Prospectus

Constructing an FPGA Module to Pair with a TI-RSLK MAX Robot and MSP432 for Educational Use

(Technical Topic)

Examining the Adoption of FPGAs through Computing Technology Diffusion

(STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The FPGA (Field Programmable Gate Array) is currently a somewhat niche computer processing hardware overshadowed by technologies such as the CPU (Central Processing Unit) and ASIC (Application Specific Integrated Circuit). CPUs, known as the "brains" of most personal computers and laptops, provide a high amount of flexibility and range in the computations and instructions they can execute. However, they are not optimized for particular tasks and can use a lot of power. On the other end of the spectrum, ASICs are integrated circuits designed to process a specific computation on the hardware level. This means that they are extremely optimized for a given operation, and consume less power, but provide no flexibility or breadth with respect to the kinds of processing they can do. FPGAs occupy a middle space between these technologies by giving high optimization for given computations with the flexibility to adapt to different requirements. FPGAs are similar to ASICs in that they are set up to do certain tasks, but different in that while ASICs are manufactured in a set way, FPGAs are large collections of logic blocks that the user connects to create a hardware processing system. In short, with FPGAs, the user can program both the software program and the hardware system that the software will run on. This allows for hardware adjustments (or entirely new architectures) to be made on the fly in response to performance feedback or specification changes.

While FPGAs outperform other solutions in acceleration applications in many metrics such as latency, flexibility, and parallelism, other significant factors dissuade computing companies from choosing FPGAs as their default accelerator. The aim of the STS research is to examine the diffusion of FPGAs through a lens mindful of the characteristics and trends that have driven other computing technologies to success. The aim of the technical research is to provide a solution to a commonly cited issue with FPGAs—they are difficult to learn—by delivering a module designed to help UVA ECE students learn about FPGAs. This research can provide insight into how computing technologies are diffused and adopted, and how by extension engineers can better design these technologies to meet the continuously increasing data processing demands of the world.

Technical Topic

One barrier between FPGAs and a large share of the computing market is their steep learning curve, as evidenced by the vast array of literature discussing how to teach necessary skills to students and articles explicitly stating the learning curve as a drawback to using them (Bacon, 2013; Balid, 2013; Liu, 2015; Walters). FPGAs are difficult to begin using because of, among other things, the lack of standardization of terminology between different manufactures, the overwhelming variety of tools and files needed to build a project from scratch, and the various design choices, program errors, and debugging methods that are specific to FPGAs. The goal of this technical research would be to deliver a library or package to be used by UVA's Electrical and Computer Engineering department to foster FPGA knowledge and development skills in interested students. The ECE department purchased many TI-RSLK MAX robots driven by TI-MSP432 microcontrollers (essentially a very small embedded computer) to use in a new embedded programming course sequence—this technical research would specifically create this package for an FPGA to interface with the robot and the microcontroller (or instead of the microcontroller) to drive the robot. The rationale for designing a package for these robots rather than others is many students will already understand many fundamental embedded computing concepts within the contexts of these robots. Thus, adding an FPGA course or module would provide a platform for students to learn about and use FPGAs within a familiar context, ensuring that the focus is on FPGA-specific concepts rather than adjustment to the surrounding environment.

In pursuing this technical research, I will consult ECE professors involved with the new embedded course sequence such as Professor Dugan. I will use my existing knowledge of FPGA programming and design, and can also consult my current FPGA Design professor (Professor Stan) while creating this library. Further, there are many existing FPGA pedagogical sources to draw on for inspiration. One paper (Balid, 2013) contains many useful comparisons and justifications in choosing hardware and software for the course. While the paper is from 2013, and therefore references older technologies, the kinds of comparisons used to determine which hardware and software will help students learn the most will be extremely useful to me when making choices for which FPGA boards, peripherals, and software library I choose to use and write.

Another paper spends significantly more time discussing how the class organization and structure fits with the technical components and the existing knowledge students already have (Liu, 2015). This framework of basing design choices around what students already know is very important, and providing tangible examples of how to do this will significantly help my research. Again, this paper is comparatively old, so the specific hardware choices are likely not useful, but I should use the same considerations when evaluating options during this research.

STS Topic

As stated in the introduction, FPGAs provide many performance-based advantages over other computing hardware but have consistently failed to expand beyond prototyping and niche usages. There is a vacuum of literature that holistically evaluates why this is the case from a sociotechnical perspective. This is problematic, as limitations in the understanding of how computing technologies are diffused lead to limitations in the design of technologies attempting to meet computing demands—particularly those that may go beyond the performance abilities of established architectures. This STS research will attempt to tell the story of FPGA diffusion through the last two decades and evaluate predictions on how FPGAs will continue to evolve and be used in the future. This research will begin by presenting general principles and frameworks to use when examining the diffusion of innovation. Much of this information will come from a paper discussing different perspectives on diffusion of innovation (Abrahamson, 1991). I will then examine well-known and widely adopted computing technologies such as cloud computing, the USB drive, and GPUs (Graphics Processing Unit) to contextualize the diffusion of innovation principles within the computing space. The frameworks and concepts presented in Abrahamson's paper will be used to examine literature on these technologies to identify characteristics, trends, and other factors that are important for adoption.

Such literature includes an interview with the creator and lead developer of the USB drive (Johnson, 2019). This article provides good insight into what the developers of the technology felt was important to include in the design, as well as what specific characteristics they felt were successful. Finding literature that represents views leaning more towards a technologically uninformed consumer's viewpoint and a manufacturer's viewpoint would be excellent complements to this article. Sources that discuss the rise of cloud computing and its adoption will also be useful. One such source (Oredo, 2019) discusses how the various pressures exerted on companies to conform to popular technologies influenced the adoption of cloud computing in Kenya. Not only is this paradigm itself a potential framework to use, but the data and conclusions drawn will be important to contrast with other studies based in more developed areas of the world. More sources discussing the creation of cloud computing and its adoption in developed countries such as the United States should be found and used as complements to the information presented in Oredo's paper. Finally, literature documenting the rise of the GPU, not only in its original application to handle graphics but also in how its usage has evolved to compute parallel problems, would be good to analyze in the same way since the GPU is not only a computing technology, but is a competitor of FPGAs.

From the examination of the previous technologies, I expect to find specific characteristics, trends, or other factors related to successful diffusion and adoption in the computing space. I will then use these factors to tell and analyze the development and diffusion of FPGAs. One source (Mencer, 2020) gives good highlights of events to research when documenting the evolution of FPGAs. This article and many others (Bacon, 2013) highlight deficiencies that FPGAs have been unable to overcome at critical points in their history—it is likely that these deficiencies correspond to characteristics discovered in the first stage of my research that lead to successful adoption, so further research and comparison of these deficiencies will be critical. It is expected that one such characteristic is performance compared to direct competitors, so several papers ((Boutros, 2018), (Kuon, 2007)) examining performance comparisons between FPGAs, ASICs, and CPUs will be helpful in providing data points for this factor. As other characteristics are identified, it will be important to find literature detailing the relationship between FPGAs and those characteristics.

Finally, one source (Mencer, 2020) contains a collection of expert predictions on how FPGAs may evolve over the next decade. Making comparisons between the trends and factors found in the analyzation of other computing technologies and these predictions will provide interesting material for discussion about the future of FPGAs in this research.

Conclusion

FPGAs are an interesting option for hardware acceleration and computation. This STS research aims to tell the story of the creation and diffusion of FPGAs through a lens informed by STS theories and frameworks that identifies specific characteristics and factors that historically influence successful adoption in computing. The technical research aims to make learning how to work with FPGAs easier, which addresses one commonly cited barrier to their widespread adoption, and will deliver a library or package to be used in a new embedded programming course or module with UVA ECE's new robots. Through this combined research, a better understanding of why FPGAs have historically been poorly diffused and potential steps to increase their adoption will be presented and evaluated. This more holistic understanding becomes ever more important as the world rushes toward a future increasingly reliant on vast quantities of diverse computation that reaches the limits of the established architectures it currently uses.

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