators, scientists, artists, hackers, and overall geeks"[3]. Focusing on digital design which is the gateway to fabrication, LVL1 eschews expensive commercial software for freeware. They support the use of OPENSCAD for making "functional 3D drawings for printing" and KiCAD for electrical schematics.

The Bartholomew County Library operates what it describes as a "Digital Media Lab" in its basement which it calls the Digital Underground. It offers PC and iMAC work stations, a WACOM board, 3D printer and scanner, and a green screen recording studio. It describes itself as providing tools to be used to express creativity in many different ways. "Record a song using our digital recording studio, create some album art using Adobe Photoshop or Illustrator, and finish up by recording a music video using the green screen. The sky is the limit as far as what you can do with the space and tools provided." [3] Also in Columbus there are some facilities providing workshops etc. that are dedicated to particular skills such as bicycle technology and wood working.

The take-home message from our observations is that a creative 3D design facility such as our Spatial Innovation Lab requires dynamic IT organization beyond the scope of IUPUC UITS. Also it appears that IUPUI has a long list of resources but that they are siloed and dedicated to labs, research, and projects and not very available to undergraduate student's creative expression. Also it appears at IU and IUPUI, 3D design facilities supporting art design and engineering design are as immiscible as ever.

SIL OBJECTIVE AND WORK FLOW

The objective of the SIL is to encourage creativity and innovation by providing a readily accessible facility with the best and most up-to-date software and hardware resources that enables the innovator to easily capture spatial design concepts in 2D or 3D digital images in as quick and intuitive a manner as possible, and then create the easiest methods for a digital work flow enabling the transformation of the captured design concepts to their appropriate level of specificity enabling the development of finished product such as reports, presentations, posters, videos, 3D detailed CAD drawings, engineering analysis, simulation, interactive virtual reality space, or CNC fabrication interfaces, or any combination as is appropriate to the project.

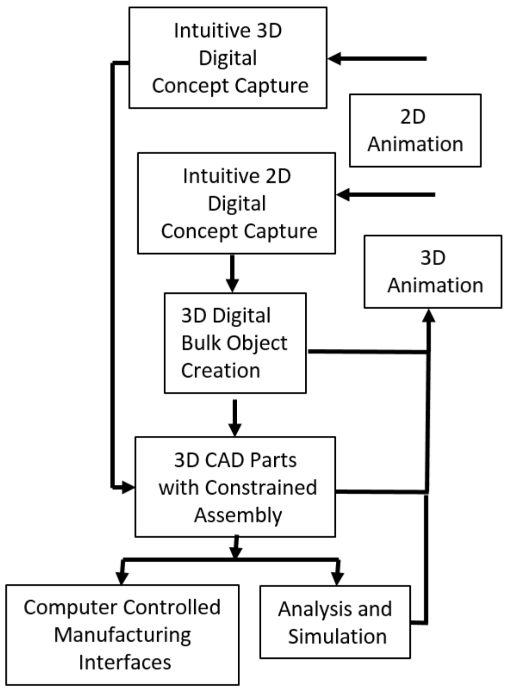

Fig.1 SIL Work Flow

Fig.1 shows the envisioned work flow. It's elements are:

A. DIGITAL 2D CONCEPT CAPTURE

Engineering design texts state that most design starts with a hand sketch [1]. Animators state that animation projects (2D or 3D) start with a scene drawing or painting that is used as the inspiration. A photograph is another means of 2D concept capture. To be used in a digital work flow, the 2D sketch must be converted to digital imagery. This can be done by scanning the sketch or painting and then using it (or the photo) as a template for 2D layered drawing or 3D drawing. New tools like the Wacom board can be used in conjunction with painting or layered 3D drawing software so that the most intuitive method of concept capture, drawing by hand, can be done digitally.

B. DIGITAL 3D CONCEPT CAPTURE

This is one of the most exciting recently emerging technologies being offered today. Use of tools such as the HTC Vive VR system with Google Tilt Brush allow the artist to "step into" the picture by being immersed in a 15' x 15' VR space and painting in 3D, something that has never been done before and opens many possibilities. Another intuitive and fundamental process of 3D Concept Capture is sculpting. Zbrush attempts to digitalize this fundamental intuitive process by allowing the artist to poke and prod a 3D digital piece of clay. The sculpting process is further computer enhanced by allowing the use of axis of symmetry, masks, and copying techniques as sculpting aids.

C. 3D DIGITAL BULK OBJECT CREATION

2D digital images must be converted to 3D objects. This can be accomplished by importing them into 3D drawing software such as SketchUp, Rhino or Creo and using the images as templates for creating 3D drawings. Zbrush is an example of 3D Digital Concept Capture by sculpting being directly converting it to a 3D digital bulk object as its output is a meshed 3D closed surfaces that can be imported into other software for further processing. 3D Drawing software such as SketchUp and Rhino have striven to make 3D drawing as intuitive as possible so that they can be used as Digital 3D Concept Capture tools with 3D Digital Bulk Objects being directly created. However, 3D VR painting, exciting as it may be, does not create closed surfaces so, as far as is known by the author, 2D snap shots or videos must be taken of the 3D painting and used as templates for 3D Digital Object Conversion in 3D drawing software.

D. 3D CAD PARTS WITH CONSTRAINED ASSEMBLY

In order to proceed further with analysis and fabrication the innovation must be broken into detailed parts and assemblies. This evokes the metaphysical question of what is an object. Intuitive 3D drawing software such as SketchUp allows quick 3D Concept Capture by allowing the innovator to easily create dimensional 3D bulk objects expressing the innovators concepts. These apps also facilitate the groupings of objects into sub-parts, the creation of libraries of sub-parts, and access to cloud based libraries of previously drawn sub-objects. However actual fabrication of the innovation requires division of the concept down to detailed drawings of its most elemental objects commonly called in the vernacular "parts". A part can be easily defined as the objects that must be individually fabricated or purchased to be assembled to physically create the functional innovation. Further, while animation can be created from less detailed 2D and 3D digital concept captures, analysis and simulation require that the innovation be assembled with constrained degrees of freedom.

E. 2D ANIMATION

Animation in general is the presentation of a stream of images at a fixed rate of time described as either "frames per second" (fps) or Herz (Hz). When slightly altered images are presented at rates > ≈5Hz the brain perceives motion rather than individual images. Common frame rates are 24, 30.25, 50, and 300 fps.[2] 2D Animation can occur anytime after Digital 2D Concept Capture or Digital 3D Concept Capture although it is greatly simplified if it is done with 3D Digital Bulk Object Creation where 2D images can be generated by slightly moving the spatial orientation of the 3D bulk objects or slightly changing the "camera orientation" or "lighting". 3D Drawing software usually offers animation assistance tools. For example, SketchUp offers a free tool called FlightPath2 that creates scenes at a specific rate along a specified path.

F. 3D ANIMATION

3D animation in the art world often refers to what in this paper has been described as 2D animation generated from the manipulation of 3D bulk objects and perspectives. It is argued in this paper that this is really computer assisted 2D animation commonly called Computer-Generated Imagery or CGI as the end result is a stream of 2D images. The emergence of VR technology can be used to create “real” 3D animation where the presentation invokes both eyes slightly differently triggering the brain’s interpretation of parallax imagery to infer depth perception.

G. ANALYSIS AND SIMULATION

Analysis and simulation differ from animation in one very important and fundamental regard, the time based response of the innovation to applied loadings must follow the laws of physics. As such the constraints and degrees of freedom of the assembled parts must be defined as is done with 3D CAD models. In addition other information about the objects such as material properties etc. must also be known. It is worth commenting that many video games are in fact simulations and the reactions of the digital objects are controlled by algorithms that model physical law response of the objects to user of game player loading inputs. It could be said that many video games are event driven simulations

H. COMPUTER CONTROLLED MANUFACTURING INTERERFACES

The effects of computer controlled manufacturing is omnipresent in modern society revolutionizing not only industrial scale fabrication but in small business and craft and hobby projects. Laser engraving, laser cutting, waterjet, CNC stamping, 3D printing and other additive manufacturing, vinly cutting and even sewing machine stitchery.

MANAGEMENT PROCESS ELEMENTS

A. CONSTANT EXPERIMENTATION

The present Spatial Innovation Lab (SIL) looks generationally different than it would have had been if assembled 5 years ago. Thus, we embrace as our motto that “Creation is a work a work in progress.”. To this end we understand that our true objective is to implement a process rather than a temporal collection of equipment and software. And just as the physical lab will continuously evolve and undergo change so must our management process – starting with initial concepts and changing as required.

B. ORGANIC LEARNING

The SIL is not only a community resource it is itself an ongoing exploration of the best technology - showcasing it, but most importantly making it usable to the community. Thus, all of our procedures both administrative and investigative must reflect the concept of organic learning, that is, whatever is learned by individual members of the transient assemblage we call our community, is documented, transmitted, and taught, so knowledge and know-how is retained within the community for as long as it is relevant.

C. STAFFING AND STRUCTURING A SUSTAINABLE ORGANIZATION

From ISAM 2016 it was learned that many of the leading academic makerspaces are student run. While this seems ultimately desirable, with our small size and non-traditional student body, it appears necessary to us to establish a sustainable team to form a combination of part time paid students and industry specialists along with management roles filled by unpaid student SIL community members.

D. ESTABLISH METRICS

Any long term, large scale project should establish for itself measurable metrics to mark its progress.

E. SUSTAINABLE FUNDING

The seed money to establish the SIL has come from remaining money for the CASEL lab. However, at some point additional funding will be required to sustain the SIL. Fortunately, the Columbus community is very interested in STEM education and innovation promotion. We intend to use the SIL capabilities to complete projects such as our architecting the “Creator’s Atrium” to establish community and corporate interest.

INITIAL ORGANIZATION

A. PAID POSITIONS

Faculty Director -The faculty director oversees and directs the staffing and procedure development for the Imagineering Lab. This volunteer unpaid position is unfortunately being performed by the writer as we seek to implement the Imagineering Lab in a sustainable manner. If successful in creating a sustainable organization it can be transferred to other faculty members.

ME-IT Administrator and Assistant – It is apparent that IUPUC ME has to establish an IT organization similar to IUPUI’s CNC lab previously discussed. To this end we have established an ME remote server so that our community can use our engineering software anytime from anywhere that they have internet access. However, in addition to this ME oversight of nearly 60 computers, and computer interfaced devices, all requiring a long list of software, drivers, toolkits etc. is necessary for a stable environment that allows “on-the-fly” project management. Thus we have hired 2 students part time, a senior ME-IT Administrator and a underclass assistant to replace the administrator on graduation.

ME Lab Administrator and Assistant - The Me Lab Administrator helps to establish and enforce procedures concerning use, maintenance, and storage of equipment, policies regarding “checking out” Imagineering Lab equipment for project use, and policies for environment and safety. We have also hired a successor candidate assistant.

Industry Applied Technology Experts (IATE’s) - A prime asset available to us is that the Columbus area has many “world class” technical experts working in the area. We employ some of them on an hourly basis to advise and assist us in our projects. Examples would be the head drafting coach of Cummins assisting our students in CREO. For the SIL we will be looking for IATE’s in architecture, art, design, animation and CNC.

B. UNPAID COMMUNITY ROLES

Explorers - The only way to learn software apps is by immersion by using the app to do projects. The learning curve can be greatly accelerated by tutorials, online and offline courses, and user’s guides. This is the role of the explorer. Once software is identified for trial, someone has to gain knowledge by immersion and use. The role of the explorer is to provide a knowledgeable assessment of the usefulness software and devices to the SIL work flow and to provide training aids for others.

Bridge Builders - Key to the digital work flow is bridge building. As outlined, the SIL work flow takes the output of applications and devises and translates them into inputs for other applications and devices further down the workflow. Identifying procedures to do this is what we call bridge building,

Mentors - As the name implies mentors are SIL members that have acquired mastery of specific tasks in the SIL work flow and are willing to assist other SIL members.

Interest Group Coordinators - It is hoped that interest groups will naturally arise such as ‘animation for video’s or “movie making” or interest groups centered craft projects or interest groups on taking innovations into production or interest groups in VR game production, etc. It is hoped that these interest groups will play a key role in explorations and mentoring as well identifying new applications, upgrades and devices for SIL acquisition.

CURRENT SOFTWARE AND DEVICES

Table 1 Current List of Main Supported SIL Suite Apps and Devices

WACOM drawing board	Intuitive stylus drawing and painting. Used by Herron School of Art School.
Fuel3D 3D Scanner	Referred by Herron. Fuel 3D Professional software is now free and we are evaluating.
HTC Vive	Provides up to 15’ x 15’ room scale fully immersive virtual reality platform.
Adobe Creative Cloud	Is supported at no cost from IUware. 2D layered drawing, video capture, edit, photo edit.
Tilt Brush	3D painting in immersive VR environment.
Zbrush 4R8	3D intuitive sculpting. 3D meshed surfaces.
SketchUpPro	Intuitive quick, dimensional 3D modeling.
Rhino 5	3D modeling including 3-D capture of point clouds.
Creo 4.0	Full 3D parametric CAD, including parts. Assemblies, linkages, degrees of freedom, simulation etc..
Ansys	Stress and thermal fluid flow analysis.
3D printing postprocessing	Maintained by Purdue Polytechnic.
CAM	Maintained by IUPUI and Purdue Polytechnic

METRICS

The SIL, started last summer has had little chance to accumulate metric measures. But as anyone who has undergone large scale project management know, it is important to identify metrics at the start of the project so as to gage progress.

Table 2 Metrics

Participants	Numbers in the SIL Community.
Task achievement	1) Number of software apps and devises explored. 2) Number of mentors by subject. 3) Number of bridges built.
Diversity	Diversity in this context means diversity in background such as ME students, architects, artists, craft people, liberal arts and humanities.
ME-IT policies	Establishment of routines and policies that allow “on-the-fly” software addition while enforcing good IT management policy.
General Management policies	Facility access, qualification tracking, safety and environment, hiring and staffing, marketing, budget and purchasing.
Funding	Grants, project contributions
Dream Station Utilization	Replication of devices, hours used.

Table 3 Activitiy Markers by Academic Year

Activity	Year 15/16	16/17	17/18
ME-IT Student Coordinators	0	0	2
Supported Software Apps	8	11	21
Explorers/Bridge Builders	1	3	7
Student Mentors	0	2	4
Active Users (Outside Classes)	0	7	18
Interest Groups	0	1	3
Projects Completed	8	11	21

CONCLUSION

Acquiring and installing an initial collection of software and devises to comprise a prototype dream station and Spatial Innovation Lab was easy compared to the design and implementation of management processes leading to a sustainable community resource. This paper represents a road map for this effort which it is hoped is useful to other small organizations thinking of attempting a Spatial Innovation Lab. In keeping with our motto “Creation is a work in progress.” we expect continuous alterations to this plan.

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[3] All quotations are from organization websites last accessed between 8/1/2017 to 8/14/2017.