MATHEMATICAL BASIS OF USABILITY

Gopal Tadepalli
Department of Computer Science and Engineering, College of Engineering - Anna University, India
gopal@annauniv.edu; gopal.tadepalli@gmail.com

МАТЕМАТИЧЕСКИ ОСНОВИ НА ИЗПОЛЗВАЕМОСТТА

Abstract

Mathematical notation is a system of symbolic representations of mathematical objects and ideas. It includes simple symbolic representations such as numbers, functions, symbols, variables and also more complex symbols like matrices. User input of mathematical notation by means of standard input devices – a computer keyboard and a mouse – presents several challenges. These arise mostly from the fact that these devices were designed for a different purpose - for input of plain text with the addition of a limited support for keyboard commands and the ability to mark a single spot on the screen.

Keywords: *Symbols; Mathematics; Notation; Keyboard; Mouse.*

INTRODUCTION

Historically, calculating devices began with the Abacus in China. Napier's Bones by John Napier, Pascaline by Blaise Pascal, Difference & Analytical Engines by Charles Babbage, Tabulating Machines by Herman Hollerith are all good examples of calculating devices. The electronic scientific calculators ushered in machines that perform certain mathematical functions at a push button or a pre-defined combination of push buttons. The business calculators perform only the typical arithmetic operations. Please see the Figure 1 below.

Figure 1: Sample Electronic Scientific Calculators

The author has worked on usability testing of two models of calculators from a manufacturer. The calculators make mathematics usable enough.

The era of digital computers advanced rapidly and gained the acceptability of the scientific community at an amazing speed. Digital Computers brought in a variety of input devices of which the Keyboard and Mouse are most popular. Please see the Figure 2 below.

Figure 2: The Gamut of Input Devices for the Digital Computer

The idea of using combinations of push buttons / keys made possible to support keyboards for mathematical symbols that are not native to the QWERTY Keyboard [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]. Please see the Figure 3 below for a mathematical keyboard.

Figure 3: A Mathematical Keyboard

A universal math keyboard with all keys and their combinations that work exclusively for mathematical functions is shown in Figure 4 below.

Figure 4: A Universal Math Keyboard

The provision of a virtual keyboard enables the on-screen use of the keyboard layouts with the use of a mouse. The Math Keyboard layout supports all characters defined in the international mathematics standard ISO 80000-2 and a small collection of other characters.

Cleverly chosen combinations of the keys wired into the keyboard make even multilingualism happen. The usability study of the efficiency and effectiveness of the design of combinations of the keys is very illuminating.

Current software systems display mathematical formulae with ease but struggle to provide means of input that is both intuitive and time efficient. This requirement is very important when focusing on search engines. The requirements and challenges in developing a mathematical formulae input user interface include

- means of selecting symbols from a large domain effectively using standard input devices

- means of specifying and / or correcting placement of symbols within a mathematical notation
- efficient navigation within a mathematical notation and selection of focus and scope in semantically aware systems - the ability to distinguish lexically, syntactically and even semantically equal symbols.

Mathematical notation is becoming more important as software is more often used in day-to day life. Schools are starting to support e-learning, science is penetrating www and search engines can handle more complex questions. Existing systems do not meet all these challenges satisfactorily. They either rely heavily on graphical menus and the use of the computer mouse or force user to use a programming language.

The author has worked with open-source software for mathematics such as Axiom, Cadabra and GAP. As a matter of fact, the author designed and developed a prize-winning software for "Geometric Analogy Problems" way back in 1988. Currently, there is a long list of both commercial and open-source software exclusively for mathematical notations and functions. Each of these software solutions have their own interface design and are difficult to move from one software to another.

Most word processing software today support "equation tools" to include mathematical formulae, notations and symbols along with the text. The word processing can be multilingual. One must often switch between reading / typing mathematical symbols and reading / typing words. Some emerging patterns relating the mathematics to language may minimize the number of such switches.

The existing user interfaces are also converted into a document format manually and this document is used to build the prototype in the tool. The prototype is used for usability evaluation using the following usability metrics.

1. Layout complexity, which partly decides on the ease of use of the user interface, the time taken by a novice user to complete tasks, which is an iso metric
2. Functional feedback, which is the ratio of the number the perceptible functions to the number of hidden functions.

More the functional feedback, more are the number of perceptible functions, and hence more is the usability. However, the layout complexity increases. The layout complexity is a severe limitation for hardware implementations.

EXHIBITION

The Halden Reactor was one of the first experimental reactors in the world, built into a mountain cave in the middle of the town of Halden which is 120 km south of Oslo. The reactor went critical for the first time in June 1959. The experimental programme is run under the auspices of the OECD Halden Reactor Project [HRP]. This was established in 1958 as joint undertaking of the OECD Nuclear Energy Agency. The Halden reactor was shut down permanently in June 2018. The Project was an international collaboration with 21countries participating and sharing the research outcomes.

This report presents a methodology based on the Picasso – 3 User Interface Management System [UIMS] developed for the Halden Reactor Project [HRP], Norway. An UIMS is a mechanism for separating process or business logic from Graphical user interface [GUI] code in a computer program. The author of this report has been involved with this work.

Mathematics and problem-solving are inseparable. Mathematics has its language - a unique set of terms, symbols, and rules. A sound understanding of these mathematical terms is crucial for comprehending mathematical ideas. The mathematical vocabulary, problem-solving, clear communication, and writing in mathematics require language skills. The reality is that most math problems are expressed in words. A command of natural language becomes important to solve complex equations. The connection between language and mathematics is often not immediately apparent. In real life, mathematics often relies on language. Most of the works outlined in this paper indicate the infancy of working with the connections between language and mathematics. In the interconnected world, understanding this relationship becomes important.

The user requirements are obtained from the user using a form-like template and the data is converted into a prototype using the tool Picasso. Please see the Figure 5 below. Although the reactor is shut down, Halden's human factors element survived and has taken center stage. There are three kinds of code due to the requirement of "Separation of Concerns." They are as follows.

- **User Interface/View:** Usability Concerns
- Logic: Design and Coding of the program
- Data/Model: For storage and retrieval of real-world information

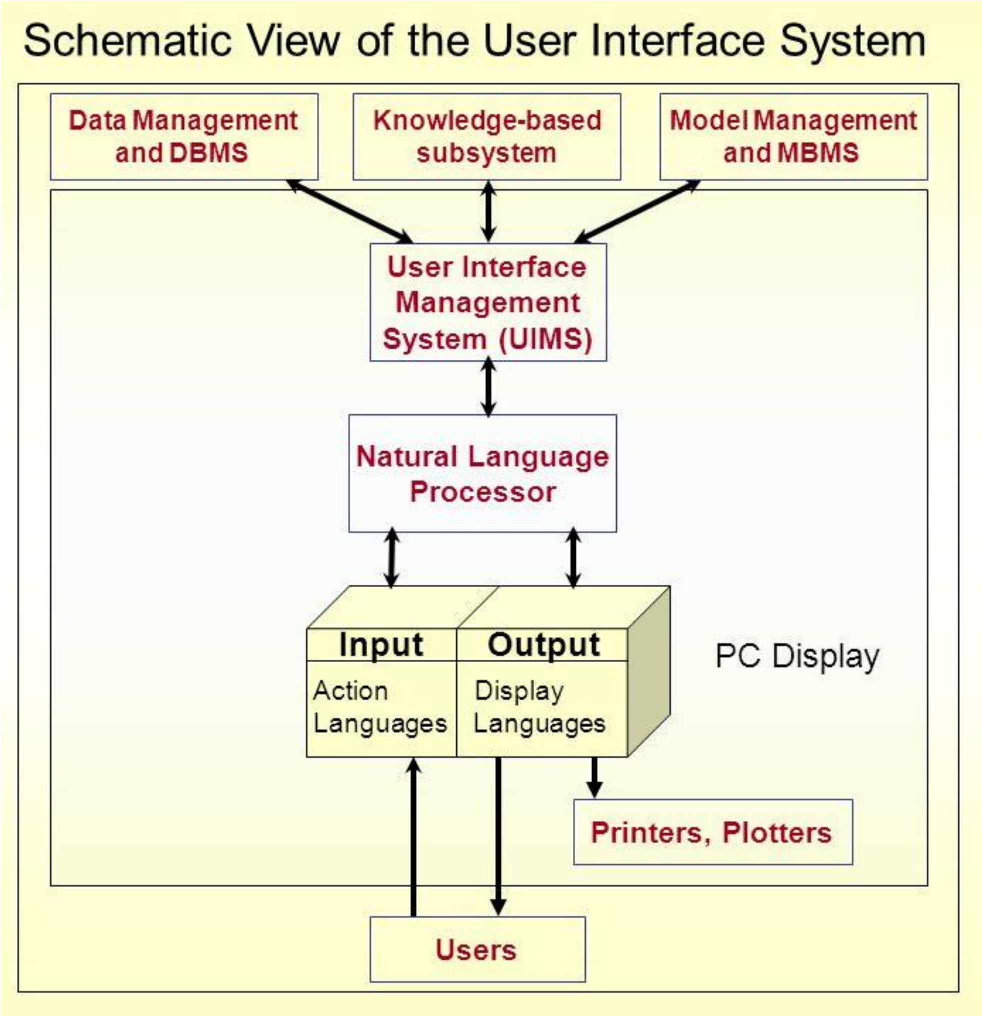

Figure 5: The UIMS Block Schematic

The power of abstraction and integration in Picasso – 3 UIMS is depicted in Figure 6.

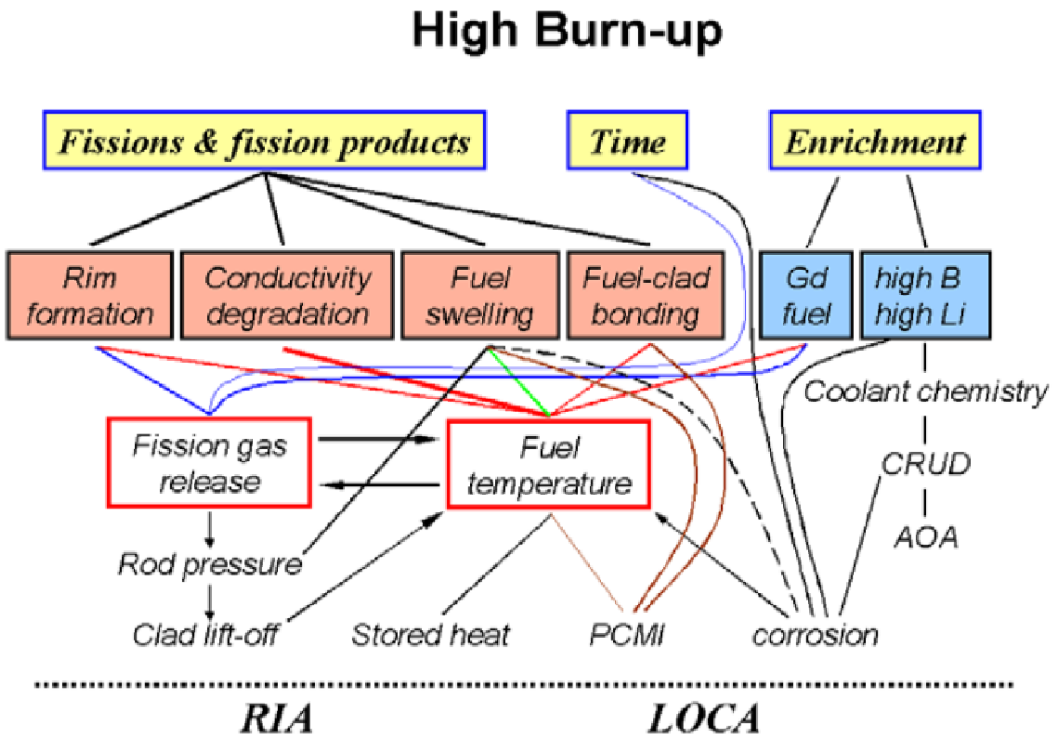

Figure 6: All Real Time Mathematics for "High Burn – Up" Conditions of the Halden Reactor in Picasso - 3

Conclusion

Software is ubiquitous and has impacted virtually every discipline of human endeavor. It is thus very difficult to make many disciplines specify the required interface in terms of the software engineering discipline. However, if the requirements can be mathematically described and a tool like the Picasso – 3 is used, the user interfaces for any discipline can be tailor made without the drudgery of a lingua franca that is meant by the computational languages. The improved usability of working with mathematics has been a strong influence on mathematics and scientific computing.

References

1. Baraka Loibanguti, "Calculating Devices", Advanced Mathematics, Text © Loibanguti B, 2022
2. J. Mišutka and J. Klíma, "Mathematical User Interface", WDS'09 Proceedings of Contributed Papers, Part I, pp 56–61, 2009
3. Jakob Nielsen and Thomas K Landauer, "A Mathematical Model of the Finding of Usability Problems", INTERCHI'93, 24 – 29 April 1993.
4. Kjell Arne Barmsnes, Arne Hornæs, Øystein Jakobsen and Rune Storkås, "PICASSO: A User Interface Management System for Real-Time Applications", User Interfaces for Expert Systems, London, March 11-12, 1992.
5. Lawrence A. Rowe, Joseph A. Konstan, Brian C. Smith, Steve Seitz, and Chung Liu, "The PICASSO Application Framework", UIST'91, pp 95 – 105, November 11-13, 1991.
6. Michalis Xenos, "Usability Perspective in Software Quality", Usability Engineering Workshop, Proceedings of the 8th Panhellenic Conference on Informatics with international participation, Vol. 2, pp. 523-529, Cyprus, 2001.
7. Pollanen M., Wisniewski T.and Yu X, "A Novice Interface for the Real-Time Communication of Mathematical Expressions", in Proceedings of the 2007 Mathematical User-Interface Workshop, Linz, Austria, 2007.

8. Sagar Shinde, Akil Mulagirisamy, Daulappa Bhalke and Lalitkumar Wadhwa, "Recognition of Math Expressions & Symbols using Machine Learning", Turkish Online Journal of Qualitative Inquiry (TOJQI), Volume 12, Issue 8, pp 5987- 6000, July 2021.
9. Ulrika Wikstr¨om Hultdin *, Ewa Bergqvist, Tomas Bergqvist, Lotta Vingsle, Magnus ¨Osterholm, "Applying a new framework of connections between mathematical symbols and natural language", Journal of Mathematical Behavior, Vol. 72, 101097, 2023
10. Wiesenack, W, "Halden Reactor Project Activities, Achievements And International Collaboration". International conference on WWER fuel performance, modelling and experimental support, Bulgaria, pp 16 – 22, 2003.

Received: 25-09-2024 Accepted: 06-12-2024 Published: 20-12-2024

Cite as:
Tadepalli, G. (2024). "Mathematical Basis of Usability", Science Series "Innovative STEM Education", volume 06, ISSN: 2683-1333, pp. 7-13, 2024. DOI: https://doi.org/10.55630/STEM.2024.0601