Initiatives in Reviving the Free Open Source Software Based Learning for Control System Engineering Education

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Abstract: This manuscript explores the transformative integration of Free and Open-Source Software (FOSS), particularly Scilab, in control engineering education at Universitas 17 Agustus 1945 (UTA45) in Jakarta, Indonesia. The paper emphasizes the interdisciplinary nature of control engineering and its crucial role in technological innovations. It discusses the challenges in control engineering education, highlighting the importance of comprehending intricate diagrams and the incorporation of software tools. The focus shifts to the utilization of FOSS in control engineering education, emphasizing online accessibility, multimedia learning resources, mathematical modeling, comparative analysis, lab migration, and rapid prototyping. Control System is an applicative subject that relied on modern computation tools and concept together with the advancement of our current technology. Thus the implementation of FOSS also considered as the advancement in this field. Although the existence of the current software in control engineering education has support the modelling and simulation purposes, many industries are applied control engineering without using that software. Scilab is a FOSS computation software that run in multi Operating System environment such as Microsoft Windows, Linux and Macintosh. The integration of Scilab in control engineering education fosters an accessible, inclusive, and engaging learning environment, preparing students for the challenges of the future.

1 INTRODUCTION

Control Engineering is an interdisciplinary field that contribute to the development of human civilization. It is tightly related with electrical engineering, electronics engineering, mechanical engineering, automobile engineering, instrumentation engineering, mechatronics engineering, aerospace engineering, and chemical engineering (Bajpai, 2018). It plays a pivotal role in shaping modern technological innovations. It also encompasses a diverse range of applications, from mathematical modeling and simulation to in-depth analysis, making it an essential discipline in various engineering domains (Bajpai, 2018).

One of the fundamental challenges in control engineering education lies in the comprehend intricate interrelated diagrams, that holding significant implications for the analysis and design. These diagrams including the time-response plots, pole-zero maps, root locus, and frequency domain diagrams, such as Bode, Nyquist, and Nichols plots, among others (Marin, 2020). Examples of these implementations—which applied in the field of aerospace—were including linearization concept (Muliadi, 2016b and Muliadi, 2015).

For educational purposes, the incorporation of software tools is significant to facilitate the learning and application of control engineering concepts. Software tools become important instruments in the tasks accomplishment which involving mathematical modeling, simulation, and analysis. It also providing students with a platform to experiment, visualize, and understand complex control system behaviors (Chacón, 2015).

Notable proprietary software like MATLAB, Simulink (MATLAB-based graphical programming environment), and LabVIEW have traditionally served as standard tools, offering a technical and numerical computing environment. Moreover,

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interactive learning tools, including Java applets and software like MATLAB and Simulink, have been utilized to engage students actively, enhancing their understanding of intricate concepts.

In Indonesia, the lecturer worked to be aligned with the Law for Teachers and Lecturers with the crucial roles, i.e. to be facilitator, motivator, trigger, learning engineer, and to be inspiration of learning to their student. To increase the quality of national education, the following roles will be also involved i.e. to be informer, communicator, transformer, agents of change, innovator, counselor and administrator (Muliadi, 2016a).

In recent years, a paradigm shift has been marked by the initiatives to adopt Free and Open-Source Software (FOSS) that equivalents of their type of proprietary tools. FOSS, characterized by its modifiability and can be redistribute freely (Fortunato, 2021), aligns with the paradigm of open knowledge sharing. The FOSS movement has gained momentum, with initiatives like the Free and Open Software in Education (FOSSEE) project by MHRD in India promoting the use of open source tools in educational institutions (Bajpai, 2018). FOSS is featured to these three fundamental criteria: the freedom to use the software for any purpose, the ability to study and modify its operation, and the liberty to redistribute the software and its modified versions (Lehtola, 2022).

FOSS also offers several advantages in teaching, including access to source code, availability of precompiled binaries, and general applicability beyond academia environment (Lehtola, 2022). Furthermore, for educational purposes, FOSS provides additional benefits such as free redistribution and ease of installation, enabling students to work seamlessly on diverse hardware platforms (Lehtola, 2022). It also facilitates access to source code, fostering a deeper understanding of underlying algorithms. Additionally, FOSS supports sophisticated workflows, allowing students to deeply involve into programming and interface various programs effectively (Lehtola, 2022).

In the context of Control System Engineering, the integration of FOSS has emerged as a transformative force. Several FOSS tools, such as Scilab, Octave, and Python-based libraries like SciPy and control, have gained prominence in control engineering education. Scilab, an open source software platform, enables students to design and analyze control engineering problems by manipulating associated parameters (Bajpai, 2018). Scilab Cloud, an online simulation tool, offers a versatile platform for the analysis of mathematical equations pertinent to control engineering (Bajpai, 2018). Moreover, Scilab codes have been developed for solved examples in engineering equipped with its textbooks, enriching the educational experience (Bajpai, 2018). Workshops and educational initiatives leverage Scilab to solve mathematical and simulation problems, enhancing students' practical understanding of control engineering concepts (Bajpai, 2018). The adoption of FOSS in control engineering education signifies a paradigm shift, empowering students with accessible, versatile, and collaborative tools, fostering a new era of hands-on learning and innovation in the field of Control System Engineering.

2 FOSS UTILIZATION IN CONTROL ENGINEERING EDUCATION

In this current digital age, the access to educational resources has been revolutionized, due to the online platforms and the development of FOSS. The integration of FOSS tools into teaching activities has significantly transformed the landscape of control engineering education, offering accessible and cost-effective solutions to students and educators alike. This section delves into the various facets of FOSS implementation in control engineering education, highlighting the diverse tools and platforms that facilitate interactive learning experiences.

2.1 Online Accessibility and Mobile Learning

Online platforms have grown into a cornerstone of modern education, breaking down geographical barriers and providing students with unprecedented access to resources (Rabek, 2019). Scilab Cloud, an online simulation tool, exemplifies the power of online accessibility. Utilizable from 4G-enabled smartphones, Scilab Cloud empowers students to create diverse plots and solve intricate mathematical equations, all through a user-friendly interface (Bajpai, 2018). In India, the development of the cloud service that allows the execution of Scilab codes without the need for local installations, ensuring seamless online access to computational tools. Furthermore, initiatives like the Aakash tablet and laptop, pioneered by the Ministry of Human Resource Development (MHRD), provide cost-effective solutions for e-learning, enhancing accessibility and affordability in educational technology (Bajpai, 2018).

2.2 Rich Multimedia Learning Resources

In the realm of control engineering, multimedia resources play a pivotal role in enhancing understanding and engagement. Videos and web-based lectures dedicated to control engineering cover a broad spectrum of topics, ranging from basic control principles to specialized domains like aerospace control, digital control, and industrial automation (Bajpai, 2018). These resources serve as invaluable supplements to traditional classroom teaching, offering students a dynamic and interactive learning experience.

2.3 Mathematical Modeling and Optimization with FOSS

FOSS tools such as Scilab and GNU Octave have become instrumental in solving mathematical modeling and simulation problems. Students can explore complex systems and visualize their behavior by employing these tools, fostering a deeper understanding of theoretical concepts. In India, the Optimization Toolbox (OR tool) developed by FOSSEE India facilitates the solution of mathematical optimization problems, empowering students to delve into the realm of real-world applications (Bajpai, 2018).

2.4 Examples Based and Comparative Analysis Based Learning

A cornerstone of effective learning is a hands-on experience, and FOSS tools enable such experience in precise fashion. For hands on purpose, the Scilab codes that readily available on the Scilab India website, serve as learning aids for students. By downloading these codes, students can manipulate variables within the problems, conducting comparative analyses and sharpening their problem-solving skills. This approach not only reinforces theoretical knowledge but also nurtures a mindset of experimentation and exploration (Bajpai, 2018).

2.5 Lab Migration and Remote Access Initiatives

The Lab Migration project, a significant endeavor in the field of control engineering education, aims to started a transition at labs from proprietary software usages into open-source alternatives. Traditionally, proprietary software like MATLAB, Simulink, and LabVIEW dominated the labs that associated with control systems. However, India put initiatives like the Virtual Lab project, initiated by MHRD under the National Mission on Education through ICT, have provide public access to their expensive instruments (Bajpai, 2018). Through remote access, students can engage in practical experiments and gain hands-on experience, irrespective of their geographical location (Tugashova, 2022). This initiative not only optimizes resource utilization but also fosters collaboration and knowledge sharing across institutions.

2.6 Rapid Prototyping and Exploration of Control Methods

Rapid Control Prototyping (RCP) systems becoming important tools in the educational purpose of control engineering. Scilab, with their intuitive interfaces and robust functionalities, constitute an ideal environment for RCP systems. These platforms facilitate the exploration of diverse control methods, allowing students to experiment with different algorithms and observe real-time responses (Chamorro, 2018). By embracing FOSS tools for rapid prototyping, students can bridge the gap between theory and application, gaining practical insights into the complexities of control systems.

All of these utilization showed that the integration of FOSS in control engineering education has marked a transformative shift. From online accessibility and multimedia resources to hands-on learning experiences and remote lab access, FOSS tools enrich the educational journey, making it interactive, engaging, and universally accessible. Through these initiatives, the realm of control engineering education continues to evolve, nurturing a new generation of engineers equipped with the knowledge and skills necessary to tackle the challenges of our ever-changing world.

3 IMPLEMENTING SCILAB-BASED TEACHING FOR CONTROL SYSTEM IN UTA45

Universitas Tujuh Belas Agustus 1945 (University of the August 17th 1945) or shortened as UTA45 is a private University in Jakarta, Indonesia, managed under the Foundation named *Yayasan Perguruan Tinggi 17 Agustus 1945* Jakarta. To the Indonesians, the date of August 17th 1945 commemorate the Proclamation of Independence as the begin of

Republic of Indonesia. The university run several faculties include the Faculty of Engineering and Informatics.

The Electrical Engineering Study Program is a part of that Faculty of Engineering and Informatics and runs the Power and Energy Group together with the Control System Group. Thus, Control System Lecture is one of the course provided by the Electrical Engineering Study Program. The following explanation will describe the initiative of FOSS implementation for Control System Lecture in UT45, Jakarta, Indonesia.

3.1 Transition from MATLAB to Scilab to Enhance Control Engineering Education

In the long time teaching of control engineering education, MATLAB has become the industry-standard software tool (Chacón, 2015). Its interactive environment for scientific and engineering computations, simulations, and data visualization has been fundamental in shaping the learning experiences of countless students (Vámos, 2018). However, the landscape of educational technology is ever-evolving, and the migration from proprietary software like MATLAB into free and accessible alternatives like Scilab has become increasingly prevalent (Merzlikina, 2020). This shift is motivated by several compelling reasons, all aimed at enhancing the educational experience for students.

Therefore, in UTA45, the MATLAB and Scilab is used together in complemented and also substituted fashion. For Control System Lecture, the use of Scilab becomes substitute of MATLAB since all of its feature were sufficient for basic teaching of Control System. While in other application MATLAB is still applied within their purposes of teaching.

3.2 The Need for Accessibility and Ease of Use

One of the primary motivations behind the transition to Scilab is rooted in accessibility. Students must have the freedom to install the software on their personal computers without facing financial constraints. The ideal software should also be undemanding in terms of system requirements, ensuring that it can run smoothly on a variety of devices. Additionally, the learning curve should be manageable, allowing students to grasp the fundamentals without being overwhelmed. Scilab, with its user-friendly interface and intuitive functionalities, fulfills these criteria, making it an ideal choice for control engineering education (Merzlikina, 2020). It strikes a balance between robust features and ease of use, empowering students to engage with the software effectively.

Back in the pandemic era of Covid-19, UTA45 has to adapt the remote teaching so the students can only learn and obtain lectures from home. For Control System Lecture, that relied heavily on software, the installation of Scilab in student's own PC or Laptop becomes solution to ensure their familiarities on programming capabilities to solve engineering problems numerically.

3.3 Enhancing Visualization and Interactivity

In the realm of virtual labs and simulations, visualization and interactivity becomes significant. These aspects have proven to be pivotal when designing simulations for pedagogical purposes, especially in the complex domain of control engineering. The graphical capabilities of computers, including images and animations, serve as powerful tools to elucidate intricate concepts. Visual representations enable students to comprehend key system behaviors more easily, facilitating a deeper understanding of theoretical principles (Chacón, 2015). Furthermore, interactivity plays a vital role in the learning process. The ability to manipulate variables and observe real-time system responses empowers students to experiment and explore, fostering a hands-on understanding of control systems.

Return again to the pandemic era of Covid-19, Scilab has help the students of Control System Lecture in UTA45 to grasp adequate understandings. This is due to their ability to produce graphs, diagrams, and many visual tool that used in Control System Engineering by using Scilab in their PC or Laptop.

3.4 Empowering Hands-On Learning

The hands-on approach in control engineering education is indispensable. Students need practical experiences that go beyond theoretical concepts, allowing them to apply their knowledge in real-world scenarios. Scilab facilitates this hands-on learning through template codes and example codes (Bajpai, 2018). By providing students with structured templates, they can experiment with different variables, conduct comparative analyses, and gain valuable insights into system behaviors. This approach not only saves time in complex mathematical calculations but also encourages students to approach problems from multiple angles (Bajpai, 2018). It promotes critical thinking and problem-solving skills, essential attributes for aspiring engineers.

By using Scilab, every lecture session can be equipped by the tutorials in the hands-on activity. These strategies are very helpful to the students of Control System Lecture in UTA45 especially at remote learning in Covid-19 pandemic era. Since they can operate the virtual meetings application together with their Scilab hands on, the Lecturer can tutor them real-time by “share-screen” features.

3.5 Harnessing the Online Features of Scilab Resources

The era of online education has breaking down barriers related to time and location. Scilab's online features are a testament to this evolution. Educators can leverage Scilab's cloud service, eliminating the need for local installations (Bajpai, 2018). This is not only providing flexibility to students but also supports online class activities. Students with limited access to personal computers or laptops can now engage with Scilab through various devices, ensuring that educational opportunities are accessible to a wider demographic (Vámos, 2018). Moreover, this online functionality promotes collaborative learning, allowing students to work together on projects and assignments regardless of their physical locations.

The online features enable all students of Control System Lecture in UTA45 to access Scilab although some of them were not able to access PC or Laptop in Covid-19 pandemic era. Thus, if they can access internet and tablet phone or adequate cell phone, they can follow the lecture properly.

In summary, while at the Covid-19 pandemic era, the Control System Lecture in UTA45 has perform the transition from MATLAB to Scilab. It represents a significant step forward in control engineering education. By prioritizing accessibility, visualization, interactivity, hands-on learning, and online features, educators can create a dynamic and engaging learning environment (Jacques, 2021). Scilab's versatile capabilities empower students to explore the complexities of control systems, nurturing a generation of engineers equipped with practical skills and a deep understanding of their field. As technology continues to advance, embracing open and accessible tools like Scilab ensures that control engineering education remains at the forefront of innovation, preparing students for the challenges and opportunities of the future.

4 RESULTS AND DISCUSSION

In the ever-evolving landscape of education, the adoption of FOSS like Scilab stands as a pivotal paradigm shift, particularly in the domain of control engineering. The integration of Scilab into educational curricula represents a significant leap towards providing students with accessible, interactive, and flexible learning experiences. Scilab's user-friendly interface, coupled with its robust functionalities, makes it an ideal platform for hands-on exploration of complex control systems. As this paper has demonstrated, Scilab not only fulfills the need for a cost-effective software solution but also addresses critical challenges faced by students and educators alike.

4.1 Adapting to Advancements in Numeric Technologies

Scilab serves as a bridge between traditional teaching methods and the demands of modern numeric technologies. Its adaptability and versatility make it a suitable tool for conducting FOSS-based learning activities, enabling students to stay abreast of the latest advancements in numerical computing. By immersing students in Scilab-based learning environments, educational institutions empower the next generation of engineers with the practical skills and computational knowledge necessary to thrive in the digital age. This adaptability is crucial, considering the rapid pace at which technology continues to advance.

4.2 Flexibility for Engineering Departments

Engineering departments across educational institutions have welcomed Scilab with open arms, recognizing its potential to revolutionize the way computations are performed in educational settings. The flexibility offered by Scilab allows engineering departments to obtain adequate computational software equipped with a user-friendly Graphical User Interface (GUI). This transition not only optimizes financial resources but also ensures that students have access to cutting-edge tools that align with industry standards. Scilab's ease of use makes it an invaluable asset for educators, enabling them to focus on teaching content rather than struggling with complex software interfaces.

4.3 Overcoming Limitations Through Online Features

One of the notable advantages of Scilab lies in its online features, which have proven instrumental in overcoming various limitations faced by students. The requirement to purchase expensive computers is mitigated by Scilab's ability to operate efficiently on a wide range of devices, from high-end laptops to budget-friendly tablets. Moreover, the need for intra-computer installations is eliminated, streamlining the setup process and allowing students to focus on their coursework instead of grappling with software installations (Sorour, 2020). Additionally, the limitation of unused memory space on computers becomes a non-issue when utilizing Scilab's online functionalities, ensuring that computational resources are available without imposing constraints on local storage.

4.4 Recommendations

Based on the findings and insights presented, these recommendations then proposed for educational institutions and policymakers to further enhance the integration of Scilab in control engineering education.

4.4.1 Comprehensive Training Programs

Educational institutions should design comprehensive training programs for both students and educators to familiarize them with the features and functionalities of Scilab. These programs should focus on practical applications, ensuring that students can leverage Scilab's capabilities to solve real-world engineering problems effectively.

4.4.2 Collaborative Research Initiatives

Encourage collaborative research initiatives between educational institutions and industries, fostering an environment where Scilab is utilized for practical research endeavors. This collaboration will not only enrich the educational experience but also contribute to the development of innovative solutions in the field of control engineering.

4.4.3 Continuous Software Updates and Support

Educational institutions should collaborate with Scilab Enterprises or other relevant entities to ensure continuous software updates and technical support. Regular updates will guarantee that students and educators have access to the latest features and improvements, enhancing the overall learning experience.

4.4.4 Online Learning Platforms

Develop dedicated online learning platforms that host interactive Scilab tutorials, demonstrations, and problem-solving sessions. These platforms can serve as valuable resources for students, providing them with additional learning materials and opportunities for collaborative learning.

4.4.5 Inclusivity and Accessibility

Educational policymakers should prioritize inclusivity and accessibility by ensuring that Scilab-based educational resources are accessible to students with disabilities. This can be achieved through the development of specialized interfaces, compatibility with screen readers, and other assistive technologies, fostering an inclusive learning environment for all students.

5 CONCLUSION

In conclusion, the integration of Scilab in control engineering education marks a transformative step towards providing students with a holistic and engaging learning experience. By addressing financial constraints, simplifying software installations, and leveraging online functionalities, Scilab offers a pathway to a more accessible and inclusive educational landscape. Embracing the recommendations outlined above will not only enhance the learning experience for students but also contribute to the advancement of control engineering education as a whole, fostering a new generation of skilled engineers capable of meeting the challenges of the future.

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REFERENCES

Bajpai, S., & Kidwai, N. R. (2018). Government's Effort in Controling Engineering Education in India. *Порівняльна професійна педагогіка (Comparative Professional Pedagogy)*, (8 (1)), 75-83.

Chacón, J., Farias, G., Vargas, H., Visioli, A., & Dormido, S. (2015). Remote Interoperability Protocol: A Bridge Between Interactive Interfaces and Engineering Systems. *IFAC-PapersOnLine*, 48(29), 247-252.

Chamorro, O. J., Otoya, L. D. G., & Marulanda, J. F. F. (2018). "Rapid Control Prototyping with Scilab/Scicos, RTAI-Lab for the MIC955 Training Module of the Feedback Instruments." *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje*, 13(3), 85-92.

Fortunato, L., & Galassi, M. (2021). The Case for Free and Open Source Software in Research and Scholarship. *Philosophical Transactions of the Royal Society A*, 379(2197), 20200079.

Jacques, S., Ouahabi, A. & Lequeu, T. (2021). "Synchronous E-learning in Higher Education during the COVID-19 Pandemics." *The 2021 IEEE Global Engineering Education Conference (EDUCON)*. IEEE.

Lehtola, S., & Karttunen, A. J. (2022). Free and Open Source Software for Computational Chemistry Education. *Wiley Interdisciplinary Reviews: Computational Molecular Science*, 12(5), e1610.

Marin, L., Vargas, H., Heradio, R., de La Torre, L., Diaz, J. M., & Dormido, S. (2020). Evidence-Based Control Engineering Education: Evaluating the LCSD Simulation Tool. *IEEE Access, 8*, 170183-170194.

Merzlikina, E. I., & Prochina, O. G. (2020). "Laboratory Works on Control Theory Using Scilab/Xcos." *The 2020 V International Conference on Information Technologies in Engineering Education (Inforino)*. IEEE.

Muliadi, J., & Afrilionita, D. (2016a). "Encouraging the Innovation-Based Improvement of Teaching's Methods by the Implementation of Engineering Working System for Continuous Professional Development." *International Conference on Teacher Education and Professional Development (The 2016 InCoTePD)*, 260 - 274.

Muliadi, J. (2016b). "The Analysis of Unconventional Aircraft Flight Dynamics Model by Linearizing its Equation of Motion as Applied in BPPT's V-Tail Configuration UAV Gagak." *The 2016 Conference on Fundamental and Applied Science for Advanced Technology (ConFAST 2016)*, 020060-1 - 020060-6.

Muliadi, J. (2015). "Investigating the Accuracy of BPPT Flying Wing UAV'S Linearized Equation of Motion Compared to BPPT-04C Sriti Flight Test Data." *The 3rd IndoMS International Conference on Mathematics and Its Applications (The 3rd IICMA 2015)*, 24 - 32.

Rabek, M. & Zakova, K. (2019). "Integration of new control experiments to online environment." *The 2019 5th Experiment@ International Conference (exp@2019)*. IEEE.

Sorour, S. E., Kamel, T. M. & Abdelkader, H. E. (2021). "A Hybrid Virtual Cloud Learning Model during the COVID-19 Pandemic." *Computers, Materials & Continua*, DOI:10.32604/cmc.2021.014395.

Tugashova, L., et al. (2022). "Design of an E-Learning Course on control systems modeling for students in applied physics." *The III International Conference on Metrological Support of Innovative Technologies – ICMSIT-III-2022*. IOP Publishing.

Vámos, T., Keviczky, L., Bars, R., Benedek, A., & Sik, D. (2018). "An Introductory Overview About Systems and Control a Motivation Lecture in Control Education." In *2018 26th Mediterranean Conference on Control and Automation (MED)*. IEEE.