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The Geometric Growth of M&S Education: Pushing Forward, Pushing Outward

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Abstract

M&S education is experiencing a geometric growth that is placing it front and center as a discipline and as an interdisciplinary tool. This article discusses the evolution of the discipline of M&S. It answers: Why has M&S education experienced a forward and outward growth? What is it that makes this discipline unique? What is the current state of M&S education?

Introduction

Much has transpired in the last few years with regard to M&S education. Peruse the catalogs of universities across the country and/or institutions abroad that are home to engineering departments and you will note courses, certificates, and full curriculums are now available for students desiring to study the discipline. The technology associated with M&S—*simulation and visualization*—is now being engaged well beyond the military domain for which it served so well for so long. As such, the discipline and technology of M&S are experiencing a growth that few if any curriculums can claim. We describe it as a *geometric growth* that is pushing M&S education forward and outward.

This article discusses the evolution of the discipline of M&S: its uniqueness; its inherent aspects, and its current place as a critical technology. **Part 1** discusses the forward and outward advancement of M&S education – something unique to most academic

programs. **Part 2** explains why M&S is experiencing this geometric growth – we proffer it is a result of four inherent aspects of the discipline. **Part 3** relates the current state of M&S education, research, and development and the need for a heightened awareness of this critical technology.

Part 1: A Push Forward, A Push Outward

M&S education has experienced a **push forward** by way of the **formal recognition** it now receives in several colleges and universities across the country. Today, numerous M&S degree programs, certificates, and courses exist preparing students through training and research to become **expert developers** of this capability. All of this took place in just over two decades starting with discussions in the mid 1990s on the feasibility of course development in M&S.

For instance, in 1996 a group of academics from institutions that offered simulation courses along with representatives from non-educational organizations with vested interests in simulation education convened at the Winter Simulation Conference to share needs and concerns regarding acceptable expertise and skill-sets for M&S professionals. This group was asked to consider: "What skills do simulation professionals need?" and "Are separate simulation programs needed?" At that time there were serious reservations about the size and credibility of the M&S body of knowledge.

As such, the teaching and training available at that time was called into question. In 1996 M&S courses were drawn from “. . . existing programs in computer science, operations research, and engineering” [2]. Fast forward a decade and the new question raised centered on how to push forward an agenda for full recognition of M&S as an independent discipline [3]. In a roundtable discussion at the 2006 Spring Simulation Interoperability Workshop another group of well-established M&S academicians met to discuss M&S teaching and training. They focused on endorsing the attributes of M&S that earned it “discipline” status in that M&S possesses: 1) its own body of knowledge, 2) theory, and 3) research methodology.

As mentioned at the outset, many institutions have various M&S offerings. Old Dominion University now offers the full range of study from an undergraduate degree to Ph.D. in M&S. Other schools like Arizona State have established on-line master of engineering programs [4]. Georgia Tech offers a Certificate in Modeling and Computer Simulation (MaCS) [5]. The University of Central Florida has coupled its M&S curriculum with the field of Augmented Cognition (AugCog) as a way of developing the potential of “. . . intelligent computational systems that are capable of monitoring and adapting the systems to the changing cognitive state of human operators . . . [6].”

These few examples represent the types of M&S training taking place at institutions of higher learning. It is not the intent of this paper to cite all the programs and where they are being offered; however we can confidently say that students interested in M&S education are now presented with a variety of opportunities that were non-existent just a few short years ago. And it is with the establishment of these curriculums that we observe that forward movement of M&S education.

M&S education has also **pushed outward** as a result of **application diversity**. As a critical technology, M&S is a valuable tool for solving problems, aiding decision-making, and providing services in domains that require human behavior and human modeling and analysis. As such, inter-disciplinary programs

ranging from certificates to concentration areas are in place teaching non-engineering students how to become **expert users** of M&S for data or simulation output analysis, for training, or for treatment (as is the case in the medical and health science applications of M&S). One application area receiving much attention is the medical and health sciences.

M&S is providing practitioners in these fields the capability to better understand some of the fundamental aspects of healthcare such as human behavior, human systems, medical treatment, and disease proliferation. And, as M&S educators we are compelled to press forward with enhancing modeling capability to best represent the human factors and the human system. This can only be accomplished from a multi-disciplinary approach. And that methodology is being engaged at medical centers across the US [7].¹

For medical professionals serving as educators, medical M&S has become what Richard Satava calls *a training environment with permission to fail* where students are being taught by errors. This is because simulation facilitates the reproduction of experimental, clinical, or educational data. Couple the acknowledged shortage of healthcare providers with an aging population and the demand for treatment and services increases exponentially. Medical M&S is key to meeting those demands and many medical institutions are now requiring that simulation be part of student training. When finished, these students become expert users.

As M&S is engaged across the disciplines it is easy to observe an outward growth of M&S education via application diversity: *professionals among numerous*

¹These centers are primarily focused on research and development from the user perspective. AIMS or Advanced Initiatives in Medical Simulation is a coalition of professionals and organizations intent on promoting medical simulation to improve patient safety, reduce medical errors, train, and reduce healthcare costs. CIMIT or Center for Integration of Medicine and Innovative Technology aims to initiate and accelerate translational medical research in the domain of devices, procedures, and clinical systems engineering. Harvard's Center for Medical Simulation provides simulation training for healthcare providers through high-fidelity scenarios.

disciplines are being honed as expert users of M&S. But, what is it about the discipline of M&S that result in this geometric growth? We contend that it is the four unique aspects of the discipline.

Part 2: Four Aspects of M&S Education

We realize there will be those who argue that the four aspects we proffer are not unique to M&S – and we agree because individually, some of these aspects are found in other disciplines. What we do contend is that the uniqueness stems from the fact that all four of these aspects run concurrently and are integral to the discipline of M&S.

Aspect 1 - A Union of Discipline and Technology

M&S academicians are well aware of this; however, those outside of academe may not fully appreciate that the discipline and the technology of M&S are inseparable. And as educators we should not separate the discipline of M&S from the technology as both co-exist and are co-dependent.

Aspect 2 - Cyclical Advancement of Technology

Consider how the discipline itself and the tools of the discipline are *growing at a faster pace* than did its predecessor, computer science. This is due to the *cyclical advancement* of M&S. One simply needs to observe the relationship between *advances in the technology M&S uses* and *how M&S serves to advance technology*.

Aspect 3 - Fundamentally Multi-disciplinary

M&S also *encompasses an integrated face* by incorporating various techniques and paradigms. These techniques and paradigms are then engaged across the disciplines making M&S truly multi-disciplinary. M&S facilitates *a broader base*. M&S as a training tool can be found in user domains across the workforce (professional and non-professional) and in all learning environments.

Aspect 4 - It Takes Two: Developer and User

Student academic training begins with an understanding the core discipline of M&S. Typically, this is an engineering or computer science student. The formal training in the discipline provides the student with a learned expertise that allows him to become a modeler or **developer**. The efforts this student puts forth often result in a conception or conceptual model, or perhaps an invention or tool. That model or tool is then placed in the hands of another student, the **user**. The student who engages M&S as a user must be trained on how to use the tools and/or how to use the tool to provide a service. The user can apply the tool to further his research or, as in the case of medical and health sciences, to provide treatment (service).

Part 3: The Current State of M&S Education

For the most part, M&S education has experienced a top-down approach in its development: M&S research centers were set-up before academic programs were sanctioned, graduate curriculums were established prior to undergraduate studies. Perhaps because of this unorthodox genesis, M&S has had to prove to be a flexible and enduring discipline. Its success is evident - the discipline of M&S is now experiencing a full spectrum of academic programs from undergraduate to graduate with research agendas that span traditional M&S studies of ontology and standards to human behavioral analysis. This development, which we call the *rounding-out of the discipline* occurred in a relatively short period of time and it was a necessary accomplishment.²

Broadly speaking the rounding-out adds to the credibility of M&S as a discipline and it facilitates an expansive body of expertise on the application (user) side. A significant benefit of the rounding-out has been the ability to extend the M&S education continuum into the public school systems with an invitation to high school students who are contemplating a degree in M&S. These new undergraduate programs have

²For example, Old Dominion University introduced its masters program in 1998, the Ph.D. program in 2000, and the baccalaureate program in 2010.

in-turn, stirred things in the public school systems – there are now M&S programs for designed for high school students.

Case in point, *A Model Curriculum for High Schools 2009* developed by a core group of educators with high school, community college, and university levels of expertise [8]. This particular curriculum is designed to develop the student's understanding of the systems, processes, tools, and implications of M&S. Some of the courses include geo-spatial technologies (i.e. GPS, GIS, remote sensing), gaming, medical and scientific imaging, animation, engineering drawing, transportation, distribution, warehousing, and architectural drawing. With forays into high school curriculums, the discipline of M&S continues to garner attention. And as a tool – M&S is on the minds of politicians and stakeholders across the country. So much so, that the task of developing a national strategy for M&S has been placed before a body of experts from government, industry and academia.

The Call for a National Strategy

Called together by the Congressional M&S Caucus (headed by Virginia Representative Randy Forbes), a group of M&S stakeholders was asked to develop a National Plan for M&S. What they are asked to do is determine how the government can fully exploit, fully engage, and continue to develop M&S capability at the national level?

That this discussion, at this level, is taking place speaks volumes for the discipline of M&S. The last time a formal discussion with a tangible outcome took place regarding a critical technology was in 1958 with the establishment of NASA. The nation at that time was engaged in a scientific and military competition against the Soviets. The national focus was on technical capability and product output and one significant result was that it placed the US on an innovative high. Fast forward to 2010 and ask, Can M&S play as significant a role today as did the aeronautics technology of the 1960s? Those of us who have been a part of M&S history answer, yes. Here's why:

From a global perspective M&S can be vital to concerns like homeland security strategies and foreign policy decision-making.

The US needs this technology to ensure remaining at parity with countries that are achieving technological dominance. From a domestic perspective the US homeland faces challenges in a number of domains.

Government and industry must provide solutions and take proactive measures in healthcare, transportation (to include infrastructure), and energy alternatives—these challenges must be examined and M&S is the only technology that can model, test (with repeated re-testing if needed), analyze, and proffer solutions to these and other decision-making challenges.

So it is good that this discussion of developing national strategy for M&S is taking place. It places M&S front and center, and it furthers the forward and outward advancement of M&S education.

Conclusion

This discussion introduces a number of terms to represent what we observe taking place in M&S education. That *geometric growth* – forward and outward – is remarkable. Few, if any, disciplines play such a substantial role in the R&D of other analyses. We also proffer that the four aspects that make M&S unique are in-place simultaneously: the union of discipline and technology, the cyclical advancement of the technology, the multidisciplinary capability, and the presence of developers and users.

We contend that the discipline had a top-down growth experience with graduate programs underway years prior to undergraduate curriculums. Today, the academic programs have been *rounded-out* with a full spectrum of studies now available. Application diversity and capability have placed the critical technology of M&S on the agendas of politicians and prominent stakeholders resulting in the call for a national strategy. These are quite the accomplishments for any discipline, but this is not any discipline. This is M&S, and it is experiencing a geometric growth that for the time-being sees no end.

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