On the Future of Higher Education: Darwinian and non-Darwinian Advances in Curriculum, Didactics, Technology, and Management

Alexandru Iosup
Massivizing Computer Systems group, Department of Computer Science, Faculty of Sciences, Vrije Universiteit Amsterdam
De Boelelaan 1081, 1081HV Amsterdam, the Netherlands. Email: A.Iosup@vu.nl Web: http://atlarge.science

***Abstract*—Higher education is at a crossroads in the 21st century. Around the world, the student body is massivizing and diversifying, the industry is requiring more complex skills especially in parallel and distributed systems (PDS), the educators feel overwhelmed and under-recognized, etc. The question "How to address the challenges of modern higher education, in particular, in PDS?" arises naturally, and is the focus of this talk. We posit that we must first focus on the typically implicit process of giving an answer, of which we distinguish two kinds: Darwinian processes based on incremental evolution, and non-Darwinian processes that focus on paradigmatic shifts. Starting from PDS needs, we contrast Darwinian and non-Darwinian answers in four dimensions, and give examples of non-Darwinian advances that we see as both desirable and foreseeable, in (1) curriculum; (2) didactics; (3) technology; and (4) management. We make predictions about higher education over the next decade, based on our personal experience and also on lessons drawn from recent studies in the Netherlands.**

1. Introduction

Higher education in computer science, and especially in the diverse and complex fields of parallel and distributed systems, requires rethinking in the 21st century. In ICT alone, the human-resource gap in Europe exceeds 200,000 this year and will approach 1,000,000 by 2020; a similar gap seems to exist in the US. Massivizing and diversifying this type of education is raising important challenges, such as understanding and supporting the differences in skill, culture, and goals of a new generation of students, stretching the physical and managerial limits of traditional (brick-and-mortar) institutions, and simply the increasing complexity and interdisciplinarity of the domain—parallel and distributed systems (PDS) raise significant old and new challenges, e.g., PDS science and engineering, and related to emerging ecosystems [1], respectively.

Answering the question of *"How to address the challenges of modern higher education [for parallel and distributed systems]?"* is the new Grand Challenge in education, horizon 2035, and the topic of this keynote.

2. Darwinian and Non-Darwinian Advances

Giving an answer begins with understanding the process of answering. Plenty of advances in curriculum, didactics, technology, and management have been proposed over the past two decades, aiming to address the central question of this keynote. Which of these advances should we consider? Following terminology from Arthur [2, Kindle Loc. 1874-1875], we distinguish two main extreme types of advances: (i) *Darwinian*, that is, new concepts and techniques arise from small, step-by-step variation, followed by fitness-based selection, (ii) *non-Darwinian*, that is, advances are the result of combining inter-disciplinary elements and of taking paradigmatic decisions; and their survival may be ensured by group and political decisions, instead of merely by their actual fitness.

We contrast in this talk Darwinian and non-Darwinian advances in curriculum, didactics, technology, and management that could address the question. We also make predictions regarding these advances. (Table 1 summarizes the key concepts covered in this keynote.)

TABLE 1. SUMMARY OF DARWINIAN AND NON-DARWINIAN ADVANCES IN PARALLEL AND DISTRIBUTED SYSTEMS EDUCATION.

Darwinian change	non-Darwinian change
Curriculum	
Content development by small groups	ACM/IEEE Curriculum updates
One BSc course on Comp. Organization	Systems Thinking
One MSc course on Distrib. Sys.	Design Thinking
Didactics	
Flipped classroom	Gamification
Socratic discussion	Young-researcher programmes
Local hackathons	Bootcamps, Global competitions
Technology	
Digitization	Big Data
Informatization	Cloud computing
Automation	Virtual laboratories
Management	
Factory-like (e.g., efficiency measures)	Incentives for educators
Industry-/Academia-only panels	Discussion with all stakeholders

3. Examples of Advances

We discuss examples of advances in curriculum, didactics, technology, and management, in turn:

(1) For *curriculum advances*, we contrast content development done by small groups and individuals, with the multi-ennial updates in the ACM/IEEE Curriculum, and we propose increased focus on systems and design thinking;

(2) For *advances in didactics*, we compare Darwinian advances such as flipped classrooms, Socratic discussions, and local hackathons, with gamification [3], honors-track programmes for young researchers, and bootcamps and global competitions, which we see as fitting to the complexity of the PDS topics;

(3) For *technology advances*, we contrast digitization, informatization, and automation, with the education capabilities enabled by big data, cloud computing, and virtual laboratories, all examples of the modern PDS ecosystems [1];

(4) For *management*, we contrast processes inspired from the 1990s factory-management (e.g., efficiency measures, and other bureaucratic and accountability approaches) and committees comprised of industry-/academic-members, with giving positive incentives (and tools) to educators and involving all stakeholders in the discussion.

4. Conclusion

The 21st century higher education must answer new and deep challenges, in particular for parallel and distributed systems. In this talk, focusing on PDS education, we have proposed that it is useful to understand the fundamental differences in the processes leading to Darwinian and non-Darwinian advances. Although it is too early to predict Which of these approaches will succeed, we believe it is likely that both Darwinian and non-Darwinian advances will emerge, with different impact and trade-offs.

Author Bio

Alexandru Iosup is a computer scientist and an educator. He is currently Tenured Full Professor and University Research Chair at the Vrije Universiteit Amsterdam, the Netherlands, where he leads the Massivizing Computer Systems group. He is also Associate Professor with the Distributed Systems group at TU Delft, the Netherlands, where he received his Ph.D. in 2009. His work has received numerous awards, including the Netherlands ICT-Researcher of the Year (2016), Netherlands Teacher of the Year (2015), and several SPEC SPECtacular community-awards (last in 2017). He is a member of the Young Academy of the Royal Academy of Arts and Sciences of the Netherlands. He is elected Chair of the SPEC Research Cloud Group. In his spare time, he contributes to training legal refugees in the Netherlands. His work is funded by a combination of personal grants (mid-career Vidi 2016 and early career Veni 2011), industry gifts and collaborations (e.g., Solvinity, Oracle, Intel), and EU and national projects. You can contact Alexandru by email (A.Iosup@vu.nl), visiting (check http://atlarge.science), or via Twitter (@AIosup).

Evolution of this Material

This talk uses and extends material from: (1) the analysis of content developed for young researchers in the honors-track programme at TU Delft (2010–ongoing); (2) the "Gamification Works!" TED-like talk in the Teacher of the Year of the Netherlands competition[1], and the "Gamification Works! How I Learned to Stop Worrying and Love Teaching" talk[2] given at the Netherlands all-university VSNU Education Festival (2016), and at various universities in the Netherlands and in the world (2013–2017); (3) the "Higher Education and Big Data: Vision, Ongoing Research, and Pragmatic Perspectives" talk[3] given at the NWO/MinOCW meeting on Higher Education and Big Data; (4) the "The teacher is the Future: Iosup's Hierarchy of Needs for Higher Education Teachers" talk[4] given at MinOCW (2015), VSNU (2017), and at various universities in the Netherlands (2014–2017).

Acknowledgments

The authors would like to thank the education directors and other factors responsible for allowing the development and use of a gamification-based education approach at TU Delft (2009–2016) and at Vrije Universiteit (2017–ongoing).

References

[1] A. Iosup, A. Uta, L. Versluis, G. Andreadis, E. V. Eyk, T. Hegeman, S. Talluri, V. van Beek, and L. Toader, "Massivizing computer systems: a vision to understand, design, and engineer computer ecosystems through and beyond modern distributed systems," *CoRR*, vol. abs/1802.05465, 2018. [Online]. Available: http://arxiv.org/abs/1802.05465

[2] W. B. Arthur, *The Nature of Technology*. Free Press, 2009, kindle Edition.

[3] A. Iosup and D. H. J. Epema, "An experience report on using gamification in technical higher education," in *SIGCSE*, 2014, pp. 27–32.

1. Docent van het jaar verkiezing 2014/2015: Ted Talk Alexandru Iosup, https://www.youtube.com/watch?v=lmsKMLA5dHE

2. https://atlarge-research.com/Presentations/2017/2017-02-03_GamificationWorks17tue.pdf

3. https://atlarge-research.com/Presentations/2017/2017-10-25_A-Iosup_HigherEducation+BigData.pdf

4. https://atlarge-research.com/Presentations/2017/2017-08-24_ChallengesEduNL17VSNU.pdf