To Boldly Prototype What Everyone Has Prototyped Before: The Voyages and Perspectives of Prototyping Novices

Ali Askari

Institute of Media Informatics, Ulm University, ali.askari@uni-ulm.de

Evgeny Stemasov

Institute of Media Informatics, Ulm University, evgeny.stemasov@uni-ulm.de

Microcontroller chips are commonly used in everyday electronics. Household items as well as industrial machinery and even defensive technologies rely on these Very-large-scale integration integrated circuits (VLSI IC) computing units. For a long time, experts in the fields of electrical engineering, computer science, or similar domains were required to program such units and design the components around them. Even though projects like "Basic Stamp" tried to popularize microcontrollers like the PIC16, making them more accessible for novice users in the early 90s, and several educational kits attempted the same later, it is fair to state that the concept used by the Arduino Prototyping platform enabled a broader range of people with a more diverse professional background to use microcontroller technology for themselves. Artists, hobbyists, but also people from the aforementioned technical fields use the platform for their projects, due to its simplified software and hardware environment, as well as their low entry barrier. However, with advances in electronics and the creativity of groups and individuals, projects and extensions have become more complex, and therefore, the requirements towards the capabilities, as well as the usability of such prototyping platforms have increased. With this position paper, we want to give an insight into the challenges and obstacles novice users of the Arduino platform can encounter by analyzing data from a web-forum and interpreting it by comparing it to our own observations we made as instructors in the field of hardware prototyping, followed by suggestions to an initial set of promising directions for easing the entry level for novice users.

CCS CONCEPTS • Human-centered computing~Human computer interaction (HCI)

Additional Keywords and Phrases: Arduino, Microcontroller, Rapid-Prototyping, PushShift, Fabrication

ACM Reference Format:
Ali Askari and Evgeny Stemasov. 2023. To Boldy Prototype What Everyone Has Prototyped Before: The Voyages and Perspectives of Prototyping Novices. In CHI2023 Workshop [WS2] - Beyond Prototyping Boards: Future Paradigms for Electronics Toolkits, CHI '23, April 23-28, 2023, Hamburg, Germany. ACM, New York, NY, USA, 4 pages.

1 INTRODUCTION

In the beginning, the Arduino Prototyping platform was designed to target a non-technical or non-expert user group, such as artists and schools, by increasing usability through lowering the complexity of the overall configuration process [4]. This increase in usability however also attracted technical users to the platform, as the typically required hardware

arrangements for working with such controllers, as well as software configurations for the transmission of the firmware have already been made available. This lets the user focus on the **actual challenges** of the project instead of dealing with the challenges of the prototyping environment, which makes it more attractive for the technical users. It also enables the use for non-technical users in the first place and is therefore accessible to a broader audience [12].

While such simplifications to increase usability always also introduce limitations, most use cases could be covered by the platform and the associated ATMEGA microcontrollers. Through developments over time and community efforts, a variety of boards cover the needs of diverse user groups and their requirements. Requirements have increased as the platform is nowadays used in multiple areas of application, for example education, agriculture, healthcare, home automation, and others [7]. The aspect that the access of the average population to such technologies is a welcome development becomes visible in projects that, for example, aim at enabling low-cost lab equipment and, therefore, access to education [3] or aim to support the medical field during times of global crisis [9]. The fact that the community of makers is not purely restricting itself in this developments on Arduino boards becomes apparent through the success of similar boards, most clearly through the popularity of the ESP01 and its successors [7].

As not every household currently has access to a microcontroller prototyping platform, the question regarding "if" the average population has access to this technology can be seen as obsolete. Putting the question aside if this is a desirable goal to achieve, we are left with the question of "why" this is not the case. What are the struggles with the current development of hardware-based projects? Should the community and companies focus on improving the hardware prototyping experience for novice users or easing the software-side development of the required firmware?

In this position paper, we probe into a set of topics that pose challenges to mainly new users of such prototyping tools to explore this question further. We do so by analyzing submissions made to the "Arduino Subreddit" [10] to get a sense of trends regarding the topics and comparing them to the observations and experiences we made during our ongoing time as instructors in the field of rapid prototyping and as makers ourselves. We then conclude with possible directions, focus on setting in the future derived from this insight, and depict our vision of future prototyping tools.

2 ANALYSIS: FOCUS ON CURRENT CHALLENGES

To get an initial insight into the challenges of users, we scraped and analyzed a subset of posts made on the Reddit "Arduino" Subreddit [10]. The Reddit webpage is a community where users organize themselves into so-called "Subreddits", themed sub-communities where users can join and participate in discussions, share information, and ask questions. The organization and structure are defined and enforced by the owners of those sub-communities and users appointed as moderators. The usage of Reddit as a data source has already been discussed in the past and can be seen as a valid source for this use-case [5].

Several other Subreddits also address the topics of prototyping (*e.g. r/electronics : 772k members, r/arduinoProjects : 121k members*). However, we focused on this specific Subreddit due to its structure and reasonably large community (*543k members*), appropriate for the current scope of this work.

2.1 Data Base

While direct access to Reddit data is possible through its official API and additional libraries [13], the results are limited to the last 1000 submissions. To overcome that limit, external APIs such as PushShift [2] collect historical Reddit data and make it accessible for research purposes. The legitimacy of such datasets has been discussed, and their validity can be assumed [1]. However, at the time of writing this paper, the historical dataset was not fully available and was limited to

submissions from 11-03-2022 onward. Nevertheless, this access still resulted in a total of 4345 submissions for this analysis. Future repetitions of this process can therefore lead to a deeper inside.

For the processing of the data, the Python language was used in combination with the WordCloud and GenSim Natural Language Processing (NLP) libraries [8, 11].

Due to the structure of the Arduino Subreddit, users can "flair" their submissions into categories (e.g. *"Look what I made!"*). In the first step, and for later processing, all the submissions were divided into the flairs *"Hardware Help"* and *"Software Help"* to divide the topic of the questions better, e.g. if the uploading of the code did not work due to software or hardware issues.

2.2 Results

The separation of the 4345 submissions into the above-mentioned flairs resulted in 841 "Hardware Help" flaired submissions and 609 "Software Help" flaired submissions. The rest of the submissions were either flaired otherwise or not flaired at all. While not grounded in statistical analysis, this separation may already indicate current challenges of users tending towards hardware-related problems.

Adjusted and filtered with Stopwords predefined for the English language, and extended with commonly used phrases and verbs of the submissions (e.g., "help", "problem", "trying"), the most frequently used terms according to the GenSim LDA frequency analysis in the title of **software**-related submissions were

"Serial", "Library", "Data", "IDE", "LED", "Program", "Sensor" and "Servo"

The analysis of the titles of **hardware**-related submissions resulted in the most frequently used terms

"Power", "Sensor", "Motor", "Board", "Connect", "USB", "LED" and "Stepper"

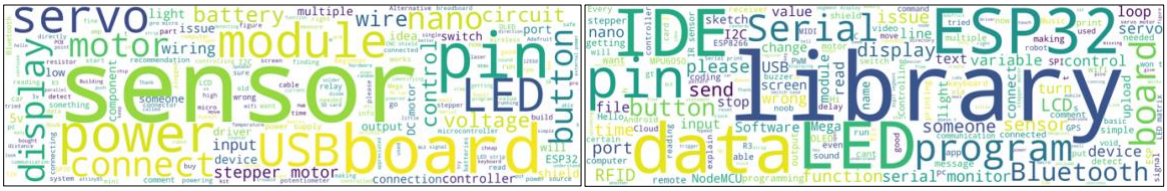

Figure 1: Word clouds generated using the frequencies of terms in the flaired submissions of the Arduino Subreddit. A larger font size represents a higher topic score for the NLP. Note that the word cloud library relies on different NLP models for its generation than the results mentioned above but uses the same set of Stopwords.

Left: "Hardware Help" flaired submissions, Right: "Software Help" flaired submissions

3 AN ATTEMPT OF INTERPRETATION

The results shown above must be set in the context of their environment. It can be assumed that the proportion of beginner questions and problems regarding typical tutorials is higher than other problems, as some users might lose interest in the topic and others presumably could move to other sources of information. This could, for example, explain the listing of "LED" in the frequently used terms, as the common first tutorial contains the task of making an LED blink. It could also be related to the increased usage of LED strips (e.g. as a low-cost way to decorate spaces) and problems regarding that topic.

We are aware of the fact, that frequency analysis alone cannot lead to the clear identification of topics and problems in the community and further classifications and methods are required to do so. However, we argue that this first insight

gained from visualizing the frequency of topics on the Subreddit can be more valuable in the scope of this position paper when combined with observations from teaching experience.

3.1 Comparison with Observations

As teachers for rapid-prototyping courses, we were able to observe the struggles of novice users on a daily basis. With respect to the frequency analysis results, we can confirm the problems regarding power management. In our case, as most students come from a computer science background, they already have a basic understanding of electricity and power supply. However, there are currently no clear guidelines in the prototyping platforms supporting the students in analysis and comprehension of the usage and consumption of power in their system. This can lead to difficult to debug errors (e.g., "brown-outs"), as especially this does not always lead to non-functioning, but rather misfunctioning systems, and therefore the source of the problem is usually suspected somewhere else.

Regarding the software problems, we can confirm the struggles with serial communication and the usage of libraries. The usage of serial communication is a necessary tool for communication with other components, but still a very technical, intangible construct. Attempts to abstract it to basic function calls supported the usability but works mainly in default use-cases and is rarely interchangeable, nor does it work with different components even though the protocols themselves are designed for such use-cases. Computer science knowledge is required to succeed in this field, even though this functionality is a key component of more complex projects. This goes along with the usage of libraries, which usage is currently often neither clearly designed nor standardized, relying heavily on users deconstructing and adapting example code, instead of understanding and engaging with the library itself.

Even though the appearance of the IDE in the frequency analysis makes sense, as the term is probably often referred to in a variety of questions, it is still to be noted that over the course of the last years, we observed that the majorities of our students prefer to use alternative IDEs such as "VisualStudio Code" with the necessary plugins. The reason could be that students are already familiar with a different IDE or that students miss common IDE functionalities like code-completion or the usage of extensions.

3.2 Enhancements

Derived from those observations, we would suggest that the first topic to tackle would be an improvement in the area of power supply and management. Sensors in the board could, for example, detect and report problems in that field **[6]**, and certain parts could be standardized, as it has already been done with the 5V and 3,3V standards. This would enable users without deeper knowledge of electrical engineering to access these prototyping platforms more easily and allow current users to save time on debugging issues.

More strict and thorough standardization of libraries and serial communication would enable novice users to access a broader range of components and reduce debugging time on issues for intermediate users. As it is visible in the frequency analysis, the term sensor is present in both types of submissions, as such input components are probably the most frequently used expansion of the capabilities of microcontroller boards. To prioritize and focus the standardization process of libraries, the community, and the industry could focus on these sorts of components first.

CONCLUSION

While our insights are not grounded in the most rigorous methods, they may still prove valuable to the community. The limitations are not only based on the methods but also on the limited and biased dataset of the online community. Similarly, our observations as educators rely on our student sample, which has mainly a computer science background. For the scope of this work, we argue to have given valuable initial insight on some possible trends and topics further developments could focus on. We envision a future where technology enhances the capabilities of humans, and with recent advances in artificial intelligence, we believe in a future where users describe their needs and technology creates the necessary prototypes for them in a matter of seconds. However, to get to this point, we cannot ignore the current struggles of novice users, and the potential for increased adoption across diverse user groups. One of them might just be the person who will bring the developments toward this vision.

BIOGRAPHIES

Ali Askari is a first-year PhD student at the Institute of Media Informatics at Ulm University, Germany. During his time as an undergraduate student, he worked as a research assistant at the institute and supported several research projects in the automotive domain. With his passion for physical prototyping, he focused on hardware-heavy projects. After graduation, Ali started his PhD in the field of HCI with a focus on Augmented-Reality in cooperation with the BMW Group, Munich. He took over the lead organization of the course "Sketching with Hardware" at Ulm University, which aims to teach prototyping to computer science and media informatics students. Extra-professionally, Ali founded a small solo business, which focuses on supporting museums and other public facilities with the realization of 3D printing projects and interactive concepts.

Evgeny Stemasov is a final-year PhD candidate in the Human-Computer-Interaction Group at Ulm University, headed by Prof. Dr. Enrico Rukzio. His works focus on the ''wicked problem'' of low-effort yet highly expressive design tools and processes for personal fabrication. To explore this, he has developed and evaluated in-situ design tools leveraging remixing, crowds, mixed reality, or tangible interaction. During his PhD, he was active as an instructor for fundamentals of HCI, taught courses on hardware prototyping, worked as a freelance developer, and interned at Autodesk Research in Toronto. His academic works have been published at venues like ACM CHI, UIST, TEI, and IEEE Pervasive Computing.

REFERENCES

[1] Baumgartner, J. et al. 2020. The Pushshift Reddit Dataset. *Proceedings of the International AAAI Conference on Web and Social Media*. 14, (May 2020), 830–839. DOI:https://doi.org/10.1609/icwsm.v14i1.7347.

[2] Baumgartner, J.M. 2023. Pushshift Reddit API Documentation.

[3] D'Ausilio, A. 2012. Arduino: a low-cost multipurpose lab equipment. *Behavior Research Methods*. 44, 2 (Jun. 2012), 305–313. DOI:https://doi.org/10.3758/s13428-011-0163-z.

[4] Gibb, A.M. and Gibb, A. NEW MEDIA ART, DESIGN, AND THE ARDUINO MICROCONTROLLER: A MALLEABLE TOOL.

[5] Jamnik, M. and Lane, D. 2019. The Use of Reddit as an Inexpensive Source for High-Quality Data. *Practical Assessment, Research, and Evaluation*. 22, 1 (Nov. 2019). DOI:https://doi.org/10.7275/j18t-c009.

[6] Kim, Y. et al. 2019. VirtualComponent: A Mixed-Reality Tool for Designing and Tuning Breadboarded Circuits. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow Scotland Uk, May 2019), 1–13.

[7] Kondaveeti, H.K. et al. 2021. A systematic literature review on prototyping with Arduino: Applications, challenges, advantages, and limitations. *Computer Science Review*. 40, (May 2021), 100364. DOI:https://doi.org/10.1016/j.cosrev.2021.100364.

[8] Mueller, A. 2023. word_cloud.

[9] Pearce, J.M. 2020. A review of open source ventilators for COVID-19 and future pandemics. *F1000Research*. 9, (Mar. 2020), 218–218. DOI:https://doi.org/10.12688/f1000research.22942.1.

[10] Reddit Arduino Subreddit: *https://www.reddit.com/r/arduino*. Accessed: 2023-02-24.

[11] Řehůřek, R. and Sojka, P. 2010. Software Framework for Topic Modelling with Large Corpora. University of Malta.

[12] Stemasov, E. et al. 2021. The Road to Ubiquitous Personal Fabrication: Modeling-Free Instead of Increasingly Simple. *IEEE Pervasive Computing*. 20, 1 (Jan. 2021), 19–27. DOI:https://doi.org/10.1109/MPRV.2020.3029650.

[13] 2023. PRAW: The Python Reddit API Wrapper. Python Reddit API Wrapper Development.