Introducing Embedded Design Concepts to Freshmen and Sophomore Engineering Students with LEGO MINDSTORMS NXT

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**Abstract**

With the world around us becoming increasingly embedded, as scientists and educators, it is our obligation to create excitement about this field early in education. While embedded platforms are an attractive option for this purpose, most freshmen and sophomore engineering students are not equipped with the skills to learn and use the complex tools that are needed to program these platforms. What are necessary are simple, intuitive environments that enable freshmen and sophomore students to experiment with creativity and apply basic engineering concepts. One of the novel tools available is the LEGO Mindstorms NXT that was recently introduced. In this paper, we will examine in depth the architecture of the LEGO Mindstorms NXT and why it is a capable embedded platform and the graphical software that makes it simple and intuitive to program the LEGO Mindstorms NXT.

1. Introduction

Kids love toys and gadgets. This is attested by the fact that most kids are familiar with, if not own, a RC Car, an Xbox, PS3 or Wii gaming system, or an iPod. On the other hand, there is a quiet crisis in academia on the decline in engineering enrollment. One common feature of most toys and gadgets today is that they are embedded in nature. They include a processor(s) and in most cases are programmable. Hence, from pure deductive analysis, one of the effective ways to stem the quiet crisis is to teach concepts with these toys and gadgets that students use today. However, most of these embedded gadgets need complicated tool chains that are considerably difficult to use than a word processing package or a web browser which is some of the more common computer skills a freshmen or sophomore student is familiar with. Ideally, the platform that can be used to introduce engineering concepts will be something familiar to the student while offering a flexible and creative environment and does not need the student to be a rocket scientist to program it. One such platform that was recently introduced was the LEGO Mindstorms NXT robotics platform. In this paper, we will examine the internals of the LEGO Mindstorms NXT and more importantly focus on what makes the platform effective to teach engineering concepts, the graphical software that is used to program it. We will also examine how students can extend their experiments by using industry standard graphical programming software in this paper.

2. Under the Hood of the LEGO MINDSTORMS NXT

The block diagram of the LEGO Mindstorms NXT “brick” is shown in figure 1. At its core, the “brick” has a 32-bit Atmel ARM7 processor with 256 KB Flash, 64 KB RAM operating at 48 MHz. Even without its co-processor, which is an Atmel 8-bit AVR processor, the brick is a formidable embedded platform that can be used to build an assortment of applications.

![Figure 1. Block Diagram for the LEGO Mindstorms NXT Brick][1]

The key point to takeaway from this section is that in order to program such an embedded device by conventional techniques would require a challenging toolchain from a freshmen or sophomore perspective.
It is also worth noting that this “toy” as per LEGO is suitable for kids from ages 8 and up. While these two observations may seem conflicting till one considers a different approach to programming embedded systems that focus more on the concepts and less on bit-level operations.

3. The Software for the NXT Brick

As mentioned in the previous section, programming the NXT brick by 8 year olds and subsequently freshmen and sophomore engineering students needs a novel approach primarily because of the limited skill set of the students. The innovation in the LEGO MINDSTORMS NXT kit is the software that is used to program the brick. Figure 2 shows an example of a program that is written in this MINDSTORMS NXT software[2].

![Figure 2. The Software for the LEGO MINDSTORMS NXT](image)

There are several things of interest to educators – first, the program is completely graphical – this helps students focus more on the design rather than spend time on learning new tools and associated abstract syntaxes. Second, because the program is graphical, it lends itself naturally to parallel programming which is an inherently hard concept to teach with traditional tools. Third, the student can configure all the parameters associated with a block at the bottom of the screen without having to navigate through multiple functions and files and finally, the software exposes key embedded concepts such as memory and resource management, helping teach the key concepts in a fun environment. For example, the student may have to, depending on the size of the program, remove some other files that were taking up memory on the brick.

4. Extending Projects Beyond the MINDSTORMS NXT software

An intuitive software is important and critical to unleashing the creativity of the students. On the other hand, students should be able to extend this knowledge to other industry standard platforms and eventually be able to leverage the more powerful design environments. The LEGO MINDSTORMS NXT provides hooks for developers to create supporting software that can be used by more advanced developers. For example, National Instruments has created a toolkit that can be used to program the LEGO MINDSTORMS NXT and is available as a complimentary download from the company website[3].

5. Conclusion and Future Work

Platforms such as LEGO MINDSTORMS NXT are compact, cost-effective and simple packages that provides students with flexibility to design and develop embedded systems without having to worry about the complications of the toolchains that traditional embedded platforms have posed. Such a platform helps in encouraging creativity and enables students to absorb concepts effectively. In this paper, we looked under the hood of the LEGO MINDSTORMS NXT brick and at the innovative software approach that powers the brick. We also examined avenues that students can use to extend their ideas and projects beyond the LEGO MINDSTORMS NXT software and leverage industry standard tools. We believe one of the key elements in solving the quiet crisis will involve such intuitive platforms as the LEGO MINDSTORMS NXT.

6. References

