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ΙΚΥ

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TURN THE SHIP AROUND: TRANSFORMING PROJECT TEAMS TO HIGH PERFORMING TEAMS BY BREAKING TRADITIONAL APPROACHES MANAGING PROJECTS

Dr. Tomaž Aljaž *

Faculty of Industrial Engineering Novo mesto, Šegova ul.112, SI-8000, Novo mesto, Slovenia

E-mail (corresponding author): tomaz.aljaz@gmail.com

1. INTRODUCTION

Organizations consider project management to be the competitive advantage of the future. In recent years, IT projects have proven to have a significant impact on improving the business processes and better customer services thus enabling organizations to become more competitive in global market. However, there is significant space for improvement. The Standish Group Chaos Study report (Standish Group, 2015) defined that project success is limited to the triple constraint, which has been the standard for the Project Management Institute for a number of years - schedule, cost, and scope. Using the triple constraint, the Standish Group evaluated projects as successful, challenged or failed. Successful means that project met all three of the triple constraints: schedule, cost, and scope, challenged that project would have met two out of three constraints (e.g., delivered on time and on budget but not with the desired scope), and failed means that project was canceled before it is completed, or completed but not used.

The results of this study, shown in Figure 1, revealing that in year 2015 only 29% software projects were completed on-time, on-budget and scope. On the other hand, 19% of projects were cancelled before they ever are completed and 52% of projects increase their cost, scope or time based on their original estimates.

MODERN RESOLUTION FOR ALL PROJECTS

	2011	2012	2013	2014	2015
SUCCESSFUL	29%	27%	31%	28%	29%
CHALLENGED	49%	56%	50%	55%	52%
FAILED	22%	17%	19%	17%	19%

The Modern Resolution (OnTime, OnBudget, with a satisfactory result) of all software projects from FY2011-2015 within the new CHAOS database. Please note that for the rest of this report CHAOS Resolution will refer to the Modern Resolution definition not the Traditional Resolution definition.

Figure 1. Standish Group Chaos Study revealing success rate of IT projects.

In order to address these needs, several traditional project management practices will be challenged. Moreover, the methodology that was introduced by dr. Eliyahu M. Goldratt, called Theory of Constrains (TOC) (Goldratt, 2018), will be used as main improvement approach throughout the paper. The TOC tools and applications are introduced to solve business problems in a practical and effective manner. The methodology assumes that every system or organization can be characterized as network of interdependent processes or elements. This means that systems are analogous to chains, or networks of chains. Like a chain, the system performance is limited by the weakest link - constraint. This means that no matter how much effort you put into improving the processes of a system, only the improvements to the weakest link will produce any detectable system improvement. The TOC provide tools and applications that enable organizations to identify the constraints (or few of them), exploit them and subordinate others based on that decision in order to get the most out of the existing system or organization. To accomplish this, TOC shifts the focus of management from optimizing separate organizational units, functions and resources to increasing the flow of throughput generated by the entire system.

The TOC's key processes are focused on removing barriers that prevent each part of the system from working together as an integrated whole.

2. BACKGROUND

In this chapter it will be described the main topics, from project execution point of view, that affects the performance and effectiveness of project teams. Additionally, it will be show effects of unappropriated management of Work-In-Progress (inventory), promoting efficiency of people involved (multitasking) instead of effective system, and negative consequences of human behavior like student syndrome, Parkinson’s law in traditionally managed project (portfolio with shared resources) environment. At the end, proposed solution will be described using TOC application for managing WIP called Critical Chain Project Management (CCPM).

The WIP refers to a component of a company's inventory that is partially completed. In IT environment, this means unfinished tasks. The main evils of high WIP are according to (Rohnen, Pass, 2007): reduced performance of the organization, long response times, reduction of throughput, high operating expenses, diminished quality, diminished response to market and technology changes, etc. As we can see from a Figure 2, the number of active tasks (work in progress) plays important role in project(s) throughput. The goal is to have right amount of WIP.

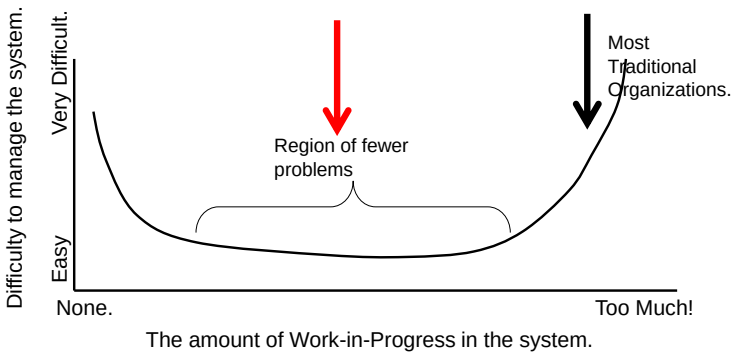


Figure 2. Bathtub approach. (Holt, et all, 2014)

As results, one of the first recommended activity, as described in (Rohnen, Pass, 2007), when organizational throughput is below expectations is to freeze or cancel at least 20 % of already approved project tasks or projects. With that the system will (short term) freed resources of some unproductive work and useless paper work (e.g., providing reports why they are late), and provide them opportunity to finish already started tasks / projects. First positive effective will be seen in short time, usually already in few months.

Moreover, resource utilization have deep impact of the performance of the organization. In order to understand this impact, Kingman's formula (Millhiser, et all, 2008) gives an approximation of the waiting time of the parts for a single process based on its utilization and variance. This equation (or more precisely approximation) shows two factors that influence lead time and queue length. One important factor is the utilization. The higher utilization it is, the longer is queue. Eventually queue will approach to infinity as utilization approaches 100%, as shown in Figure 3.

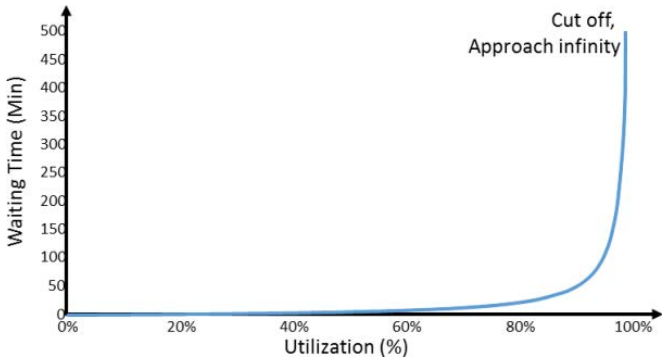


Figure 3. Interpretation of the Kingmann's Formula.

In order to understand impact of resource utilization, example of 5 interdependent people can be used. All of them are utilized 90%, means that every task will take approximately 90/10= 9 x longer than initially planned. Simple task of 1 day of work by every resource with 90% utilization (may) at the end take 9d x 5 = 45 days, as shown

in Figure 4.

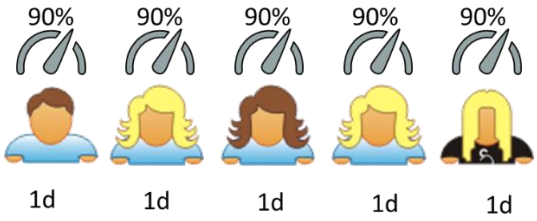


Figure 4. Resource utilization example following the Kingmann's Formula.

Next improvements is focusing to reduce multitasking. Multitasking is defined as activity when people tries to perform two or more tasks simultaneously, switching from one task to another, or perform two or more tasks in rapid succession, as described in (Realization b, 2019). Simple exercise, shown in Figure 5, can give good indication on throughput in multitask environment – should it be executed as indicated in first row or second row? Similar Online game can be found by using following URL http://bit.do/ePmau.

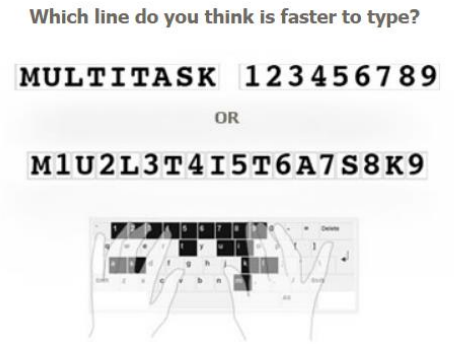


Figure 5. Effect of multitasking.

On individual personal level, research study (Realization a, 2019) shows that up to 40% of their (working) time people can waste while switching between tasks. The results on a system level, within organization, are even higher as described in research study. The main negative effects are related to unsynchronized priorities by people working on those tasks and high work-in-process for managers who are managing them. Unsynchronized priorities shows that people / teams instead of working together on the same streams in tandem to finish it, each person / team is focused on different streams and these streams (usually) that do not overlap. In addition, managers are flooded with too many active streams and projects at the same time that need to support, thus providing non-optimal support for people / teams that needs their support and proactivity. Results in this study shows that once multitasking was eliminated or reduced, organizations showed tremendous increases in throughput and significant reductions in delivery time. The mean throughput increase was almost 60% and cycle

time was reduced by 31%.

According to described above, next activity according to (Holt et all, 2014) is to stagger projects (tasks) and identify how many active project can our organization sustain. Clearly, first top-priority project will have all available resources and it will able move very fast. Adding another project, and if there are no resource conflicts, the throughput of the projects it can be even doubled. With approving more projects in the system throughput will improve accordingly until number of project will saturate the system and throughput will start to suffer, as more and more resource conflicts between projects will be present. Adding more projects will even more drastically reduce throughput, until resource conflicts will be so high that the project throughput will almost stop and people will suffer from this chaotic environment (remember utilization issue and Kingman's formula).

As way forward to improve performance and effectiveness of the project teams is to introduce policy of approving new project / tasks based on highest business / customer value and availability / utilization of critical resources. In organizations, that cost accounting is main tool for approving projects, a lot of effort is spent on unproductive work, usually done by the most experienced and critical resources – detailed estimating of needed workload for project. On the other hand, as indicated in (Agile Upgrade, 2019), estimated are always wrong. Therefore, simplified solution for workload estimates should be used in order to increase availability of critical resource - can be used like they are known in Agile project management environment (Usman et all, 2015). As result, changes of policy how are estimates done and used, including associated project approval process is needed. Once this will be used, the availability of critical resources will increase and additionally improve throughput of the system, project teams.

The powerful and robust TOC solution that is intended to manage the flow of work through a (development) process rather than managing the capacity of resources is called Drum-Buffer-Rope (DBR) (Aljaž, 2014). It is designed to protect against general cause variation that cannot be removed from the system and some special cause variation (e.g., Murphy). As basis for its work, it uses first three steps of five focusing steps defined by TOC: Identify the system constraint, decide how to exploit the system constraint and Subordinate everything else to the above decisions. Basic principle of DBR is shown in Figure 6. As it can be seen, Workstation C is the weakest link – constraint of the system. Therefore, we need to control the pace of new tasks / material based on the pace that Workstation C can handle. Moreover, Workstation C has also a buffer in order to protect itself against variability and Murphy of execution done on first two workstations, Workstation A and Workstation B, respectively.

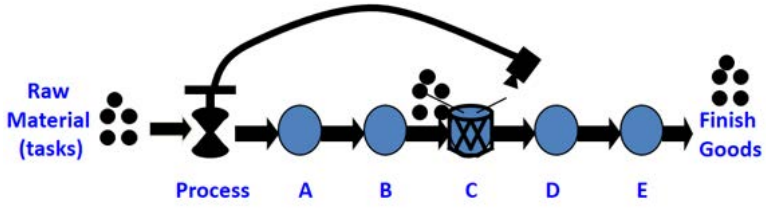


Figure 6. Basic principles of Drum Buffer Rope (DBR).

With DBR approach, we can identify that some of the Workstations will be part of the time idle, due to the "rope" process of the DBR – not releasing more tasks / material as constraint (Drum) can handle. That approach is contradictory to well established work policy, where people needs to work e.g., 8h per day, 40h per week – if there is no work available, managers are required to find it. Clearly, change of organization working policy, associated measurements and cultural changes needs to be addressed in order to full utilize the performance improvements that can be achieved using DBR approach.

In order to address management of project portfolio with shared resources, DBR-like approach for project management TOC defines CCPM (Millhiser, 2008). It should be noted that CCPM is not only project management methodology, but in their core also address human behavior in project like student effect ("Why to do today what you can put off to tomorrow), Parkinson law (Work expands to fill the time available) and protects against Murphy (if something can go wrong, it will go wrong).

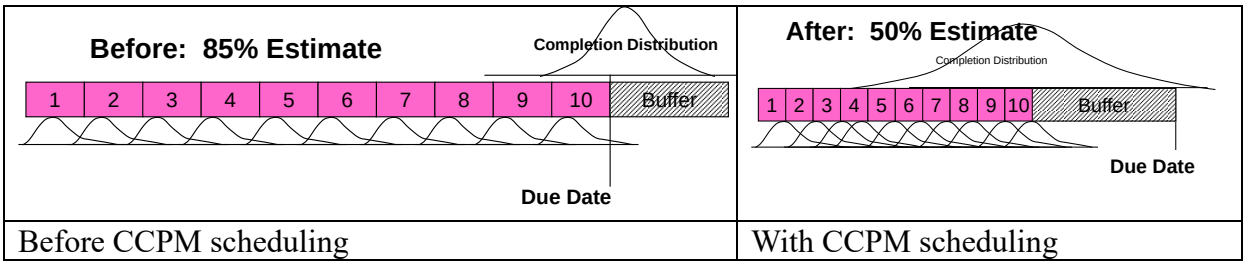


Figure 7. Example of CCPM scheduling. (Holt et all, 2014)

Moreover, CCPM does not change the logic of the project tasks, it just shorten task duration for 50% and put 50% of removed safety back in project strategic place – project buffer (variation can be better used on central place as on individual tasks). As shown in Figure 7, there is in each project tasks buffer (safety) and all tasks are estimated with 85% confidence level. If we add additional buffer at the end of the project to protect due date, the impact of student syndrome and Parkinson law will have negative effect. With 50% reduction of task and returning 50% of the safety back in project buffer, results in reducing project lead time for 25% percent. Example before and after CCPM scheduling is shown in Figure 8 and Figure 9, using cc-(M)Pulse software add-on for MS Project 2007 (Spherical Angle, 2005).

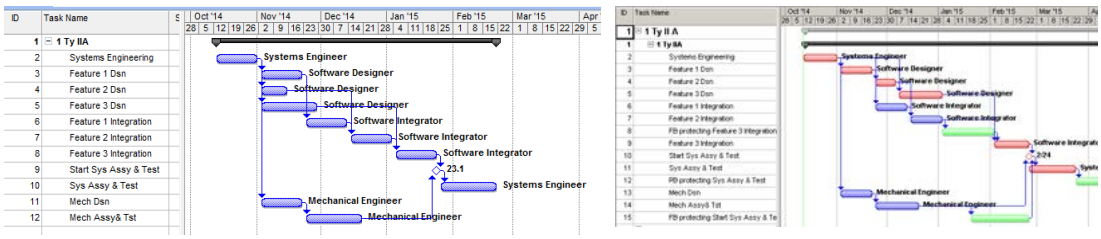


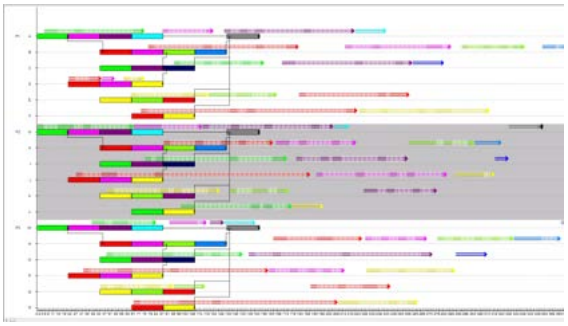
Figure 8. Simple project before applying CCPM scheduling.

Figure 9. Simple project with CCPM scheduling.

Having this approach in project portfolio execution also needs change of policy, rules, measurements and culture of working within organizations. Especially, it requires that resources are not any more accountable for their estimates. This strategy goes against the established management practice of "holding people accountable" for their estimates. Once trust is established and be accepted that buffer on project level is cumulative buffer (safety, prioritization) of all project tasks (on critical chain) and it is available for any project task will need it, the throughput of project portfolio will increase significantly – showing clear working priorities and focus.

3. METHODOLOGY, RESULTS AND DISCUSSION

It is very difficult to analyze the same project with different parameters and approaches, as we are not able to provide the same project conditions (even if the scope is the same). Thre are too many excuses and reasons for differences, too much variability in task execution and every issue is different. It is much better to use simulator to analyze one or more projects many times with different parameters and monitor the results. In order to do that PmSim simulator (Elyakim, 1998) will be used.



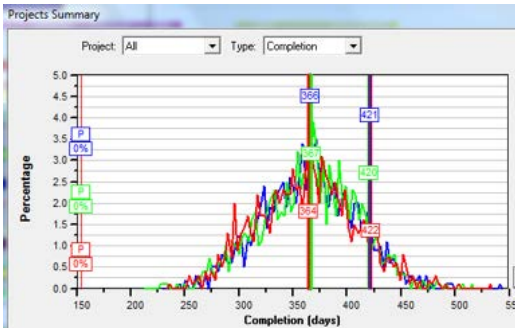


Figure 10. Results of project portfolio execution.

Figure 11. Distribution of project completion time and probability to be on defined time.

The Figure 10**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** provides simple project portfolio with three projects that share the same resources (each resource is marked with different color). All three projects are approved for execution on the same day. Planned finished of all project is 154 working days. Clearly, it can be seen that planned finished duration of all project is unrealistic. This is immediately visible on first simulation days, as the green resource cannot work on three projects simultaneously. As simulation is continuing, multitasking, student syndrome and Parkinson law comes into effect and results in a situation that no one from (top) management in a company would accept. This devastating effect is visible on **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** and **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**, where none of projects will be finished in planned duration, even more, expected duration to complete project has increased from

154 to 421 days, with 90% probability – almost 3 times longer than planned. Simulation was done with 1000 runs.

In order to improve situation, first step of five focusing steps of TOC it will be used – identify system constraint. Using data from Figure 10**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**, it can be identified that Resource red is system constraint and it is limiting project(s) throughput. Next, following second step of five focusing steps, it needs to be decided how to exploit systems constraint – resource red needs to have clear task priorities that needs to execute. As result, it will improve its effectiveness by reducing time wasted on multitasking, especially jumping from a project to a project. Moreover, all other resources need to subordinate to this decision – third step of TOC. This is called staggering, as shown in Figure 12.

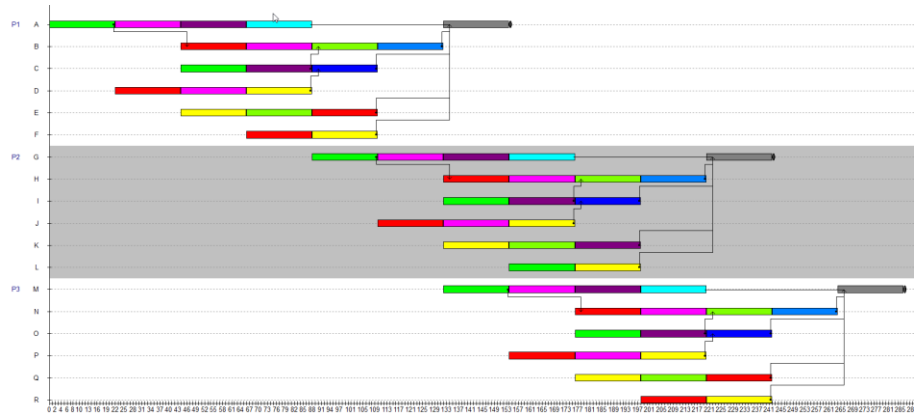


Figure 12. Planned project portfolio with staggering.

With staggering on project portfolio, as shown in Figure 13**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** and **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**, situation slightly improved, thus first project has 24% probability that it will be finished on predicted duration, realistically it will take about 201 days - almost 30% longer than planned. Remaining two projects face negative effect of Project 1, having a lot of multitasking due to prolongation of first project tasks and unclear working priorities, thus predicted finish in 310 days and 378 days, respectively.

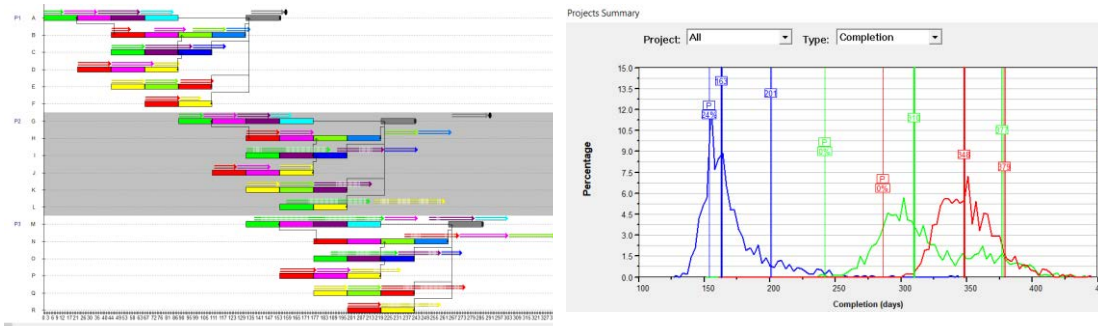
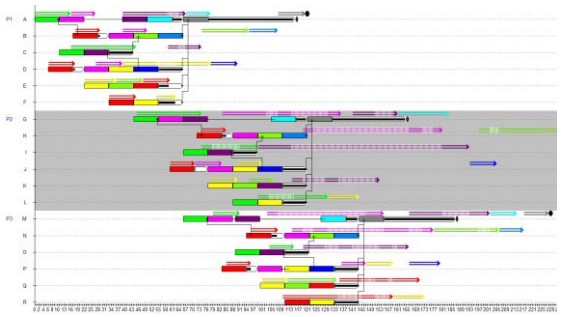


Figure 13. Results of project portfolio execution with staggering.

Figure 14. Distribution of project completion time and probability to be on defined time with staggering.

As it was identified in previous paragraph, only with staggering based on constraint resource, it will not provide desired results. Improvement related to project execution and interdependency of constraint between projects needs to be addressed. In this paper it will be presented well proven solution of TOC related to project management – CCPM. Project plan remains the same, only the duration of task and how we are managing execution is changed, focusing to address multitasking issues and human behavior (student syndrome, Parkinson's law), as described in previous chapter.

The results are better as in previous example, thus first project is predicted to be finished in 117 days, second project finished in 165 days, and third project finished in 219 days with 90% probability, as shown in Figure 15 and Figure 16**Figure *18***. On the other hand, initial estimation of the project durations (project end date) were not satisfactory, first project will be finished in planned date with 83% probability, second with 34% probability and thirds with only 25% probability, respectively.



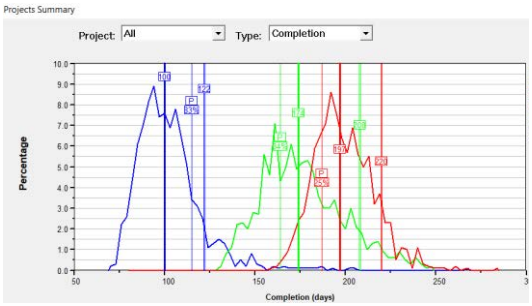


Figure 15. Results of project portfolio execution using CCPM.

Figure 16. Distribution of project completion time using CCPM.

Unfortunately, this approach has one major drawback. It is not taking account that constraint resource (in our example resource Red) has also variability and uncertainty in its task execution. Therefore, if any deviation in task execution from reduced tasks estimates (due to issues, uncertainty, Murphy, and higher priority tasks) is in place, it has direct impact on the tasks on the other portfolio projects. This is not desired situation. As results, and to give realistic project plans, it is needed to add buffer (safety) at constraint resource, called drum buffer, and is placed before a constraint resource on a project level.

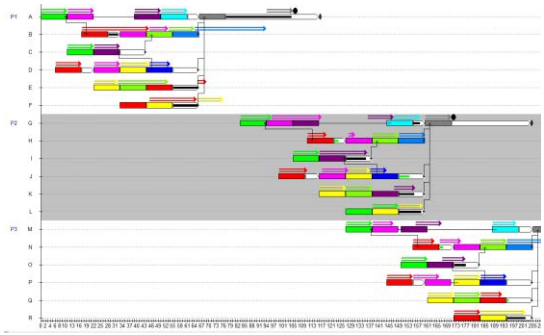


Figure 17. Results of project portfolio execution using CCPM, with 100% drum buffer.

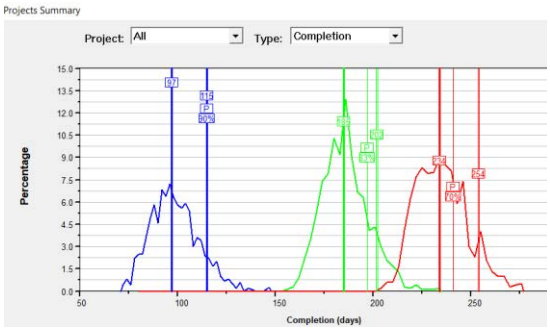


Figure 18. Distribution of project completion time using CCPM, with 100% drum buffer.

In our example, it is estimated 100% drum buffer, to buffer variability and protect against Murphy. This example with 100% drum buffer results in additional improvement on project portfolio level, having first project finished in 115 days, second project finished in 202 days, and third project finished in 254 days with 90% probability, as shown in Figure 17 and Figure 18. Moreover, initial estimation of the project durations (project end date) are now significantly improved first project will be finished in planned date with 90% probability, second with 83% probability and thirds with 70% probability, respectively.

4. CONCLUSION

The failure rate of IT projects is high and even when they are successfully completed that success is difficult to replicate across the portfolio of projects. The main question arises – how we can improve of management of portfolio of projects in order to have predictable results. This paper presents common sense approach supported by Theory of Constraints tools and applications how to manage portfolio of projects. This approach is in many cases contradictorily to existing way of managing portfolio of projects with shared resources, where most of the projects flow "the best they can" throughout the system. Change of existing working policies, rules (and measurements) and even a culture within organization is required. Managing the load towards the (critical) resources and having clear priorities enables increase of the performance of the project portfolio – system, thus leaving behind individual effectiveness. Simulations demonstrate that staggering the release of work into the system reduce workload on most critical resources and increase predictability of project deliverables. Moreover, introducing CCPM methodology in project portfolio, addressing also human behaviour like student syndrome and Parkinson's law, additionally improve the performance of the portfolio – system.

Finally, in this paper it was presented that different way of working can produce meaningful results, especially if address properly – towards the system constraint. Tools and applications of TOC can help reaching this goal to build highly efficient project team, boosting throughput on project execution and to deliver as many of them as possible without jeopardizing scope and allocated budget, all with existing resources and without changes how project tasks are executed.

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FAST PRINTED CIRCUIT BOARD PROTOTYPE PRODUCTION LINE IN EDUCATIONAN ENVIRONMENT

Bertalan, Beszédes[1]

[1] Óbuda University, Alba Regia Technical Faculty

Székesfehérvár, Hungary

beszedes.bertalan@amk.uni-obuda.hu

ABSTRACT

This paper is proposing a production line, what is used for research, and in blended-learning course of Electronic Technology, Electrical Manufacturing and Testing, and Electronic Design and Fast Prototype Production targets to designing printed circuit boards, and manufacturing files, as well as to handle PCB designing software environments, in order to manufacture prototype electrical circuits. The article presents several concrete examples of the application of various rapid prototyping technologies, what is used in education.

1. INTRODUCTION

The purpose of prototype production is to create a component or module that can be used to perform various tests during product development. ECAD / ECAM systems and rapid prototype manufacturing processes significantly accelerate the product development process, however, the usage of the conventional breadboards, perf boards(prototype PCBs) and development boards are also indispensable.

The fast prototype production line is capable of producing many different models. Depending on the needed technology, there are many different procedures involved. Each main technological step belongs to different stations. The common feature of each station is that human intervention is required to operate it.

Figure 1 shows the relationships between the most commonly used procedures. The diagram gives an overview of the applicable design methods. If we create the ECAD model of the module, we can reduce the lead time by performing virtual tests or make the prototype module based on the ECAD model. Manufacturing can be done with fast prototype production, or with manual soldering on prototype board.

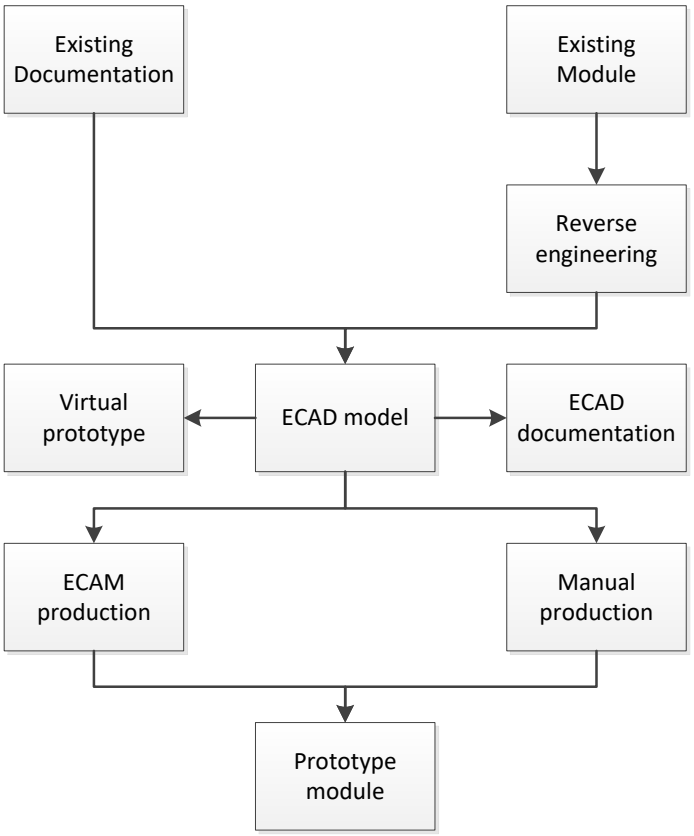

Figure 1. Prototype production method.

2. FAST PCB PRODUCTION LINE DESCRIPTION

The physical location of production line modules can be seen in Fig. 2. It is located in a square based room. Each block in the figure below represents a physical module, which implements a process station. Each module is an individual workstation, which requires human intervention.

In Fig. 2. a simple workpiece path is also shown – as an example. The workpiece path depends on the needed a technological steps, it can contains multiple loops, it can swap work stations, or it can skip stations.

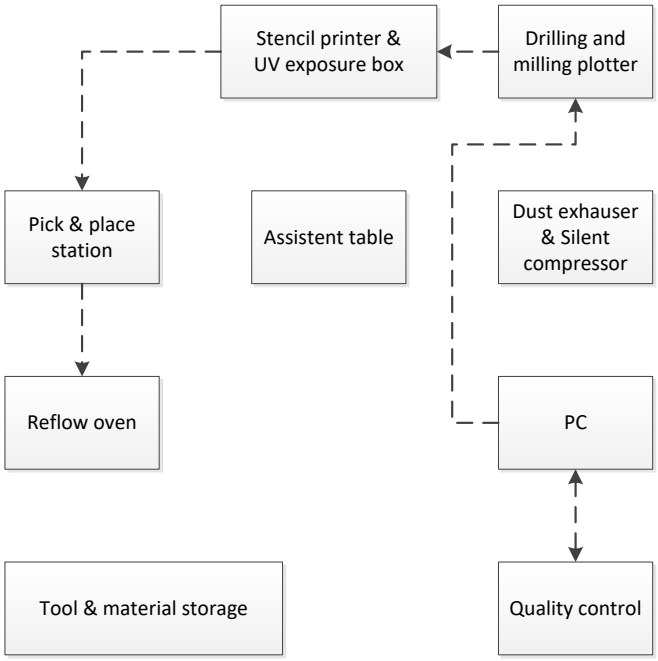

Figure 2. Physical location of production line modules and an example for workpiece path.

2.1 Substrate

The base material, or substrate, is usually fiberglass for research purposes, and bakelite for educational purposes. This solid core gives the PCB its rigidity and thickness. It is possible to use different thickness. The most common thickness for the products is 1.6mm (0.063"). Some of the products use a 0.8mm thick board.

2.2 Circuit without substrate

For simple circuits, for quick tests it is useful to quick solder together the components without any substrate. It gives proper galvanic connection between the components, much better than a breadboard. Disadvantage is that the uninsulated components legs can cause a short circuit and it need to soldering for modification. Fig. 3 shows an example.

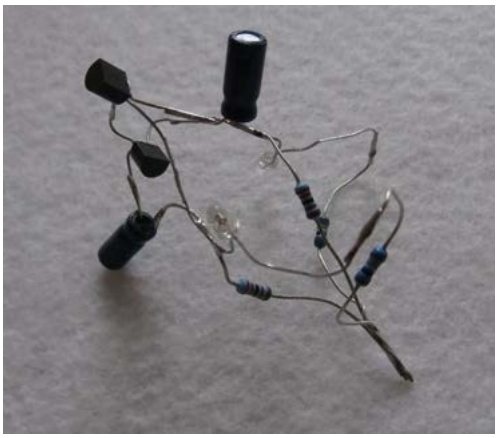

Figure 3. Physical location of production line modules and an example for workiece path.

2.3 Proto board as a substrate

With a proto board it is possible to prototype more complex circuits, but still have limitations in complexity. Proto boards in most case, single sided boards, easy to solder, and gives proper substrate to the circuit. It could take a long time to solder circuits with numerous lines, sometimes lot of external wires are required, and harder to find mistakes. Fig. 4 shows an example.

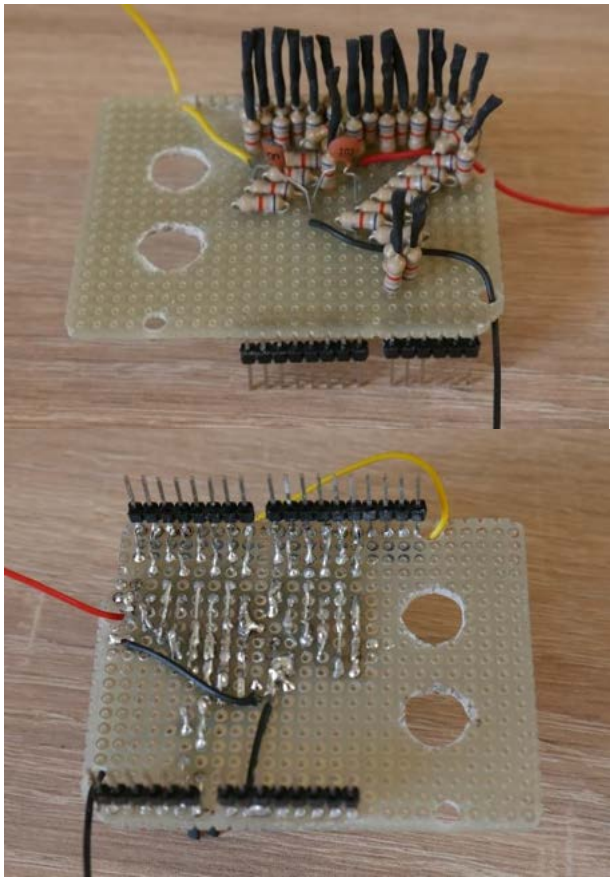

Figure 4. Proto board circuit top and bottom side.

2.4 Etched PCB

PCB etching methods are not used for because of hazardous and toxic chemical liquids and gases. That is why the PCB milling machine is chosen for prototype production, it also can produce the required quality.

2.5 Adapter board

The usage of an SMD/THD adapter board can make the soldering and wiring method much easier, and much reliable prototype can be made. Different type of adapter boards are exist, for different SMD IC pitch sizes 1.27mm, 0.8mm, 0.65mm, 0.5mm, stc. The most commonly used are SO and QFP packages adapted to DIP packages. Fig. 5 shows an example.

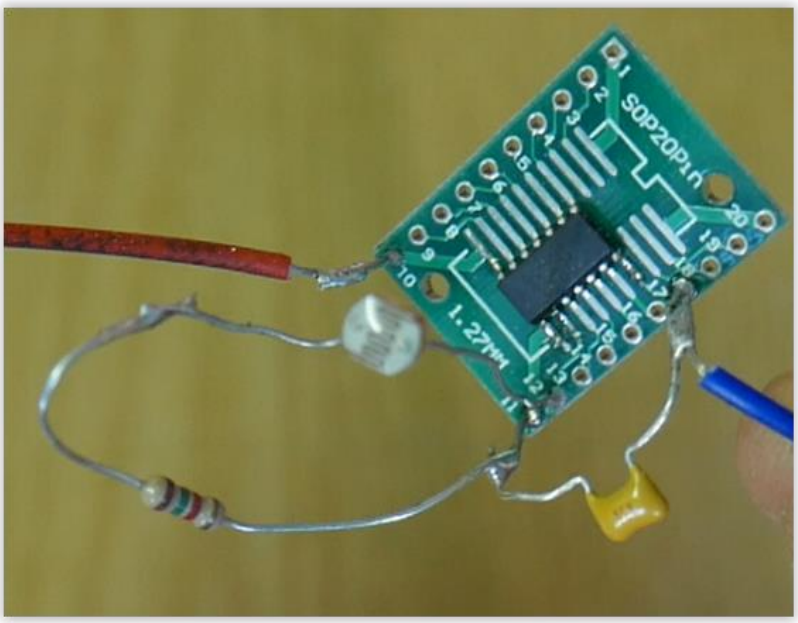

Figure 5. SO IC mounted on adapter board.

2.6 Front panel

With the milling plotter a – for example instrument – front panel easily can be made. The baseplate can be bakelite or fiber glass PCB – in the last case, single sided PCB is recommended. Fig. 6 shows an example.

Figure 6. Front panel example (back panel).

2.7 Milled PCB

The final product of a milling machine can be seen in Fig. 7. It is a double sided PCB without through hole galvanization, soldermask or silkscreen. Vias had been made by thin resistor legs.

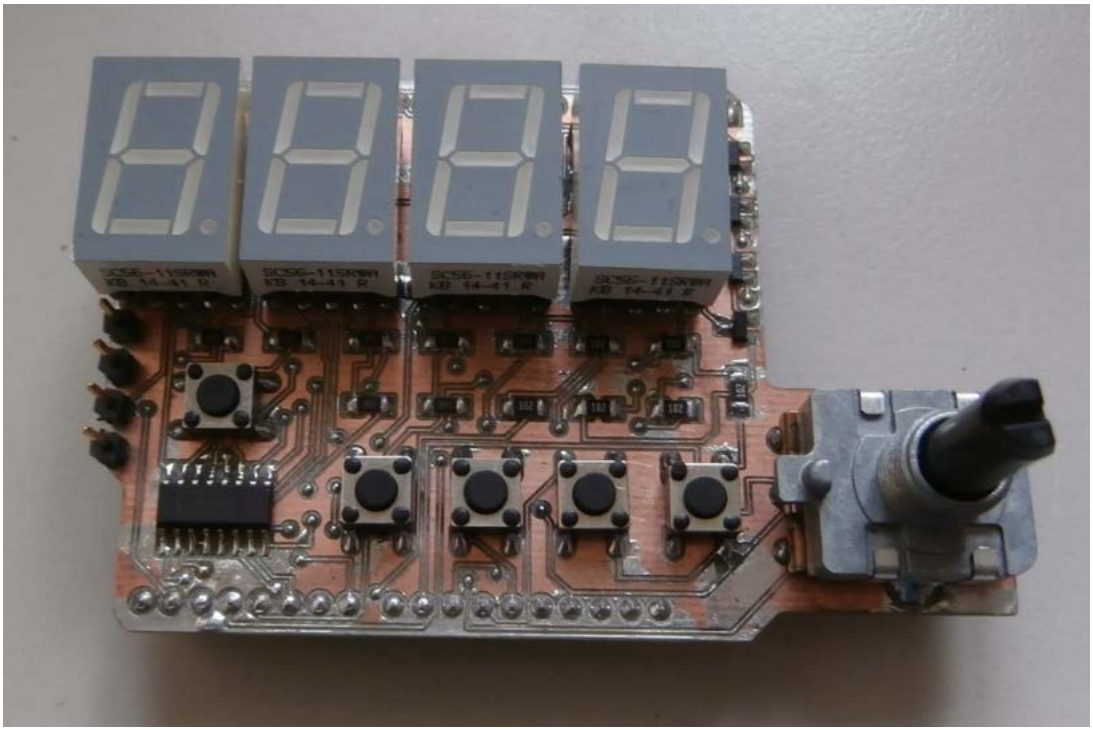

Figure 7. Milled, assembled PCB.

3. USED TECHNOLOGIES

The choice of material, the choice of parts, the manufacturing technology, the choice of component and board size depends on the purpose of the test. In addition to the classic manufacturing processes, prototype manufacturing technologys are expanded the capabilities of the designers over the past decades.

3.1 Manufacturing technologies

The prototype PCB – what is used in education – can single of double sided, it can contain surface mounted or through hole components (or both). As an option the PCB can contain a soldermask or silkscreen technological step. At both case the proper chemicals, the UV exposure and the reflow oven and a laser printer also used.

Component implantation and soldering can be done with hand, or with equipment. (It may also be mixed.) If soldering is going to be with the help of the reflow oven, then the PCB need to be pasted with the stencil printer. For the stencil printer, the stencil need to be made with the milling machine, from the proper manufacturing files. On Fig. 8., the technological steps are summarized in a flowchart.

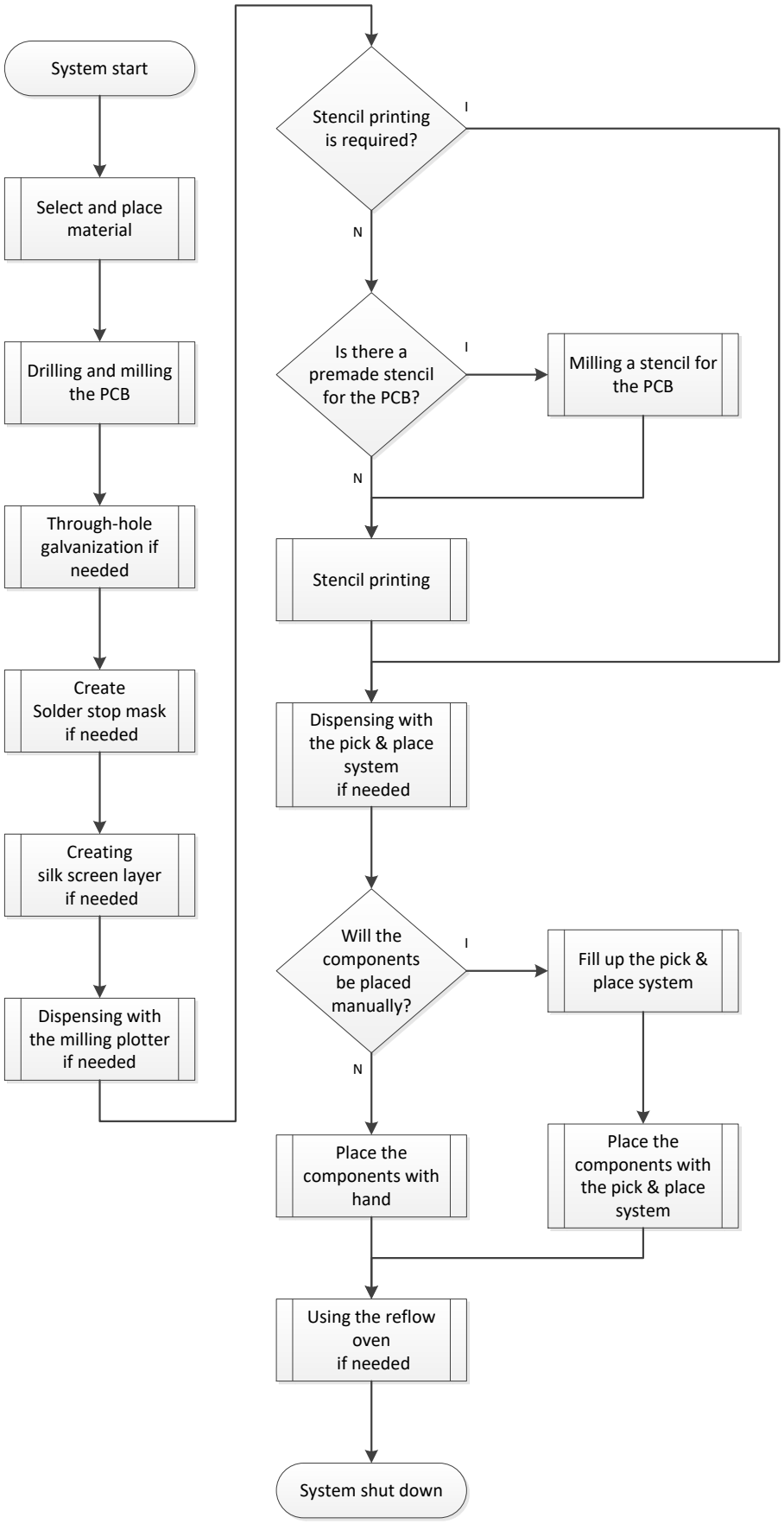

Figure 8. Technological flowchart.

3.2 Milling and drilling station

Among the workstations, the milling machine is the most used and the most complex. With the help of this station, front panels, single or double sided PCBs, stencils can be made. In the lab, polyimide stencils can be fabricated (not stainless steel stencils), because it can tolerate the high temperature of the cutting process.

For double sided boards, fiducial marking drills are made. After milling the first side of the board, the board need to be flipped, and the fiducials will give the new position of the workable area of the board. A built in camera system will locate the fiducials, and make sure that the top and the bottom side of the PCB is cover each other exactly. On Fig. 9., the task execution order are summarized in a flowchart.

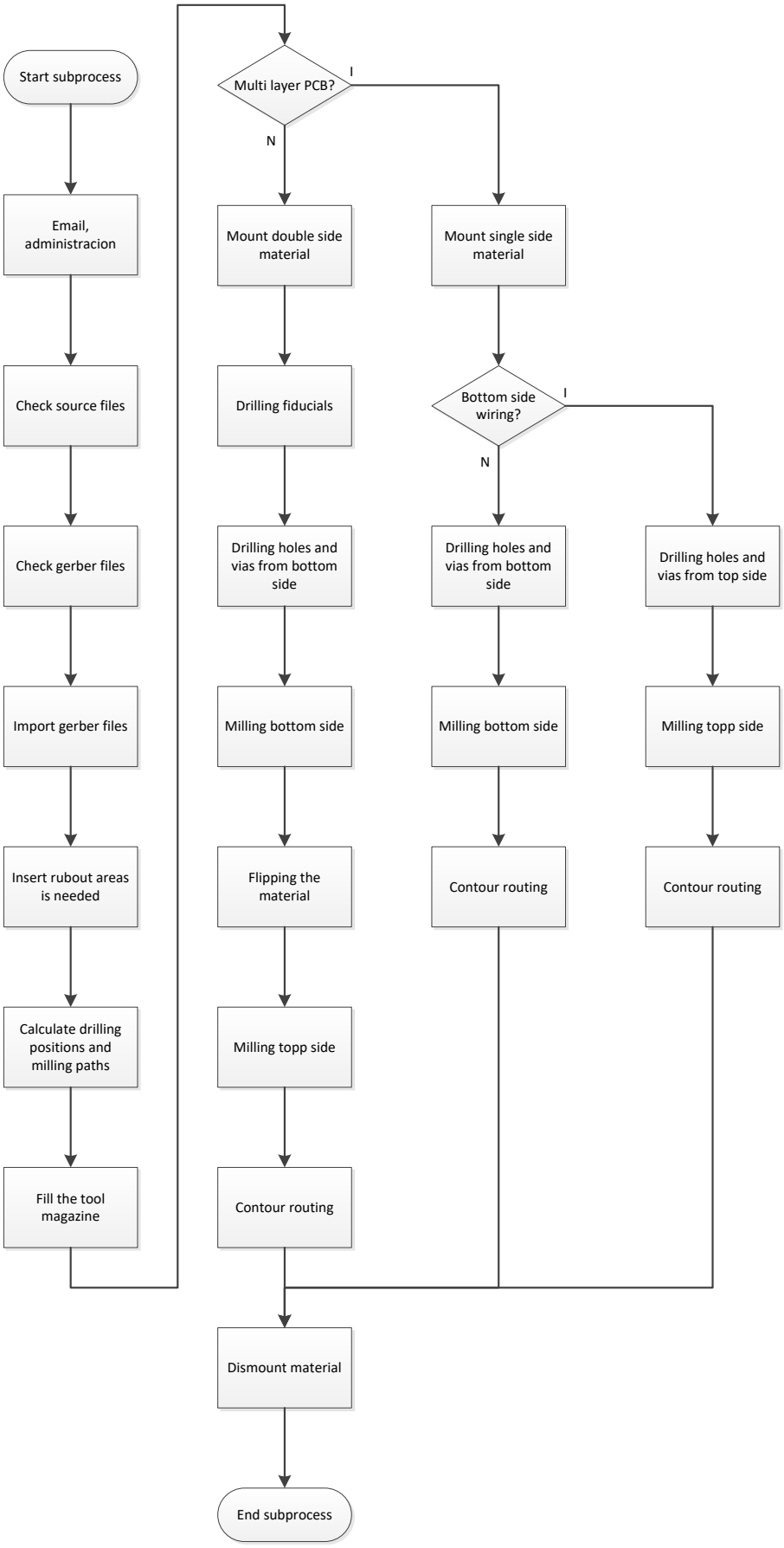

Figure 9. Milling and drilling station task execution flowchart.

3.3 Used softwares

For research and for educational purposes Autodesk Eagle is used as the ECAD software, and CircuitPro is used as the ECAM software. Further additional softwares are also used, for example, MicroCap for simulation, Gerbv for checking gerber files.

4. CONCLUSION

The fast PCB prototyping production line provide a good in-house research and development solution. It is also very useful in educational environment. Students can learn all steps from design to production, and it is expose students to tools used in the commercial industry.

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BLENDED LEARNING: EMBEDDING GIT AND MARKDOWN IN AN IT CURRICULUM

Dams, T[1], D'Haese, D[1], Overdulve, K[1] and Vanthournout, G[1]

[1]Artesis Plantijn University College,

Antwerp, Belgium tim.dams@ap.be

ABSTRACT

This paper describes an innovative model to teach Git and Markdown using blended learning in a 3-year professional bachelor IT-oriented curriculum. We present 5 real-life use cases that demonstrate how our teaching model leads to a higher level of proficiency in applying these tools amongst our students. In particular, the use of Git improves inter-student collaboration and student participation significantly. We also present challenges faced when using Markdown to manage large written assignments, as well as future directions in fraud detection and learning analytics.

1. INTRODUCTION

Git is an open-source distributed version control system. It has become the dominant tool to share code within both the open source community and professional software development teams. Therefore, it is an invaluable skill for computer science curriculum. Markdown is a simple markup language that has emerged as the de facto standard to write documentation in the Git community. Starting from day one, we view Git and Markdown as an essential part of the curriculum that spans most course modules ubiquitously. This results in a high level of proficiency in applying the tools and an improved level of collaboration-related skills in our students.

In this paper, we describe an innovative teaching model we introduced in our department (bachelors Electronics-ICT and applied informatics). Teaching Git in a computer science curriculum is not new (Chatley, 2019) (Cochez, Isomöttönen , Tirronen , & Itkonen , 2013) (Blauw, 2018) (Angulo & Aktunc, 2018) (Seongtaek , Adithya Varanasi, & Parikh, 2018). Nevertheless, our model embraces blended learning in order to have a less formal way of teaching Git and its related components in a cross-curricular manner. We also present specific use cases in how to apply our model to maximize the learning rate of Git in students.

2.1 GIT

The adaptation of Git world-wide has surpassed that of centralized source code versioning systems such as SVN and CVS (Thompson, 2019). There is no definite answer as to why Git has gained its dominant position. We do know that it quickly

gained a lot of traction in the open-source community as it was written by Linus Torvalds and used to provide version control for the Linux kernel. There is a clear correlation between the rise of GitHub Inc. as a cloud-based hosting platform for Git repositories and the increase in popularity of Git.

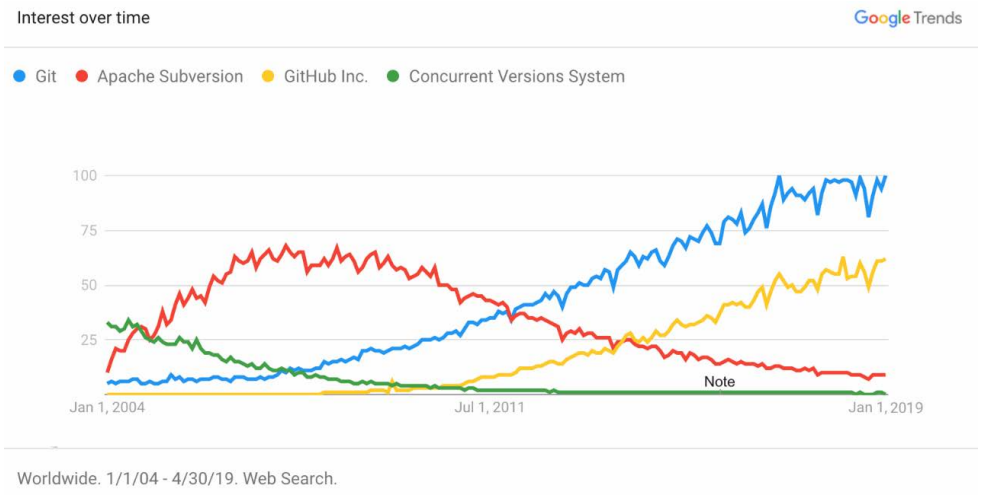

Figure 1 Google trends clearly shows the rising popularity of Git and GitHub throughout the years (Google Trends, 2019).

A clear difference between Git and earlier centralized source code versioning systems is its distributed nature which provides several benefits, such as:

- One does not need a centralized server to host the source code. A Git repository can be created on a developer's machine and provide source code versioning without going through the configuration and setup of a server.
- The distributed nature of Git works well in an open-source context where maintainers of popular software repositories want to avoid giving "untrusted" developers permissions to their central repository with the possibility of them breaking functionality. Instead, Git allows developers to fork (public) repositories, make contributions and request to have those contributions added in the central repositories through pull requests. Large corporations - even when not making their repositories public or contributing to open source projects - have found this distributed model to be an efficient way to break large teams into smaller subteams, each with their own fork in which contributions can be made to the main repository.

Realistically though, in terms of infrastructure, most small and medium-sized teams use Git similarly to how CVS and SVN were used: through a centralized repository that individual developers clone and to which they push changes.

Since the inception of Git, Linus wanted to make branching in software repositories an easy and common operation that developers could use. Until then, SVN/CVS users would generally work on the 'trunk' branch and hardly ever change branches. Git changed this model and made branches first-class citizens that are often

used efficiently. By using branching efficiently, developers can work on multiple features at the same time, store work in progress to perform a hotfix in production, have their code reviewed through pull requests, and so on. Efficient branching strategies such as Git Flow can also ensure that new features are pushed from feature branches to 'next release' branches without impacting the stable 'current release' codebase.

Until now we have described Git as a distributed version control system, but it has been used for a lot more than that. In addition to version control, it has been used to host and backup source code in cloud-based hosting platforms such as GitHub, Gitlab, Bitbucket; to share code; as a very powerful undo tool; as a history tool and a log book; an accountability tool ; as a code review tool and as a debugging tool.

2.2 MARKDOWN

Markdown is a surprisingly simple markup language that originated in 2004 (Swartz & Gruber, 2004). It is well-integrated into GitHub and the default markup language used for the `Readme.MD` file. It allows custom formatting using plaintext files and is well known for its use of the hashtag prefixes to indicate the heading level but also allows for tables, lists, references, and other formatting as demonstrated in Figure 2.

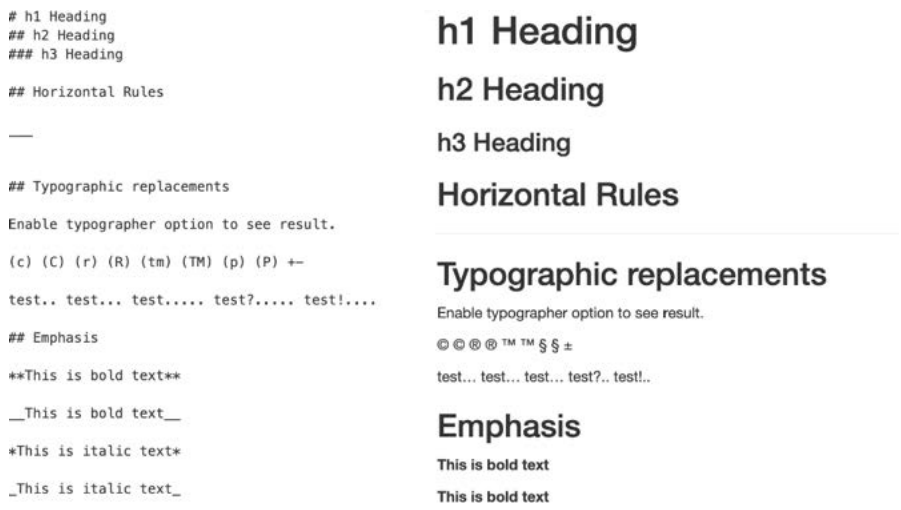

Figure 2 Example of how a Markdown document (left) is compiled to a formatted document (right)

The main advantage of Markdown is that it allows separating content from formatting. Also, Markdown is written in plaintext files, allowing the files to be versioned effectively using Git. When the author prepares a document in Markdown format, the reader can choose the formatting style to render it with; for the web, for PDF reports, …. Additionally, Markdown allows for mixing human languages with programming languages and mathematical formulas in a single document. With the proper plugins, code snippets are being rendered with programming language-specific highlighting and regular text is checked for correct spelling and grammar.

2.3 BLENDED LEARNING

Blended learning refers to the deliberate blending of face-to-face and online instructional activities, with the goal of stimulating and supporting learning (Boelens, De Wever, & Voet, 2017). With the enduring growth of ICT in education, this approach to teaching and learning has been implemented (and studied) frequently (Drysdale, Graham, Spring, & Halverson, 2013). The continued interest in the design of effective blended learning environment is partially triggered by the notion that it offers opportunities for optimizing learning with regard to the development of students' self-regulation of their learning process and the acquisition of job-relevant skills and competences (Spranjers, et al., 2015) (Van Laer & Elen, 2018).

3. OUR TEACHING MODEL

For several years, we employ a progressive model for teaching Git. It can be used as a guideline, allowing teachers to know what can, and cannot be expected from students at a certain point in a 3- year curriculum. Consider this model as a baseline from which teachers are allowed to deviate in their respective classes.

In this model, we broaden the scope of what we expect from students when using Git throughout the 3-year professional bachelor program:

- In the first year, students learn how to create their own local Git repositories as a versioning tool and how to use basic commands. Note that at this point we don't use GitHub or other cloud-based Git hosting platforms. Everything is done on the students' personal laptop in 'single-user' projects.
- In the second year, we use Git as a collaboration tool by introducing remote repositories and services (GitHub, GitLab, etc.) and its related commands. Students learn how to use Git in small team projects (max 4 to 5 students) and how to deal with merge conflicts. Simultaneously, they learn more advanced Git topics such as bisecting, (interactive) rebasing, reflog, structuring of Git commits, etc. theoretically.
- In the third and final year, students apply these advanced topics and apply them in long (>4 months) and big (>5 students) team projects. Students are forced to follow the Git flow branching strategy and contribute changes through pull requests.

There are three main reasons for applying a progressive model to teach Git.

Firstly, good teaching with a maximum learning impact should challenge students just beyond their current capabilities. Git, not unlike software programming, mixes basic and more advanced concepts. Just like we do not explain variables in the same lecture as metaprogramming to create domain specific languages, we do not teach based Git commits in the same lectures as reflogging or interactive rebasing. Nevertheless, this is what a lot of workshops on Git do. We noticed that students could efficiently learn how to create commits in the master branch and push them to remote repositories, but completely lose track when moving on to branching, merging,

conflicts, and so on. Recently, we also introduced Markdown in our model for written documentation.

Secondly, by using Git cross-curricularly, students discover the productivity benefits of using Git across a wide range of course modules. The first year's assignments contain rather simple individual assignments for which disciplined Git use, branching and merge conflicts is largely irrelevant. When moving to larger and more complex team assignments, however, students are faced with challenges on how to share code, how to work on the same files with potential conflicting changes, and so on. We then address these challenges by teaching the relevant Git concepts.

Thirdly, our model of teaching Git follows a similar trajectory as the required Git expertise for professional developers. Junior developers in established software teams generally only commit and push code in feature branches but do not have a final responsibility in the quality of the software process. When moving on to becoming medior developers, they get the chance to review contributions of other developers and to give comments on how well they perceive that best Git practices and good software development principles were applied. Senior software developers and team leads have a final responsibility in making sure a proper development process is followed with high-quality software as a result. Especially when leading a team that is part of a larger organization working on a specific product, you want to make sure that the code that your team produces is well written, does not accidentally break the software or build process of other teams, contains modular Git commits with helpful commit messages, and so on. If code produced by your team member does not adhere to high-quality standards, it requires more advanced knowledge of Git to be able to clean up the situation by editing the commits that introduced bad source code, rewording commit messages, rearranging the commits to be more logical, and so on. Additionally, you are the go-to person when a team member messed up to for example recover lost commits when a team member can no longer find yesterday's work.

4. RESULTS

As a result of introducing the teaching model in a cross-curricular fashion, multiple lectures have developed non-trivial use cases that we did not originally envision. We sorted these use cases in increasing order of complexity.

4.1 CASE 1: ADVANCED TEAM COLLABORATION

In addition to the standard benefits of Git such as version control and backup, Git also provides import benefits from an educational point of view.

- It gives a centralized overview of all the group projects, including issue tracking, source code contributions, documentation, communication, etc.
- It allows us to evaluate individual student's contribution to the group performance by using Git(hub) activity reports, in combination with formal peer evaluation and a permanent process evaluation an example of

which is shown in Figure 3.

- Students can continue working on projects started by other students in previous years.
- By forcing students to follow a code review process, they learn to critically evaluate their own contributions and the contributions of their fellow students. The latter allows them to learn from their peers and to break free from personal biases.

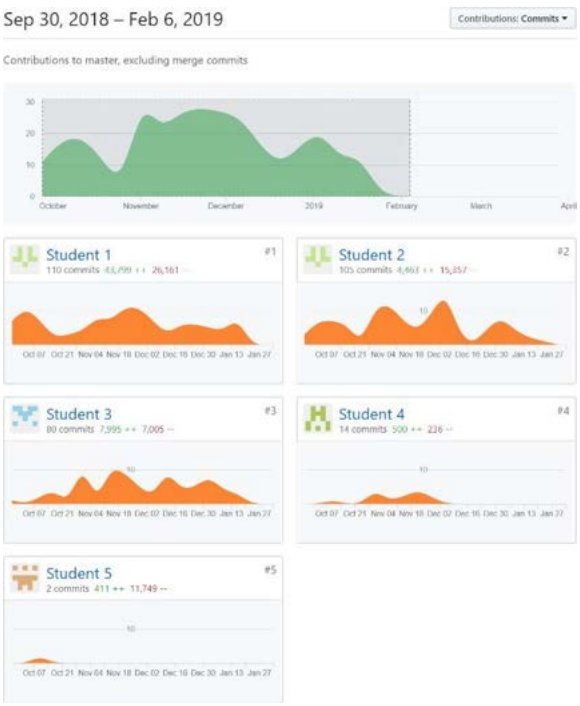

Figure 3. Thanks to the insights module in GitHub, teachers have a high-level overview of the development process. In this (redacted) example, student 4 and 5 had a low impact on the project result.

4.2 CASE 2: GITHUB CLASSROOMS

GitHub Classroom is a free to use platform specifically designed for academic institutions. It gives the institution an organizational GitHub account. Teachers benefit from tools to more quickly create and manage the relevant repositories of a single course module or assignment.

Students can either create their own repositories or choose to be added to a repository created by a classmate. GitHub automatically takes care of the scaffolding part of the project setup. At the time of writing, we have over 550 repositories (most of them private) that were created by students since 2014.

4.3 CASE 3: GITBOOK SYLLABI AND STUDENT PARTICIPATION

GitBook is a commercial platform to host online syllabi with free-to-use licenses on request. It uses a powerful WYSIWYG editor that uses Git internally to add

version control to documents, without requiring explicit Git expertise from the author(s). As an alternative to their commercial hosting platform GitBook has also released open-source tools to host your own document and generate pdf and e-book (epub, mobi) versions of syllabi with custom styling.

Currently, we host two online syllabi (Dams, 2018) (Van Houtven, 2018) that are used as required materials for the respective course modules. Student feedback has shown that there is a high appreciation for online syllabi.

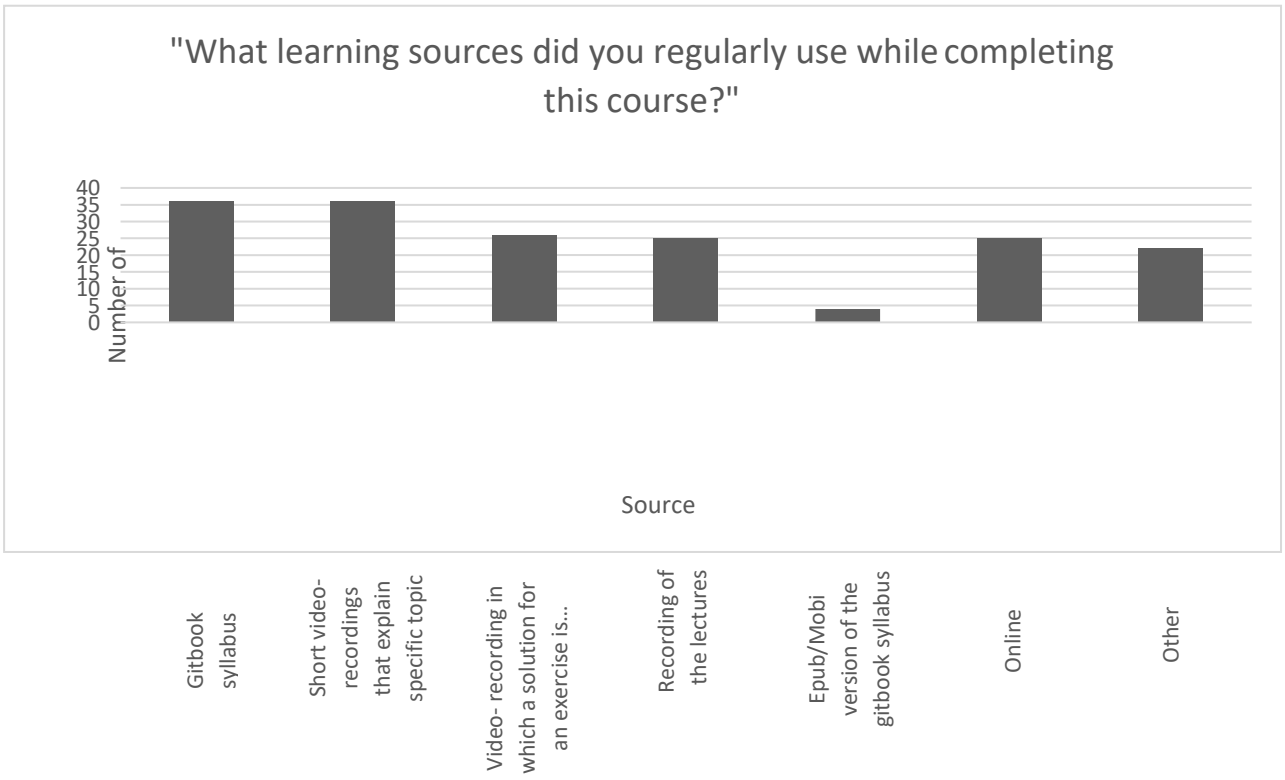

Figure 4 Questionnaire results after one semester in which students (year 1) followed a course module that included a GitBook syllabus. It was striking how many students that noted to appreciate the fact that the syllabus could be easily reviewed on their mobile.

The syllabi itself can be written in Markdown and hosted on GitHub. Every modification in the Markdown source material is immediately shown on the online syllabus, allowing typo corrections or additions to be made throughout the course module. Basic analytics are also included, allowing the lecturer to gain insights on how the syllabus is being used. For example, a list of most performed searches for a given period can be viewed. Users can also up and downvote pages, resulting in a "health-overview" per page.

Even though we only teach advanced Git concepts later in our curriculum, students are allowed to contribute to the syllabus by forking the main repository and creating a pull request with their changes. This teaches astute to help improve the

quality of the syllabus and apply advanced Git concepts realistically (similarly to contributing to open-source projects).

Several open-source alternatives to GitBook exist such as GitHub Pages and docsify.js. However, we chose GitBook because it is easy to use and allows (limited) free hosting, which facilitates setup by non-technical teacher teams.

4.4 CASE 4: MARKDOWN THESIS AND LAB REPORTS

We noticed an increase in the use of GitHub classroom and Markdown for non-programming assignments, such as (lab) reports, documentation and homework.

Since several years, bachelor theses of our students are written in Markdown and compiled to GitBook PDF versions. Even though this results in consistent and professional looking documents, some challenges remain with the use of third-party plugins and making the PDF output match the official University College template.

4.5 CASE 5: AUTOMATED REPORT EVALUATION

Continuing on the previous case, evaluating reports written through Git and Markdown allow them to be more efficiently evaluated, especially if several intermediate evaluations are organized to monitor the report process.

For the class of IT architecture, the reports of 18 groups were collected before the onset and at the end of 6 practical classes to check progress during and in between classes. In total, the exercise amounted to 11 versions per report resulting in more than 100 versions in total. Each group was given a template report containing all the necessary sections including detailed instructions on how to complete each section. Through this evaluation method, we were able to follow the evolution of the reports in time as demonstrated for four groups in Figure 5 below. Of course, such basic analyses can be extended with more advanced quantitative linguistic measures such as those representing information content and complexity.

Although not class-wide, the majority of the students indicated in an in-house survey that they were happy to use Markdown and understood its benefits.

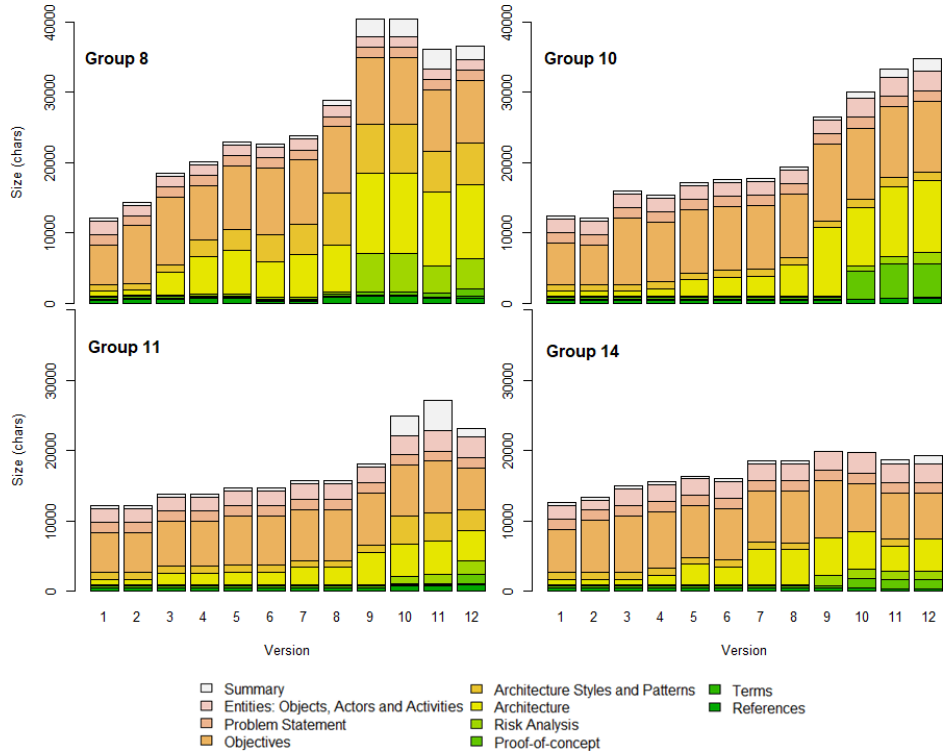

Figure 5: The progress of a technical report displayed for 4 (out of the 19) student groups. The 4 groups display varying overall sizes and a different evolution of their sections. Analyses were done in R (R version 3.5.1, 2018- 07-02) using the stringdistpackage to calculated similarity indices among strings (R Core Team, 2018).

5. FUTURE DIRECTION AND CHALLENGES

Currently, this is the third year in which we use the Git teaching model, meaning that our current last year students are the first to graduate under this model. Below is a digest of the experiences we had since the onset of the teaching model.

5.1 ACCEPTANCE

Firstly, students and teachers are rapidly becoming more fluent in Git and related technologies. Students now choose Git as their primary method of storing projects. Also, the 20+ companies in which our students complete their bachelor-thesis report that students are increasingly more adept in using in-house source-control and collaboration tools.

We don’t yet see the same appreciation of Markdown compared to Git within our student population. Some students would like more flexibility when styling their reports. Nevertheless, we find that a consistent, professional and uniform styling triumphs over the minor limitations in flexibility. Additionally, custom styling

plugins need to be developed for the generation process to make rendering PDF from Markdown adhere to the university college template more strictly.

5.2 COLLABORATIVE PLATFORM WITH CENTRAL SERVICES

At the time of writing, our central IT administration (supporting over 12000 students) has started using Gitlab for in-house projects. Students are allowed to participate in these projects on a per-project basis. We have proposed to broaden its scope and introduce a college-wide collaborative program in which staff and students can share projects and request help for specific tasks. These projects include menial tasks such as automation, utilities and scripting and more advanced topics such as the creation of a new module for our learning platform.

This platform would allow

a) non-IT-students and staff to more easily get in contact with more tech-savvy users;
b) students and staff to cooperate in a realistic business-like environment on software projects.

5.3 GIT FRAUD DETECTION

Automating assignment testing with Git is one step (Coleman & Sommer, 2018). However, we plan to go one step further and also integrate fraud detection on the assignments. Unfortunately, with improved means of communication, we have seen a significant increase in suspiciously similar solutions to homework assignments between multiple students. Detecting fraud is an important, but complex process that takes a lot of a lecturer's time.

Today, fraud is being detected ad hoc or by feeding the solutions through an automated plagiarism detector such as MOSS (Schleimer, Wilkerson, & Aiken, 2003) .Unfortunately, detecting fraud ad hoc only brings to light very obvious examples of copied code were wrong, ugly or illogical code is repeated over multiple solutions, thus triggering our memory that we have seen such weird constructions before. If we were to receive multiple similar good solutions without any obvious weird quirks in them, we have a much harder time in recognizing them as plagiarism.

MOSS detects plagiarism by comparing Abstract Syntax Tree similarity between multiple projects. This however only provides limited value as solutions to simple (typical first year) assignments will often contain strong similarities without the students having copied each other's work. MOSS can be used in later year large assignments, but as students generally add their personal flavor to those projects, it becomes difficult for them to copy each other's work because they are working on separate problems.

Therefore, a future goal is for us to turn to Git to help us make sure students submit original solutions to home assignments. Our hypothesis is that, even though

the solution to small assignments can be quite similar, the process to get to the solution should be unique to every student. Through evaluating the process, we can more clearly examine suspected fraud cases by verifying whether the solution is a logical result of the process. Suspicious patterns in the process would be a student abandoning a logical process to build a radically different solution that strongly resembles that of a fellow student; a student submitting a near identical solution *and* process to that of another student; a student having built a working solution in an unreasonably short amount of time; and so on. Ideally, we would leverage a tool that automatically evaluates the process - i.e. a tool similar to MOSS that also evaluates the process - but we need to turn to existing research to evaluate that option.

5.4 IMPROVING ON MARKDOWN WITH INTERACTIVE VISUALIZATIONS

When it comes to analyzing technical reports, we have seen that the use of Markdown – more than other formats – allows for efficient quantitative analyses on its textual content. We could extend these analyses to also include schematic diagrams (Kuosa, et al., 2016). Using vector-based formats such as the W3C standard Scalable Vector Graphics (SVG), we can make schemas within the reports searchable. For example, in the case of the architectural classes represented in Figure 5: The progress of a technical report displayed for 4 (out of the 19) student groups. The 4 groups display varying overall sizes and a different evolution of their sections. Analyses were done in R (R version 3.5.1, 2018-07-02) using the `stringdist` package to calculated similarity indices among strings ., we could analyze whether the labels represented in the architectural diagrams agree with the descriptions in the text (as was requested by the instructors).

It would also be feasible to analyze the nodes and edges of diagrams. As an example, it would be possible to automatically detect circularities in the database schemas. This would require students to use a standard software tool and/or format to draw the diagrams.

6. CONCLUSION

Through specific use-cases, we have demonstrated that Git and Markdown can facilitate blended learning. In order to maximize our student's proficiency in applying these tools, we have adopted a cross-curricular Git teaching model in a wide variety of course modules. Moreover, we introduced Markdown in a multitude of assignments, including the bachelor thesis. By sharing our findings, we hope to provide lecturers of technical subjects with a teaching model that simultaneously improves the adoption of Git and Markdown, provides new possibilities and reduces administrative overhead.

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FEM SIMULATIONS OF MATTER IRRADIATED BY LASER PULSES

Kaselouris, E[1], Orphanos, Y[1], Kosma K[1], Bakarezos E[1], Papadogiannis NA[1], Tatarakis M[1], and Dimitriou, V[1]

[1]Centre for Plasma Physics and Lasers, Hellenic Mediterranean University
73133 Chania and 74100 Rethymno, Greece

E-mail dimvasi@chania.teicrete.gr

1 INTRODUCTION

The study of laser interaction with solids, including laser produced plasmas, is one of the fastest growing fields of present-day physics. When a pulsed-laser irradiates matter, energy is transformed into electronic excitation energy and then transferred to lattices of materials through electron lattice interaction. The deposition of laser energy can produce a series of thermal effects, such as heating, melting, vaporization and phase explosion. Furthermore, effects such as ionization, plasma formation and plasma expansion as well as mechanical effects, such as material expansion, thermoelastic and plastic stresses may occur in the materials, Kaselouris et al. (2013).

Laser focusing on metal surfaces leads to the absorption of energy and a local temperature increase, with the released thermal energy subsequently expanding far from the interaction area, in the form of elastic surface waves, having characteristics dependent on the material, as well as on the laser energy and pulse duration, Davies et al. (1993). Femtosecond laser pulses interaction with metals consists of three main parts. In the first part, absorption of the laser energy occurs through photon–electron coupling within the femtosecond pulse duration. Next, energy distribution to the lattice through electron–phonon coupling occurs on the order of tens of picoseconds. Finally, energy diffuses into the bulk through phonon–phonon collisions.

We simulate the excitation of a gold thin film transducer deposited on a glass substrate by femtosecond laser pulses Orphanos et al. (2019). The numerical simulations are based on the combination of a finite difference two-temperature model with a finite element method model (TTM with FEM). The validated finite element model, Dimitriou et al. (2014), is extended to include the fs laser source excitation, provided by the TTM.

2 MATERIALS AND METHODS

The energy deposition by ultrafast fs laser pulses to the thin metal-substrate target is described by the TTM, Anisimov et al. (1974). To simulate the laser matter irradiation, a single-fluid 1D Lagrangian code is used. The material parameters evolution is described by the conservation of mass, momentum and energy, of electron and phonon subsystems. Regarding the laser parameters, the FWHM laser pulse duration t_0 is 35 fs, while the FWHM beam radius on the sample surface r_0 is 17.5 μm. The wavelength λ is 800 nm and the laser intensity profile follows the spatiotemporal distribution of Povarnitsyn et al. (2009). The system of equations is completed by the help of the semiempirical two-temperature multiphase equation of state (EOS) for Au, where the Thomas–Fermi expression for the thermal contribution of electrons is used, Shemyakin et al. (2010).

When thermal equilibrium of electrons and phonons is reached, the TTM results, considering the pressure distribution of phonons, provide the initial loading conditions to a 3D FEM model. The finite element model is developed in a commercial software, where the conservative equations of mass, momentum and energy are solved. The hydrodynamic and deviatoric behavior of the metallic target is considered simultaneously using an equation of state coupled with a strength material model. The 3D FEM model is quarter symmetric and simulates the transient structural response of a homogeneous isotropic target, composed by a metallic thin film over a BK7 substrate. The solid target dimensions are 1 mm × 1 mm × 100 μm. The Au film has a thickness of 500 nm. Symmetric boundary conditions are imposed on the two symmetry planes and reflective boundary conditions on the two sides and the bottom part of the target body. With respect to the initial conditions, the data for pressure ion distribution along the depth of the target are induced as initial conditions to the FEM model, from the TTM model simulation results. Due to the high values of pressures, that overcome the yield stress of Au, plastic deformation is induced and a compressive stress distribution in the irradiated volume is formed. It is assumed that the pressure follows a spatial radial distribution given by Arif (2009). The opto-mechanical properties of Au and BK7 as well as the temperature-dependent properties of Au are adopted from literature, Dimitriou et al. (2013).

3 RESULTS

Elastic waves on the sample target composed by an Au film of 500 nm thickness over a BK7 substrate of 1 mm thickness are generated and studied. The film is thick enough to allow the monitoring of SAWs, for relatively long time-delays, after the excitation pulse. In Figure 1 are depicted representative results of velocities, both of SAW1 and SAW2, obtained from the numerically and experimentally by the analysed interferograms Orphanos et al. (2019). The values of the velocities correspond to the typical speed of elastic Rayleigh waves in metal films, which is reported to be in the range 2–5 km/s, Zhang et al. (1991), while the values ≤ 3 km/s found for SAW1 and Au are also in agreement with literature, Lioubtchenko et al. (2011).

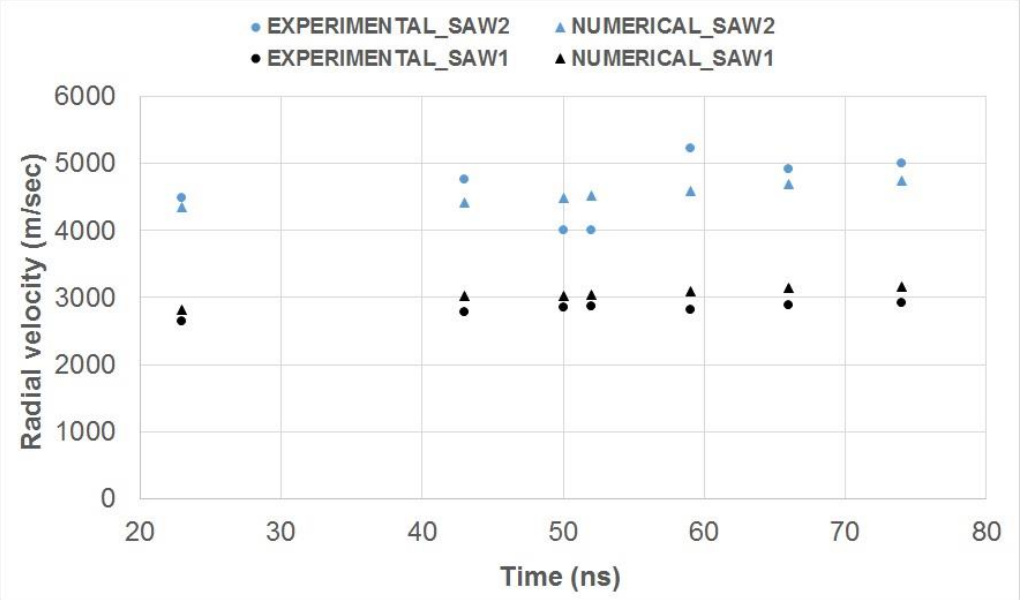

Figure 1. Velocities of SAW1 and SAW2 generated and propagated on a 500-nm-thick Au film, for an excitation energy fluence of 8.3 J/cm^2 as a function of the delay time between the pump and probe pulses.

4 CONCLUSIONS

A new simulation method is implemented where a developed FEM thermo-mechanical model is connected to a TTM, to address the ultra-short laser pulse excitation. A very good agreement is achieved between numerical and experimental results; thus, the fs-laser-generated SAWs is proven to be favourable for sample surface monitoring and defect diagnosis.

5 ACKNOWLEDGMENTS

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THE DEVELOPMENT OF THE BLIF TO EDIF CONVERTER FOR ASYNCHRONOUS DESIGN

Viktors Gopejenko[1,2], Siarhei Fedziukovich[2]

[1]Ventspils University College, Ventspils, Latvia

[2]ISMA University, Riga, Latvia

viktors.gopejenko@venta.lv

1 INTRODUCTION

BLIF format and XILINX (ISE Design Suite 14.7) development environment have been used to present asynchronous schemes. Taking into account that XILINX supports VHDL/Verilog, EDIF, Schematic and NCD file formats BLIF to EDIF converter has been developed Gopejenko (2018). The description of the software application realization for the BLIF to EDIF file format conversion is provided.

The development of the software designed to convert the format of the circuits description was dictated by the requirement to facilitate the work and communication of the engineers and researchers working in the field of integrated circuits research and development. Currently, there are many different formats to describe digital microcircuits. The majority of the digital chip design tools allow using a limited set of formats. This is the reason why engineers and researchers need to convert the description of the same scheme into various formats, which is a purely mechanical work, which is indirectly related to the development process and is a waste of resources. Due to lack of open access programs that automate this process, it was decided to develop own software to solve this problem. In the first version of the software, it was decided to implement the conversion from BLIF to EDIF.

The BLIF (Berkeley Logic Interchange Format) format is intended for describing hierarchical schemes at the logical level in the form of text. A scheme is an arbitrary combinational or sequential logical network. A Boolean function is given for each combinational element; it describes the calculation of the value of the only output of this element Berkeley lab (2005).

EDIF (Electronic Design Interchange Format) is a neutral format that stores electronic circuits and connection lists. This is one of the first attempts to create a neutral data exchange format for electronic design automation. The goal was to create a common format as opposed to proprietary formats Eurich (1986), Kahn (1996). It was expected that the number of translators required could be reduced to the number of participating systems with the introduction of EDIF format.

Both formats are quite mature and widely used in their specialized fields.

REALIZATION

It was decided to use the following high-level development algorithm:

I. To develop and realize the software model of the BLIF (Figure 1) and EDIF (Figure 2) formats.
II. To realize the parser of the initial BLIF-code for its transformation into the software BLIF model.
III. To realize the algorithm of the software model format transformation.
IV. To implement the algorithm for calculating the INIT attribute of the logical functions' truth table described in the BLIF format.
V. To realize the transformation algorithm of the EDIF model into EDIF text file.
VI. To implement the algorithm for converting BLIF to EDIF models.
VII. To implement the algorithm for converting BLIF files to EDIF files using the modules implemented in the previous steps (Figure 3).

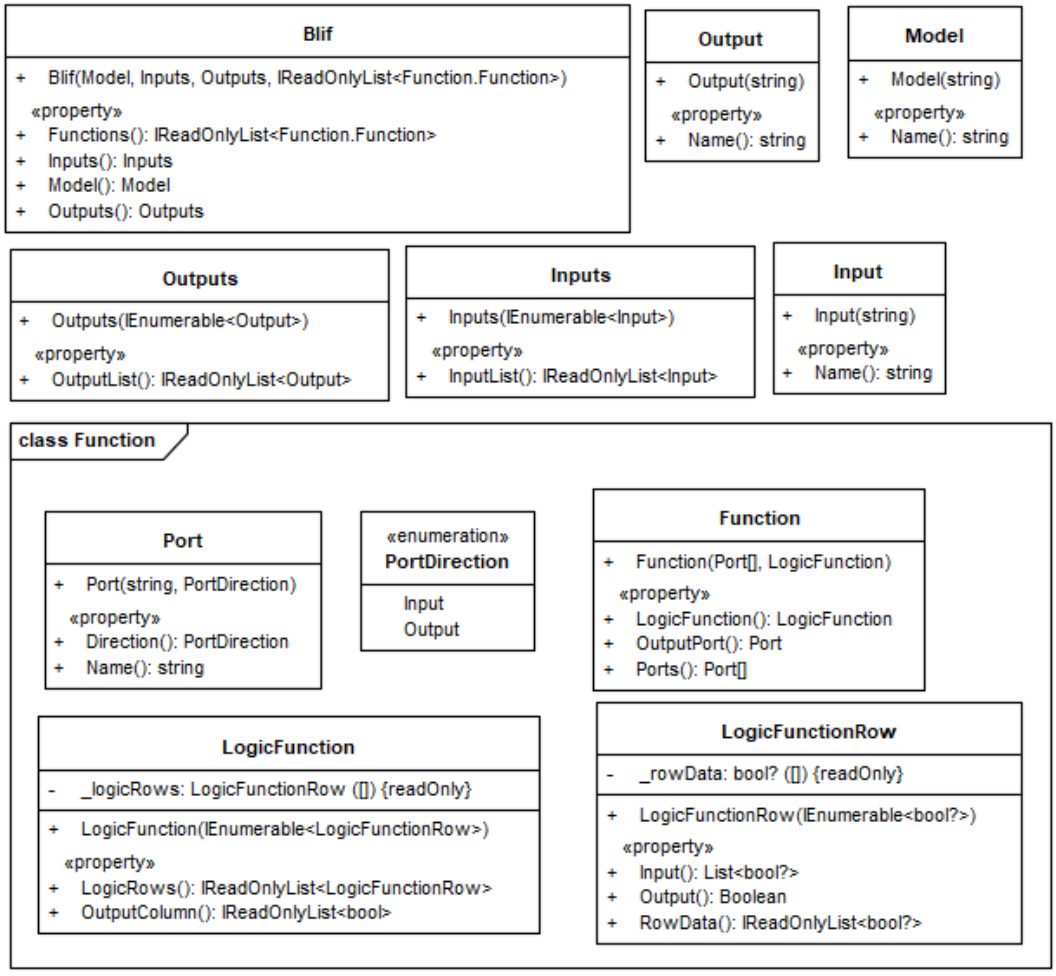

Figure 1. Software model of BLIF format

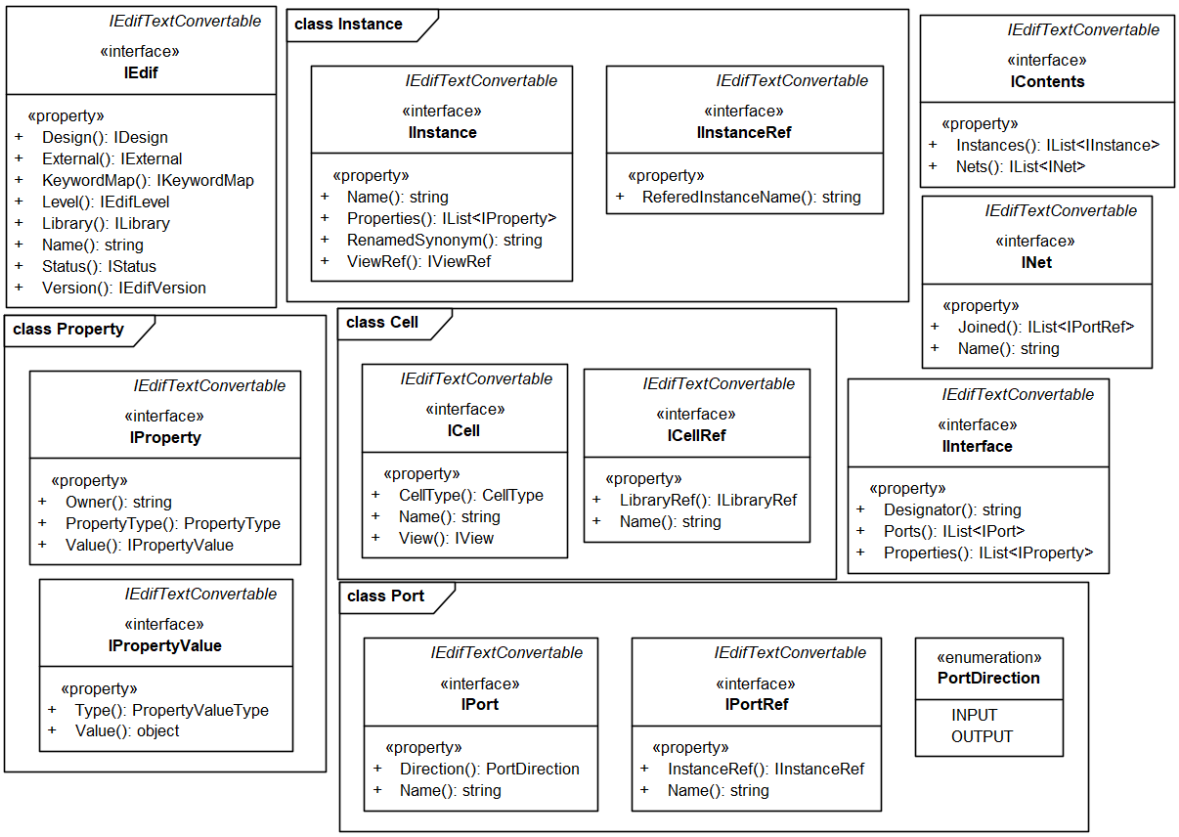

Figure 2. Software mode of EDIF format.

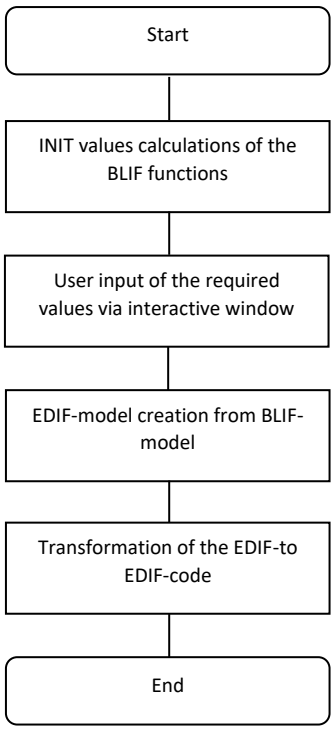

Figure 3. The high-level BLIF to EDIF file transformation algorithm scheme.

It is possible to mark out an optional but almost always necessary step to add a user interface.

Application design is based on a domain-specific approach. Domain-driven design is a set of principles and schemes that helps developers to create elegant systems of objects. When properly applied, it leads to the creation of software abstractions, which are called domain models. These models include complex business logic that eliminates the gap between the actual conditions of the product application area and the code.

Not all values that need to be added to the resulting EDIF file can be obtained from the original BLIF code/model. To obtain the missing data, a user interaction mechanism has been developed.

A calculation algorithm of the INIT attribute of the logical functions' truth table described in the BLIF format file has been implemented in the framework of the initial BLIF code transformation into the software model. It has been decided to move the given functional in a separate mode. This mode allows the user to calculate INIT values for the specified BLIF and output them to a separate INIT file format.

2 CONCLUSION

This work describes a software implementation of a software tool for BLIF to EDIF file converting. The developed software has received positive reviews from the researchers of the integrated circuits. Further development of this product can be an expansion of the supported formats list for required by an increasing number of researchers and engineers.

3 ACKNOWLEDGMENT

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ACHEIVING UNDERSTANDABLE RUMTIME BEHAVIOUR THROUGH STATE MACHINE INTERPRETATION

Höfig, Edzard

Beuth University of Applied Sciences, Luxemburger Str. 10, 13353 Berlin, Germany

edzard.hoefig@beuth-hochschule.de

1 INTRODUCTION

Operating software-intensive systems is a daunting task. One of the main issues lies in the inherent complexity of these systems and the difficulty in finding out root causes when things go wrong. Operators are often faced with a number of seemingly meaningless entries in application log files or error messages with cryptic and very technical descriptions. Even if an error message gives a clear indication of the problem, understanding which situation and system state triggered the malfunction and why this happened usually takes a lot of work by skilled engineers. Often a problem can only be properly investigated by replicating the situation in complete detail in a laboratory setting.

Clearly, having a better comprehension of the internal working of a system at runtime can aid to the understanding of malfunctions and how to prevent these. We propose to model sensible parts of a system's behaviour as a state machines, which allows for direct execution and introspection of a system's runtime state. Similar approaches are already established in the area of business process management, see OMG (2014) and OASIS (2007), but we think that it can be applied beneficially for a far greater number of applications ranging from embedded systems up to large-scale distributed ones.

2 EXPRESSING BEHAVIOUR

To be able to understand and control complex behaviour, we need to abstract from unnecessary detail, thus creating models of the behaviour in question. Through this process of abstraction, we are effectively losing information. This is helpful as it reduces complexity and enables humans to understand what is going on, but it also prevents us from replicating the original system's functionality by sole execution of the model. To mitigate this issue, we are proposing to separate programmatic behaviours in two parts: On the one hand executable models, capturing the essence of the behaviour in an easily understandable format, and on the other hand a number of so-called functional components that contain necessary programmatic functionality as black boxes with agreed-upon interfaces and dependencies, but opaque to observation of their internal workings. This explicit separation between a transparent, executable model,

which main purpose is to coordinates invocations of functional components and the opaque functional components themselves is a different approach than, e.g. using a high-level scripting language, as a scripted program still needs to capture the essential complexity of a given process, whereas the model only captures the features important to a human operator in a familiar, domain specific terminology.

We choose to employ state machines as a formalism to express executable behaviour, as it allows us to have a clear indication of the current operational state of the system. Furthermore, formalisms based on state-transition systems are well known and understood, they have a mathematical foundation in automata theory, and can be efficiently executed as discussed by J. Ebert (1993). As the term "state machine" is used quite ambiguously we would like to clarify the features that we believe to be most helpful for developing behaviour models following this approach:

i. A state machine is event-driven, reactive and has complete execution semantics when combined with required functional components.
ii. There are states, transitions and input symbols (events). This corresponds to the well-known finite state machine (FSM) formalism.
iii. It also encompasses the features defined by the extended finite state machine (EFSM) model by K.-T.T. Cheng and A.S. Krishnakumar (1996), adding guard conditions and actions, and introducing a context for storing values, which are accessible to the functional components, as well.
iv. It has the additional features proposed through the state chart formalism by D. Harel (1987), namely clustering ("state nesting") and orthogonality ("parallelism of the control flow")

Using these features one can express a great variety of behaviour models and there are indeed a number of important formalisms with this feature set available to use, e.g. executable versions based upon Unified Modelling Language (UML) State Machines as described by E. Höfig (2011), or State Chart XML (SCXML), a W3C (2015) Recommendation.

3 RUNTIME INTERPRETATION

Once a behaviour has been expressed as a model it becomes possible to execute the model, given clear execution semantics and complete bindings to the functional components. Conventionally, this is done by using a specific compiler, providing a state machine as input and generating code in a programming language of choice, for example as described for the Rhapsody tool by D. Harel and H. Kugler (2004). The resulting code is then integrated into a system's source code base. There are some drawbacks to this approach:

i. The behaviour model cannot easily be inspected or observed during runtime.
ii. The model cannot be changed without building the whole or a part of the system.
iii. The model cannot easily be adapted during runtime.

Regarding execution we follow a different strategy: instead of generating software artefacts from the behaviour model, we are relying on an interpretation engine that executes the model at runtime. This allows for easy inspection of the executing behaviour model(s) in a system and even supports runtime adaption without system restart, e.g. in regard to changed administrative or environmental conditions.

4 ADVANTAGES AND LIMITS OF THE APPROACH

Using interpretation has drawbacks, most notably a performance penalty when compared to generated code. For example, we found that the average performance for an interpreter using UML State Machines is about 20 times slower when compared to generated C++ code. On average, the memory overhead is about 70 times worse than with the generated approach. See E. Höfig (2011) for a further discussion on the subject, or E. Höfig et al. (2011) for a shorter overview. Although this number seems to be quite drastic, we deem this not to be problematic as it can be expected that runtime critical code is implemented as part of the functional components, rather than in the model. Our approach does not dictate a certain runtime system in regard to the functional components, so in this case there would be no major performance penalty involved.

We did show the viability of the approach using case studies and experimental implementations on a variety of architectures, ranging from an 8bit embedded microcontroller platform as described by E. Höfig et al. (2009) to internet routers, detailed by Höfig and Coşkun (2009), as well as distributed, service-oriented architectures as discussed by E. Höfig and P.H. Deussen (2011). Probably the largest issue with this approach lies in the sensible design of the behaviour models, which need to be useful to operators, but still cover most of the system's functionality to allow for a helpful statement in case of a malfunction.

5. CONCLUSION

We proposed that during system design and development the functionality should deliberately be separated in two distinct entities: functional components (opaque blocks of functionality) and behaviour models (transparent, inspectable state machines coordinating the execution of functional components). We are arguing that this approach can be used regardless of the underlying platform and assert that by following this approach, it becomes easier to understand in which state a system resides when a malfunction is encountered. Furthermore, once such a mechanism is in place, it allows for runtime adaptability of a system's functionality as for example demonstrated by P.H. Deussen et. al (2010).

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SENSORS BASED ON CHAOTIC ELECTRONIC CIRCUITS

Korneta, W

Lomza State University of Applied Sciences, Akademicka 1, 18-400 Łomża, Poland

wkorneta@pwsip.edu.pl

1 INTRODUCTION

A sensor is a device that turns stimulus into electrical output signal. Sensors can be classified in a variety of ways, e.g. by measurand (temperature, pressure, voltage, magnetic field, etc.), or by measurement technique. In recent years sensors in which the measuring technique uses the properties of dynamic chaotic behavior have attracted considerable attention. These sensors can be divided into three groups:

- sensors using the correlation between variations of a signal and slow continuous deformation of chaotic attractor,
- sensors using changes of the operation regime caused by a signal,
- sensors using fast jumps of dynamic trajectory between two different regions of the phase space.

The aim of this presentation is to give examples of sensors based on electronic circuits with chaotic dynamic behavior.

2 SENSORS BASED ON CONTINUOUS DEFORMATION OF CHAOTIC ATTRACTOR

The attractor is a subsets of the phase space of a dynamical system describing its dynamical behavior. The simplest sensors based on chaotic systems relate variations of a signal the sensor measure with variations of a parametr characterizing deformations of an attractor. These parameters can be global describing the overall shape of the attractor, or local referring to its specific part. Sensors of this type follow the concept of linear sensing.

The global parameters used are the following:

- the Hausdorff dimension and the correlation dimension obtained by splitting the phase space in cells and calculating the number of cell the attractor passes through or the probability that the attractor point is in a given cell Teodorescu and Huela (2012),

- the correlation coefficient and the statistical dissimilarity obtained by comparison of gray-scale images of the reference and the measured attractors

Teodorescu and Huela (2012),

- the geometric shape parameters like the attractor diameter (average, horizontal and vertical), the average ratio of the increment on the vertical axis to the increment on the horizontal axis, the average squared length of the segments in the phase diagram, a diagonalization coefficient, etc. Teodorescu et al. (2002),

- the average values of two sequences of samples representing the attractor Teodorescu and Cojocaru (2012).

The software computation of the first two parameters is time consuming and difficult for the hardware implementation. The parameters in the third group are easy to compute and implement in the hardware. The simplest measure of the attractor variation are the last parameters. The average of the absolute value of the output signal of a sensor with element composed of the measured saline solution and electrodes was used for water salinity measurements Teodorescu and Cojocaru (2012).

The local parameters used to characterize changes of the attractor caused by changes of the sensed signal are the probability that the trajectory is located in a specified region of the phase space measured by the average time spent by dynamic trajectory in a given region of the phase space Teodorescu, and Huela (2012), or the curvature and the torsion of the attractor.

3 SENSORS BASED ON CHANGES OF DYNAMICS

The bifurcation diagram of non linear system exhibit several different regimes and bifurcation points. When the regime changes, the dynamic of the sensor changes and this change can be very fast with important change of dynamic trajectory. Sensors whose dynamic is chaotic change their operation regime under the influence of the change of the measured signal. If the operating point of the sensor is in the vicinity of the bifurcation point, very small change of the value of the sensed parameter causes the nonlinear regime to change. This significantly changes the attractor shape if the transition is from one type of chaotic regime to another or dynamic behavior if the transition is between chaotic regime and periodic or stable regime Cojocaru (2014). The change of the value of the sensed parameter may cause the sensor to go through all regions of the bifurcation diagram. This allows the development of a multiple-window type sensors by the manner of coding the measured signal values as a specific dynamic regime Teodorescu et al. (2001). These sensors possible explain high sensitivity of natural sensing systems Teodorescu (2000).

4 BISTABLE CHAOTIC SENSORS

The operation of conventional bistable sensors is performed by applying known periodic bias signal to saturate it and drive very rapidly between its two states Ripka (2003), Ando et al. (2005). Bistable sensors operating in a noisy environment driven by a noise have also been proposed Gammaitoni et al. (2002). In recent years bistable noise activated chaotic sensors based on continuous fast jumps of dynamic trajectory between different regions of the phase space have been presented, described and studied Teodorescu et al. (2014), Korneta et al. (2015, 2017). Bistable systems driven by external signal embedded in a noise are used to model sensory neurons Longtin et al. (1992), Bulsara (1994). The quiescent neuron state corresponds to the residence of dynamic trajectory in a specific region of the phase space, whereas firing events correspond to fast jumps of dynamic trajectory between different regions of the phase space. The output of bistable noise activated chaotic sensor was quantified by the proportion of the residence time of dynamic trajectory in one specific region of the phase space to the total observation time and by the spike-count rate i.e. the number of jumps per second Korneta et al. (2015, 2017). The obtained sensor transfer functions depend on the noise intensity and the sensor can be in measuring, tuning, or on-off control mode. It was shown that the noise activated bistable chaotic sensors require the optimal noise intensity for the target signal detection and measurement. The recently proposed nonlinear bistable sensor driven only by chaotic dynamics eliminates the need for an external signal to induce jumps of dynamic trajectory between two different regions of the phase space Korneta et al. (2018). This sensor is based on electronic Chua circuit operating in chaotic regime where double scroll attractor exists Chua et al. (1993).

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SMART FACTORY LAB – A FACILITY FOR INDUSTRIAL AUTOMATION EDUCATION

Salloker, M. G.; Steinhuber, A.

FH JOANNEUM, Institute of Electronic Engineering, Graz, Austria michael.salloker@fh-joanneum.at

1. INTRODUCTION

Industrial automation systems are undergoing a deep technological change. Following the needs of Industry 4.0 the manufacturing systems are extended with electronic systems to enable its implementation (Plattform Industrie 4.0, 2019). This leads to adaptions in student's education. Beside of introducing new concepts of automation engineering a platform for laboratory exercises is essential. The Smart Factory Lab presented here is one possible realisation for lab exercises. First the systems configuration is described, followed by the actual application in courses on industrial automation. Finally, a preview on future tasks is given.

2. SMART FACTORY LAB SYSTEM

The CP Lab of Festo Didactic is a versatile system to provide the students with a realistic manufacturing process (Festo, 2019). The base component are six conveyor belt units transporting the workpieces between the different processing stations, which are located directly above the conveyor belt unit.

Every of these stations is responsible for one manufacturing process. From the wide range of application modules offered the following ones were chosen:

- Image inspection
- Drilling
- Magazine
- Pressing
- Turning
- Heating furnace

The six conveyor belt units are arranged in a square (see figure 1). A total view of the system is shown in figure 2.

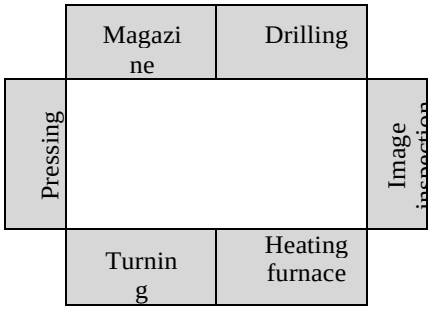

Figure 1. Arrangement of the six conveyor belt units with the corresponding processing stations.

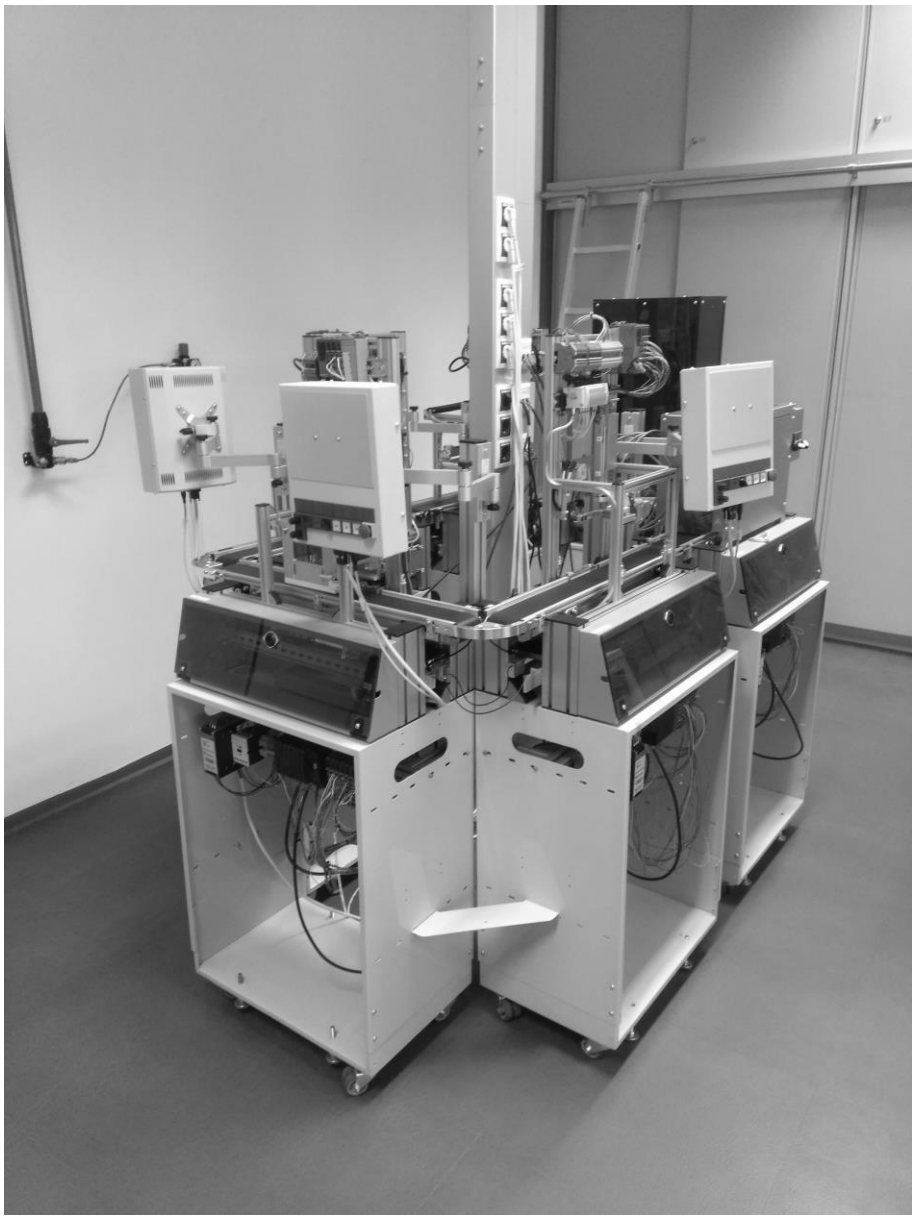

Figure 2. Total view of Smart Factory Lab.

The different components and their tasks are described in the subsequent sections.

2.1 Conveyor Belt

Every conveyor belt unit (Festo, 2016a) has the same sensors and actuators and is equipped with a X20 PLC of B&R (B&R, 2018). If the conveyor belt is free the previous conveyor belt unit pushes a transport pallet carrying a workpiece on the next belt. Here the transport pallet is moving till the middle of the conveyor belt unit. In this position the transport pallet is stopped, and the processing station is doing their tasks. After finishing the processing, the transport pallet is forwarded to the end of the conveyor belt. Here the transport pallet waits until the next conveyor belt unit is free to process a workpiece. For the communication between the conveyor belt units optical signal transmission is used.

The transport pallet includes a RFID tag. At the processing position a RFID reader is located which can read information regarding the required processing stages. The results of the actual manufacturing process can be written on the RFID tag. The communication between RFID reader and PLC is done via I/O-Link (IO-Link Community, 2018).

The conveyor belt unit includes also an interface with LEDs, switches and buttons for local operation. An emergency stop button is also available.

2.2 Image Inspection

The manufacturing process starts with an image inspection (Festo, 2016b). A camera takes a picture of the PCB and using FESTO Compact Vision System the correct position of two fuses is verified (see figure 3). The parametrisation of this unit was done in a bachelor thesis (Heilig, 2017). The control of the Compact Vision System is done with peripheral I/O modules. The communication to the PLC's CPU is realised by POWERLINK. The same setup is used for the control of the other five modules described below, they differ only in the number and type of the used I/O modules.

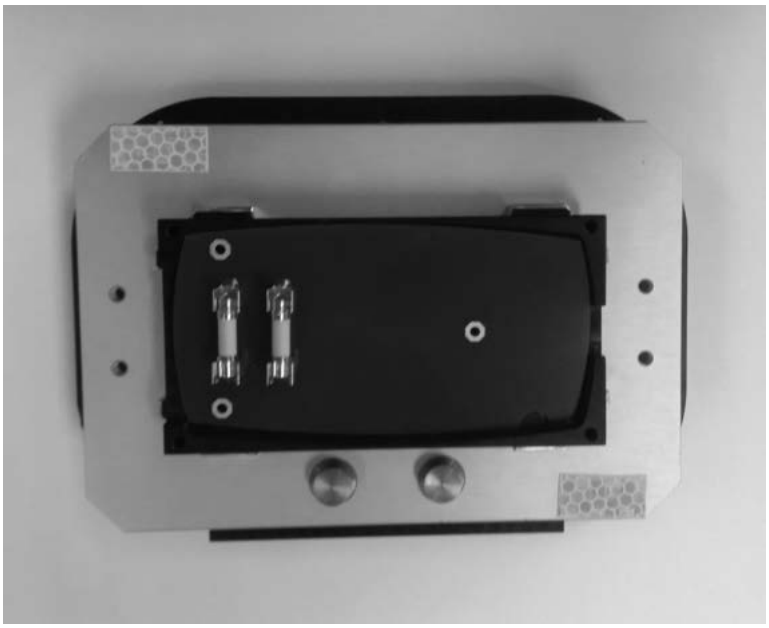

Figure 3. Workpiece on transport pallet

2.3 Drilling

The station drilling simulates a drilling process, i.e. the drills are rotating but do not penetrate the work piece due to safety reasons (Festo, 2016c).

2.4 Magazine

The workpiece is a PCB located in the lower part of a housing. The magazine holds the upper parts of the housing, separates one and puts it on the workpiece below the module (Festo, 2016d).

2.5 Pressing

After putting the upper part of the housing on our workpiece the two parts of the housing must be fixed by pressing them together (Festo, 2016e).

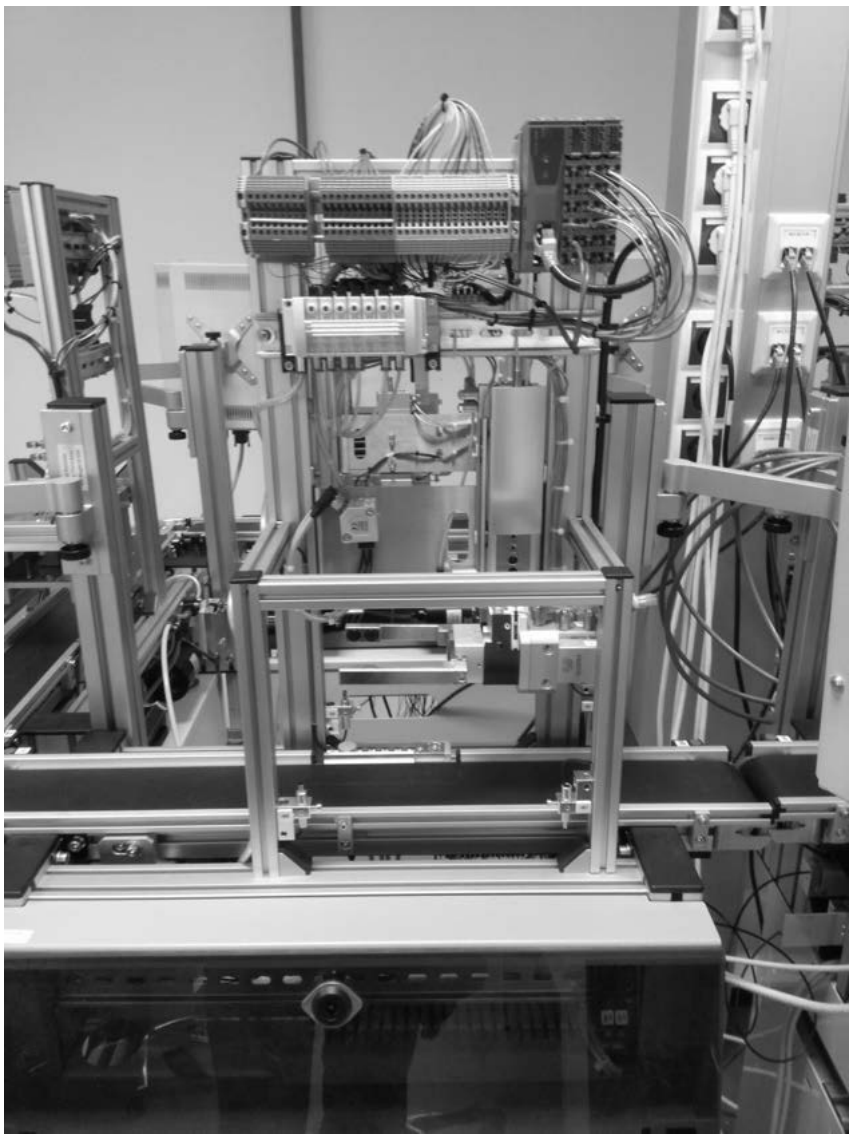

Figure 4. Module turning. On the top the bus communication and the I/O modules for the application module can be seen.

2.6 Turning

At this module the workpiece is flipped upside down and put down on the transfer pallet again (Festo, 2016f). Figure 4 gives a detailed look of this module.

2.7 Heating furnace

In the furnace the workpiece is heated up to 70°C, the temperature is kept constant for some minutes and afterwards the transfer pallet moves out of the furnace (Festo, 2016g). This is the end of the production process.

3. EDUCATIONAL OBJECTIVES

The manufacturing process described in chapter 2 allows the realisation of a big variety of educational objectives. The smart factory lab is used in two courses of the 4th and 5th semester in the bachelor's degree programme Electronics and Computer Engineering. At ths level the students have good knowledge on the needed engineering skills and should be able to apply them in an industrial application. The overall goal is to start up a production process, after the mechanical assembly and the electrical installation are finished. The different tasks are described in the order of the start-up procedure.

The work on these tasks is done in pairs, so students are not alone but have a partner for discussion like in a professional environment. On the other hand, the group is not to big, so both group members must contribute to fulfil the tasks.

3.1 System analysis

The first step is the analysis of the system. From the overall functionality the students must develop a concept for the conveyor belt and the six application modules. While it is quite easy to describe and realise the regular processes, the error handling is much more complicated. First all possible issues, e.g. the blocking of a transport pallet, must be identified. In the next step a detection of the issue in the control software must be found and at last an error handling is needed. That means, it must be possible to solve the issue with the operating elements on the plant using the software on the PLC. A special feature is the treatment of the emergency stop.

An important tool to support this process are state diagrams, which must be used by the students.

3.2 Modular software design

An important demand is a modular software design. The students must identify similar tasks which turn up several times at different points in the plant and which are appropriate for the design of functions or data structures. This is supported using C as programming language.

Most of all the software of the conveyor belt unit is a component which, once it is be programmed and tested, can be distributed to the other five units. They differ only in the hardware configuration and the software of the application modules but

implementing clearly defined interfaces allow this and demonstrate the importance of a well-structured software development process.

3.3 Electrical installation

In industrial plants the electrical installation can make troubles. Therefor it is necessary to test the connections of the PLC's I/Os with the sensors and actuators. To make this more realistic it is possible to swap or interrupt connections.

3.4 Control Engineering

In the module heating furnace, the workpiece is heated up to 70°C. The temperature must be kept constant. Here students can apply their control engineering knowledge and try different controllers such as switching and PID controllers.

3.5 Software test

The end of the development process is the test of the software. Students must define test cases and realize them on the plant. A test protocol and a formal approval by the lecturers are the final steps.

The group with the best implementation has the possibility to show their results at the open house day to a wider audience.

4. CONCLUSION

Meanwhile three cycles of students completed the courses using the smart factory lab. The main advantage of these courses is integration of several skills of other prior courses like programming, software engineering, sensor technology, and communication engineering. Students experience is the interaction of these different fields in one big development process.

There are some future developments of the smart factory lab. The next step will be to integrate some touch panels for process visualisation and control which will be done in the framework of a bachelor thesis. The results of this work will be introduced in future courses.

Another possibility will be the application of model-based software design using MATLAB and its toolboxes including code generation (The Mathworks, 2018). First attempts were successful (Heer, 2019).

5. ACKNOWLEDGMENT

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LIGHTWEIGHT MULTI-LAYER MATERIAL FOR MILITARY APPLICATIONS WITH ENHANCED BALLISTIC PROPERTIES AND ABILITY FOR ELECTROMAGNETIC INTERFERENCE (EMI) SHIELDING

Marcin Wachowski[1], Robert Kosturek[1], Volodymyr Hutsaylyuk[1] and Lucjan Śnieżek[1]

[1]Military University of Technology, Faculty of Mechanical Engineering, 2 gen. W. Urbanowicza str., 00-908 Warsaw, Poland;

E-mail: marcin.wachowski@wat.edu.pl

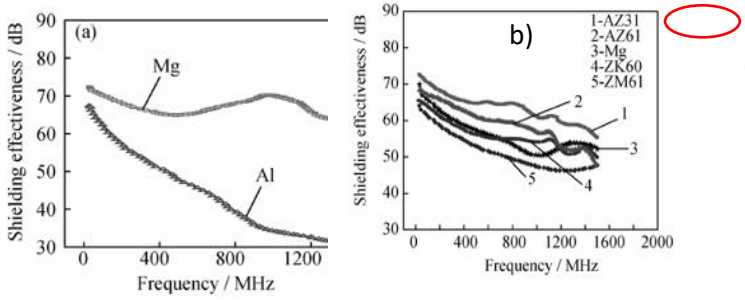
1 INTRODUCTION

Ensuring effective protection of objects exposed to projectiles, such as military vehicles or aircraft, requires an assumption of requirements already at the design stage. Typically, the main assumption when creating devices working in specific combat conditions is to design light, thin and the most durable ballistic shields. Recently published research results reveal the trend of production innovative ballistic panels having lower total weight, providing at least the same level of protection as currently used steel armor. Modern materials for armor usually consist of several layers of materials with different density. In the literature, there are attempts to create a laminar material with increased ballistic resistance consisting of aluminum and titanium alloys obtained by explosive welding method [5,6]. Technological development of military devices has increased significantly, especially in the field of unmanned platforms, automation of combat equipment and development of radio communication. Electronic systems in military and aviation constructions require an additional protection against electromagnetic interference. It creates new technological challenges, in particular in the field of radio communication, which is becoming more and more difficult due to the limitations of available frequency bands and electromagnetic interference (EMI) from wireless devices. This is connected with the increasing number of electronic components, which emit electromagnetic fields at different frequencies. The electromagnetic radiation resistance of various systems and devices became an issue, which underwent significant development in recent years and nowadays is being solved at the design stage. Electromagnetic interference occurs when electronic devices are exposed to electromagnetic radiation from external sources, operating on the same frequency range. The energy transmitted by the EM radiation beam may cause damage or destruction of sensitive components and electrical circuits, what may create a serious threat, especially in the case of aircraft constructions. This is due to the induction of

large instantaneous voltages and currents as well as local temperature rise in electrical circuits and conductors. The energy of electromagnetic radiation can also be a threat to the personnel operating the device. An example is the failure of mobile devices by an electromagnetic field emitted from a GPS transmitter of a military vehicle. Electromagnetic fields from a variety of electronic devices, such as motors, batteries and meters, can have tremendous impact on each other as well as other devices in the vicinity.

In order to eliminate the problem of electromagnetic frequency interference, the radiation can be blocked by various materials that scatter radio waves or absorb them. The role of the shields is to suppress the electromagnetic field and preventing it from spreading in the area surrounding the emission source. The values of shielding effectiveness are influenced by both reflections and the absorption of EM field wave energy. The basic element of shielding is usually the cover of the device. Technologies used to limit electromagnetic waves are based on the use of specialist coatings, such as paints that usually scatter waves, or plastics and metallic conductive materials that absorb these waves.

In order to minimize the mass and thickness of the electromagnetic shield, the most promising material applicable to EMI shields is magnesium and its alloys. Due to the high electrical conductivity, low density, high strength and better EMI shielding ability, compared to aluminum, it has become one of the most attractive shielding materials not only in the military industry but also civilian [2,3]. Mg-3AL-1Zn alloy (AZ31) has the best electromagnetic shielding properties among the known magnesium alloys, which reach values in the range of 55-73 dB at 30-1500 MHz in the undeformed material, thus significantly exceed the EMI shielding capacity of aluminum alloys (Fig.1). The quality of shielding strongly depends on the material's microstructure.



c)

Material	SE/dB		
	30MHz	900MHz	1500MHz
Pure magnesium	70	51	52
ZK60 Mg alloy	65	55	50
AZ31 Mg alloy	73	64	55
AZ61 Mg alloy	70	59	47
ZM61 Mg alloy	65	49	47
Pure copper	77	57	45
Pure aluminum(3mm)	67	36	34
2024 Al alloy	35	35	35
Cenosphere fly ash/2024 Al alloy	75	35	31
Precipitator fly ash/2024 Al alloy	77	37	32

Figure 1. a) EMI shielding efficiency of magnesium compared to aluminum. b) EMI shielding efficiency of various types of magnesium alloys. c) EMI shielding efficiency of magnesium alloys compared to aluminium alloys with thickness of 2 mm. [Z. Zhi-hua (2013)]

The results of Zhang's research showed that the ability to shield electromagnetic radiation decreases with increasing grain size [7]. Magnesium after the forging process often shows a strongly deformed fine-grained texture, which significantly affects the properties of alloys [1-3]. The texture effect on the electromagnetic shielding properties of the AZ31 magnesium alloy was also examined by K. Song, who revealed that the

EMI shielding capacity of AZ31 alloy gradually increases with the degree of texture strengthening after the rolling process [4]. AZ31 after cold rolling in the range of 20 to 60% of deformation achieves the efficiency of shielding at the level of 85-95 dB. Materials with such efficiency can be used in applications for military constructions. The best result compared to the initial undeformed sample, was obtained in the material after a deformation rate of 60%. An increase of 16 dB was obtained, which resulted in the ability to shield at the level of 88-98 dB in the frequency range 30-1500 MHz (Figure 2) [4].

Table 2 Classification of shielding effect

SE/dB	<10	10-30	30-60	60-90	>90
Classification	Less	Bad	Middle	Good	Excellent

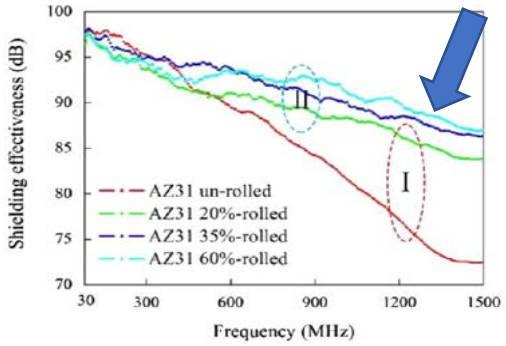


Figure 2. EMI shielding efficiency of magnesium alloy AZ31 in the frequency range 30-1500 MHz. [Z. Zhi-hua (2013), K.Song, (2015), Y.Gao (2007)]

The most prospective structural material which can increase the ballistic resistance of the AZ31 magnesium alloy is a multilayer material obtained by combining the magnesium alloy with an aluminum alloy AA2519 and a titanium alloy Ti6Al4V by using the explosive welding method. Obtaining a technologically correct joints between components require the use of a 1XXX aluminum interlayer between the AZ31 / AA2519 and AA2519 / Ti6Al4V plates.

The aim of the research is to obtain AZ31 / AA1050 / AA2519 / AA1050 / Ti6Al4V multi-layered material using explosive welding method. To examine the ballistic properties hypervelocity impact test was performed.

2 MATERIALS AND METHODS

Obtaining of the armor with increased ballistic resistance and ensured adequate protection against electromagnetic radiation in military vehicles, requires develop a technology for the production of advanced Mg-Al-Ti multi-layer material using innovative joining method. This work proposes the use of explosive welding, which is a process of high technological importance for the production of modern construction materials. The basic parameters of explosive welding are: the explosive material

detonation velocity and the distance between the plates. Additionally, the impact velocity is also one of the key factors determining the quality of the joint. The mentioned parameters and the thickness of the welded plates determine the possibility of obtaining the joints [3,4]. The correct selection of all these values allows to obtain an explosively welded joints with a wavy surface.

The process of explosive welding was carried out in the ZTW EXPLOMET company. A mixture of heating oil with ammonium nitrate (ANFO) was used as the explosive. Ballistic test of explosively welded laminate was performed under hypervelocity (4000 m/s) impact loading of projectile made of aluminium ball.

The chemical composition of the components of the multilayer material is shown in Table 1. The following thicknesses were used to make the laminate:

- magnesium alloy AZ31: 5 mm;
- aluminum alloy AA1050: 1 mm;
- aluminum alloy AA2519: 5 mm;
- aluminum alloy AA1050: 1 mm;
- titanium alloy Ti6Al4V: 5 mm.

Table 1. Chemical composition of multilayer material components.

	Chemical composition [% wt.]							
AZ31	**Al**	**Zn**	**Mn**	**Si**	**Cu**	**Ca**	**Fe**	**Mg**
	2.50<	0.60<	0.20	0.10	0.050	0.040	0.0050	Rest
AA1050	**Fe**	**Si**	**Cu**	**Mg**	**Mn**	**Zn**	**Ti**	**Al**
	0.4	0.25<	0.05<	0.18	0.05<	0.07<	0.05<	Rest
AA2519	**Fe**	**Si**	**Cu**	**Mg**	**Zr**	**Sc**	**Ti**	**Al**
	0.08	0.06	5.77	0.18	0.2	0.36	0.04	Rest
Ti6Al4V	**O**	**V**	**Al**	**Fe**	**H**	**C**	**N**	**Ti**
	<0.20	3.5	5.5	<0.30	<0.0015	<0.08	0.05<	Rest

3 RESULTS AND DISCUSSION

After the joining process, the AZ31 / AA1050 / AA2519 / AA1050 / Ti6Al4V multi-layered material (Fig. 3) was obtained.

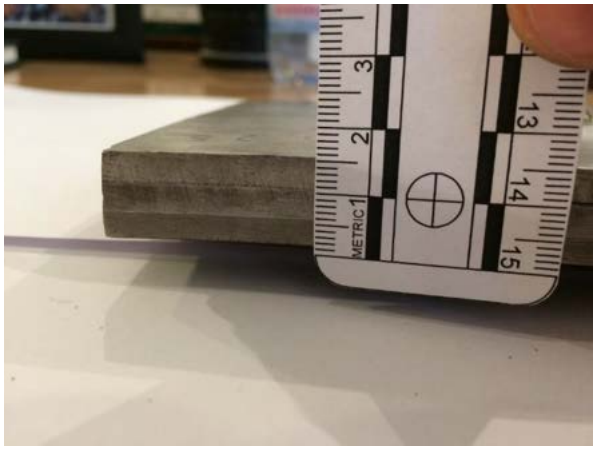


Figure 3. Explosively welded Mg-Al-Ti laminate.

The cross-section of the sample after hypervelocity ballistic test revealed penetration of the projectile through all plates expect Ti6Al4V plate (Fig. 4). Ballistic research results revealed that the projectile impact caused a large deformation of the plates and a delamination of the AZ31/AA1050 and AA1050/AA2519 joints. Maximum diameter of the crater was about 30 mm. Observation revealed smooth surfaces, which suggest that the ductile shearing is as a dominant process of perforation. Projectile impact started penetration through AZ31 which is material with the lower density than other laminate components. In the first impact stage, large amount of the projectile energy was acquired by the AZ31 plate. Further penetration was carried out through the laminate components ordered with increased density. During the penetration, the moving projectile pushed the structure directly below its nose, which caused stretching of the laminate layers. It allows to effectively dissipative energy up to stop the projectile on the Ti6Al4V plate without visible penetration. Delamination of the joints indicate that the material has reached the maximum strength limit due to perforation with the projectile and is a result of absorption of the generated energy due to the partial reflection of the shock wave from the titanium alloy. Delamination, therefore, is a phenomenon that positively affects the improvement of the ballistic properties of the produced laminate.

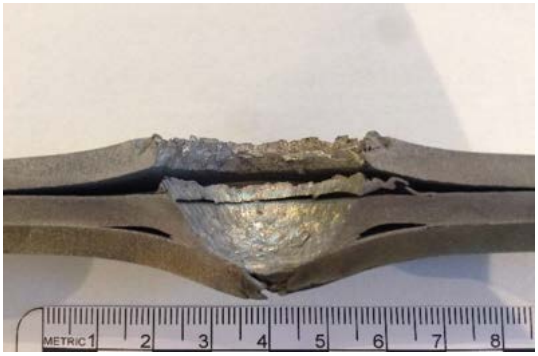


Figure 4. The cross-sections of the sample after hypervelocity ballistic test.

4 CONCLUSION

The explosive welding process allows to obtain high-quality Ti6Al4V/AA1050/AA2519/AA1050/Ti6Al4V joint free of cracks and voids. The results of ballistic test revealed that the laminate is well suited to ballistic protection

applications. Observation of the cross-section of the sample after ballistic test revealed that the ductile shearing is as a dominant process leading to perforation through the laminate components. Application of AZ31 magnesium alloy with proper deformation in multi-layer laminate allows to obtain armor with good ballistic properties against hypervelocity condition of firing with enhanced electromagnetic interference shielding.

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BIG BANG ENGINEERING SCHOOLS COMPETITION MODEL: SCHOOL SOLUTIONS FOR WATER BASED PLASTIC POLLUTION IN CHANIA, CRETE

Jonathan Westlake

STEM ambassador

j.c.westlake@staffs.ac.uk

1. INTRODUCTION

The World's marine environment is facing unprecedented change as a result of direct human activity and climate change. This will have major implications for global biodiversity (variations in all life forms), infrastructure, human health, well-being and tourism. This is a challenge that requires a range of solutions, innovations and changes to the way we currently live in places such as Chania, Crete. In this abstract an initiative called Big Bang challenge is described and of which the theme for 2019 is about plastic and how to tackle the environmental issues posed.

2. MATERIALS AND METHODS

In order to meet this challenge in the UK we have challenged the young to a Big Bang competition. The initial stages are to ensure a problem or gap in knowledge is identified for which a realistic solution can be proposed and for this we held an open evening where academics from the University industry mentors put forward some ideas for the teachers and pupils to have a think about.

The scope of the Big Bang competition is deliberately wide to promote variation and encourage ingenuity and initiative. We encourage schools to explore imaginative solutions before whittling them down to fit within real-world restrictions such as practicality and budget.

In the UK we are using the STEM umbrella (science, technology, engineering and maths) to investigate an aspect of underwater pollution and propose a solution. More recently STEM has become STEAM to include the arts. The national STEM ambassador program has created a UK wide network of experienced professionals available to schools and the author is an example of such an ambassador.

This year the theme has been underwater plastic pollution and some example ideas under the STEAM umbrella are S – the scientific impact of ingesting (eating or drinking) microplasticson health and wellbeing, T – using technological solutions such as purifying wastewater or in replacing plastics that cannot be recycled, E – engineering

solutions to remove microplasticsand fibres from water (drinking water, rivers, lakes, oceans), A – the use of visual creative arts in sorting fact from fiction in the reporting of underwater pollution. This might include investigating how journalism, photography, films and posters are used to convey these messages and their accuracy and effect and M – Using maths to look at the size, age and structure of populations underwater or in measuring water quality and river flow.

Once a team *(*up to six pupils from years 7 to 12) register their interest they are allocated a STEM
ambassador (mentor) and are asked to organise themselves and link up with their mention. Initially,
this is via a morning assembly at a school. They are given advice on how you set up their team and
of course this will set the template for how they split the tasks and work threads of their project,
so for example, Project Manager, Design, Technical, Business. Each team must have a title and
as you can imagine some very creative titles emerge.
Each team has up to 6 hours with a STEM Ambassador/professional in a mentor session and this can be in one go or spread out. The aim is to agree a basic structure for the project, ask lots of questions, critically consider a number of ideas and put them through a critical process to choose the best.
Once project selected then the team regularly get together to work on their project.

Mentors are allowed to guide and steer the group in their decision making but not implement ideas
or solutions of their own.
Mentors can accompany their school to the Big Bang regional event to provide presentation coaching.

There is no limit to how much time a team has to work on the project, however the teams that are typically do well are those who have refined their entry through a number of sessions (see next section).

We typically encourage each to team to try and agree with their teacher/mentor how many sessions they need to put in place to move the project forward and typically schedule these sessions in a project plan with tasks to achieve.

Refining the project is a question of using the expertise, equipment and resources available at each school to enhance their project and this could include 3-D printing models; using multi media to present posters; video editing, research etc). We also find that mock presentations help and get critical feedback from teachers, getting used to answering questions is useful preparation..

3. RESULTS AND DISCUSSION

A good project is one that has been attacked and critiqued from all angles and comes through as a good idea, well thought out and useful in solving the brief

A real-world product/solution and one such project was the capture of plastic with the use of sea bins as will be described at the Symposium.

Seas bins was a project idea that was put forward as a genuine solution to the brief that if refined would create a better plastic plastic capture system for habours and marinas such as in Chania.

It is important that there is some orginality to the solution proposed rather than a copy of existing solutions and it is important to show awareness of budgets and money when choosing the project idea.

The project has to be articulated in a professional poster presentation and needs to have as much research and testing of the concept from the resources at the team's disposal. We encourage each team to look at the industry, see what others have been doing, ask questions of a target audience and talk to professionals.

At the Big Bang event the judging criteria is as laid out below and includes:-

Gauging the project process, planning and organization. Was the project well planned, organised and methodical?

Research / Use of resources / External Guidance. Was effective research carried out pre-project? What resources were required? Were they appropriate? Was external guidance only given to support the project, not lead it?

Experimentation and Refinement. What tests and evaluations were used? Were they appropriate?

Innovation and Creativity. Is any aspect of the project or the team's approach original?

Project Concept
Concept, Motivation and Objectives. Was the project the team's own idea or, if set for them, how much control did they take in its development? Can they explain the concept and aims clearly?

Project Outcomes, final Outcomes and reporting.

How well does the project achieve its aim? How high is the quality of the finished product and value to what extent do the findings have 'real-world' applications?

Have the team considered the wider exploitation of the project?

Personal Skills

Problem solving. How did the team cope with problems and challenges?

Communication

Does the team's enthusiasm come across? Can the student(s) clearly articulate all aspects of the project? To what degree would the team be able to inspire others?

4. CONCLUSION

Big bang as been a huge success and the evidence shows that schools and their pupils engage with the competition.

The concept matches up mentors from industry and universities with schools enabling ideas to be explored and presented as something tangible.

At Staffordshire we have embraced the competition format and not only seek Staff to get involved but also student STEM ambassadors. For our part of the UK where aspirations to go to higher education are low, we have found that the school pupils can relate to a student who is nearer their own age and provide inspiration to go further in education

5. ACKNOWLEDGMENT

The author would like to express appreciation to the STEM team at Staffordshire University.

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The Seabin Project available at https://seabinproject.com/ May 2019

PARALLEL PROCESSING OF SEISMIC BIG-DATA FOR THE IDENTIFICATION OF DISTINCT SEISMIC REGIONS IN GREECE

Dr. Antonios J. Konstantaras

Laboratory of Computer Technology, Informatics & Electronic Devices,

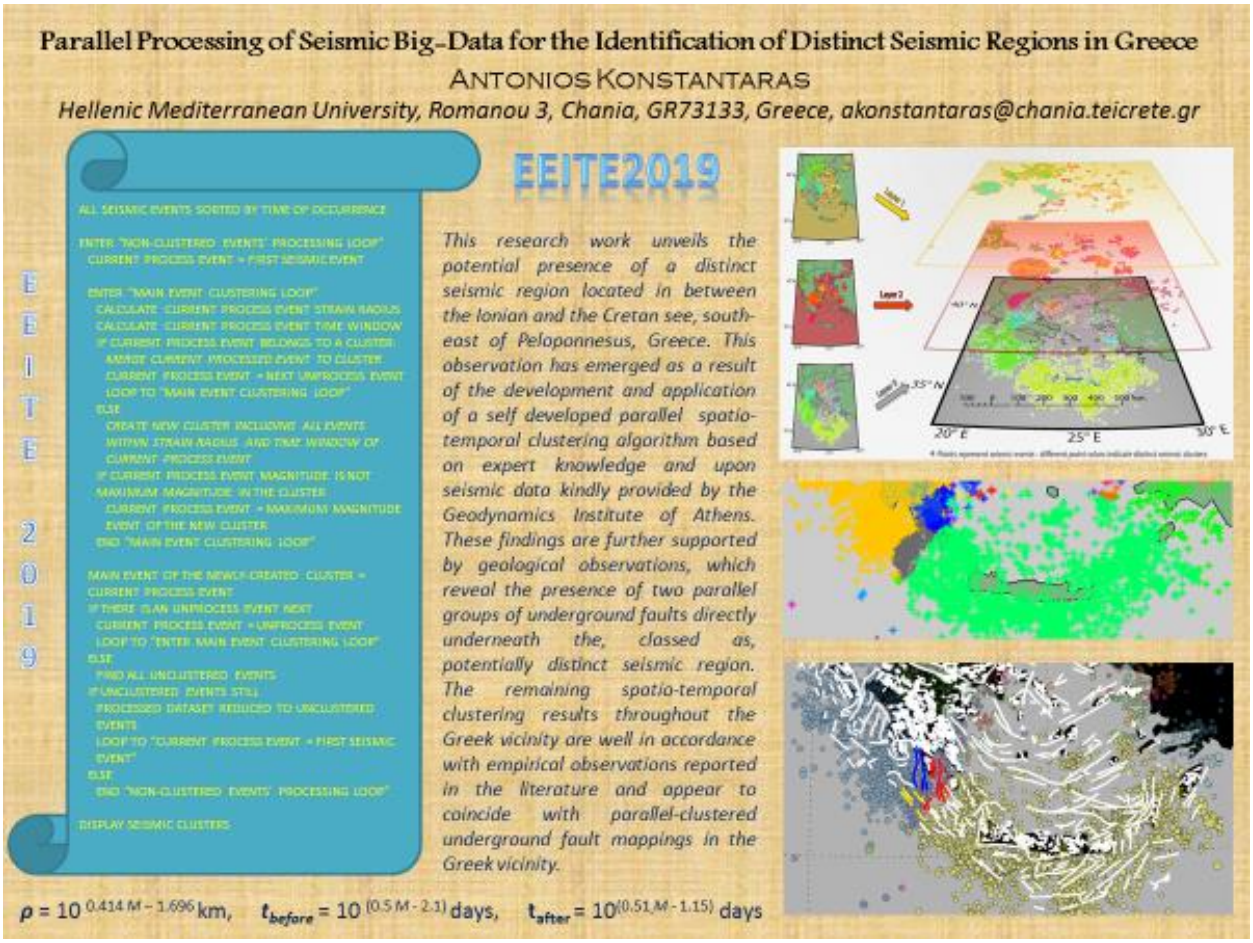
Department of Electronic Engineering, Hellenic Mediterranean University,

Romanou 3, Chalepa, Chania, P.C. GR73133, Greece

Corresponding Author's E-mail: akonstantaras@hmu.gr

1. INTRODUCTION

This research work unveils the potential presence of a distinct seismic region located in between the Ionian and the Cretan see, south-east of Peloponnesus, Greece. This observation has emerged as a result of the development and application of a self-developed parallel spatio-temporal clustering algorithm based on expert knowledge and upon seismic data kindly provided by the Geodynamics Institute of Athens. These findings are further supported by geological observations, which reveal the presence of two parallel groups of underground faults directly underneath the, classed as, potentially distinct seismic region. The remaining spatio-temporal clustering results throughout the Greek vicinity are well in accordance with empirical observations reported in the literature and appear to coincide with parallel-clustered underground fault mappings in the Greek vicinity.



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RADIATION INTENSITY ESTIMATION OF CIRCULAR LOOP ANTENNA USING ATIFICIAL INTELLIGENCE TECHNIQUES

T.N. Kapetanakis[1,2], I.O. Vardiambasis[1], E.I. Lourakis[1], and A. Maras[2]

[1] Department of Electronic Engineering, Hellenic Mediterranean University
[2] Department of Informatics and Telecommunications, University of Peloponnese
ivardia@hmu.gr

1. INTRODUCTION

Neuro-fuzzy techniques are biologically inspired techniques, *Choudhury et al. (2015), Kapetanakis et al. (2018),* suitable for complex problems requiring tedious and repeated analysis with fast and accurate convergence. They are classified into three main categories: the fuzzy logic systems (i.e. the adaptive neuro fuzzy inference system (ANFIS), the artificial neural networks (i.e. the feed-forward back-propagation NNs) and the evolutionary algorithms. All these techniques have been widely used to effectively analyze and synthesize intensive nonlinear problems, so they are attractive for several electromagnetic wave propagation, radiation and scattering problems *Kapetanakis et al. (2018), Choudhury et al. (2015), Kapetanakis et al. (2012), Mishra (2015).*

Loop antennas have ideal characteristics for many reception applications, such as direction finding and wireless telemetry for medical implantable devices, while small loops are suitable as probes for magnetic field measurements. For the circular loop antenna radiation problem a number of complex analytical techniques have been used to obtain near and far field expressions for arbitrary radius and current.

In order to solve the herein nonlinear electromagnetic problem of circular loop antenna radiation, we have uses (a) multilayer perceptron NN models *Devabhaktuni et al. (2001), Mishra (2001),* and (b) ANFIS models *Jang (1993), Kayabashi (2014)*.

All models have the same 2 inputs (the loop radius α in the range [0.05λ, 5λ], where λ stands for the wavelength, and the observation angle θ in the range [0°, 180°]), and 1 output (the radiation intensity |U(θ,α)| in the elevation plane). Simulations have been performed in MATLAB environment, where the NN toolbox has been used.

After the training process, the performance of all NNs' and ANFISs' models were evaluated for several different cases through the calculation of statistical measures, such as the testing absolute error:

$$AE_{ik} = |p_{ik} - t_k| \quad [1]$$

the testing mean absolute error:

$$MAE_i = \frac{1}{K}\sum_{k=1}^{K}|p_{ik} - t_k| \quad [2]$$

and the testing average relative error:

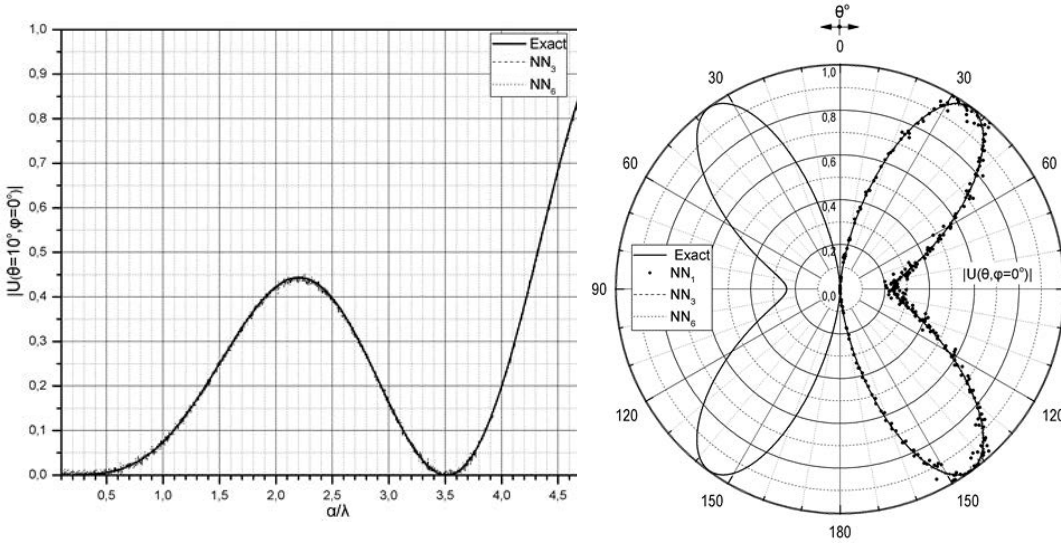
$$ARE_i = \frac{1}{K}\sum_{k=1}^{K}|p_{ik} - t_k|/t_k \quad [3]$$

where p_{ik} is the k-th (k=1,2,…,K) predicted value of the radiation intensity from the i-th (i=1,3,6) model, t_k is the corresponding desired output and exact theoretical target value, and K is the number of testing data.

The data, generated analytically from *Werner (1996),* are separated into three (the

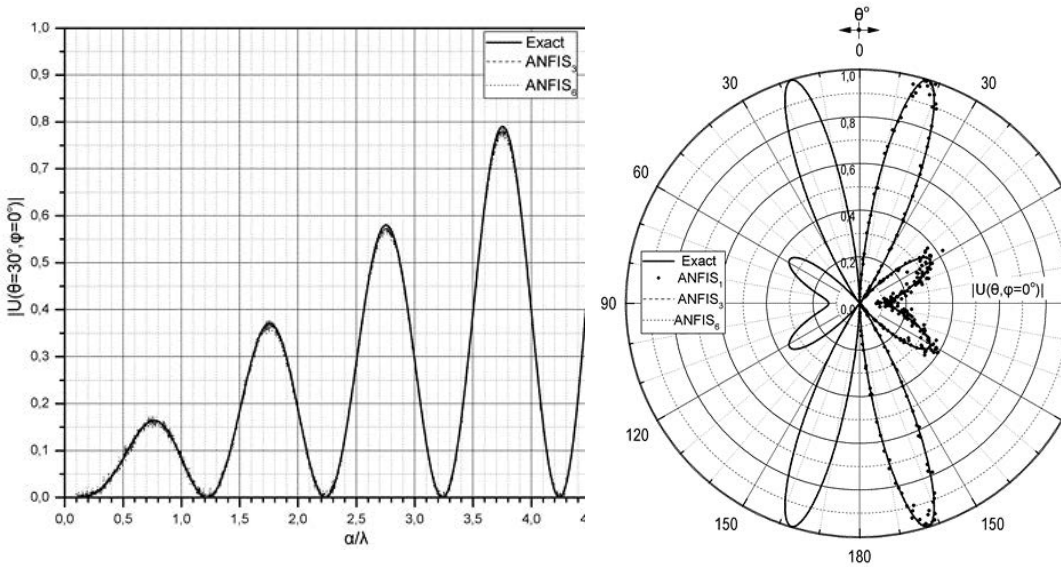
training, the validation and the testing) datasets. All models were fed with the testing input data (K=1000) and make predictions, whose quality is indicated by the measures of [1]-[3].

Comparisons of the radiation intensity |U| and the corresponding radiation patterns, predicted from the NN and the ANFIS models, with the exact theoretical data extracted from *Werner (1996)*, are presented in Figures 1 and 2 respectively.



(a) (b)

Figure. 1. Normalized radiation intensity |U| (output) versus (a) the normalized loop radius for θ=10º, or (b) the observation angle θ for α=λ/2 (inputs). Solid lines, dots, dashed lines and dotted lines represent exact (analytically extracted) values, and predicted from three different NN models consisting of 1 (NN_1), 3 (NN_3) and 6 (NN_6) MLP NNs, respectively.



(a) (b)

Figure 2. Normalized radiation intensity |U| (output) versus (a) the normalized loop radius for θ=30º, or (b) the observation angle θ for α=λ (inputs). Solid lines, dots, dashed lines and dotted lines represent exact (analytically extracted) values, and predicted from three different ANFIS models consisting of 1 ($ANFIS_1$), 3 ($ANFIS_3$), and 6 ($ANFIS_6$) ANFISs, respectively.

2. CONCLUSION

Apparently NN_6 and $ANFIS_6$ models can accurately predict the radiation intensity, while NN_3 and $ANFIS_3$ models return very good results, and NN_1 and $ANFIS_1$ models achieve poor performance. Figs. 1 and 2 reveal that the results predicted from the NN_3 and $ANFIS_3$ and the NN_6 and $ANFIS_6$ models are matching closely the analytical data, while the $ANFIS_3$ and $ANFIS_6$ models are requiring less data samples in order to be trained and being slightly more accurate in predicting the circular loop radiation intensity.

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ESTIMATION OF CIRCULAR LOOP ANTENNA CHARACTERISTICS USING NEURAL NETWORKS: THE INVERSE PROBLEM

T.N. Kapetanakis[1,2], I.O. Vardiambasis[1], M.P. Ioannidou[3], E.I. Lourakis[1], and A. Maras[2]

[1] Department of Electronic Engineering, Hellenic Mediterranean University
[2] Department of Informatics and Telecommunications, University of Peloponnese
[3] Department of Information and Electronic Engineering, International Hellenic University
ivardia@hmu.gr

1. INTRODUCTION

The radiation characteristics of antennas, such as the circular loop *Kapetanakis et al. (2012a)*, *Kapetanakis et al. (2018a)* and the short dipole array *Mishra et al. (2015)*, have been calculated recently, by application of artificial neural networks (NNs). The inverse EM problem is proved to be more challenging task *Low et al. (1992)*, *Kapetanakis et al. (2012b)*, *Kapetanakis et al. (2018b)*. The term "inverse" refers to the estimation of the radiator properties (antenna characteristics) from information gathered from measurements or analytical/numerical calculations. Here we present several NN models for the inverse circular loop radiation problem of a, loop antenna of arbitrary radius and uniform current distribution.

2. MATERIALS AND METHODS

The configuration considered herein, comprises a thin, circular, current-carrying loop of radius α, that radiates in free space, as shown in Figure 1.

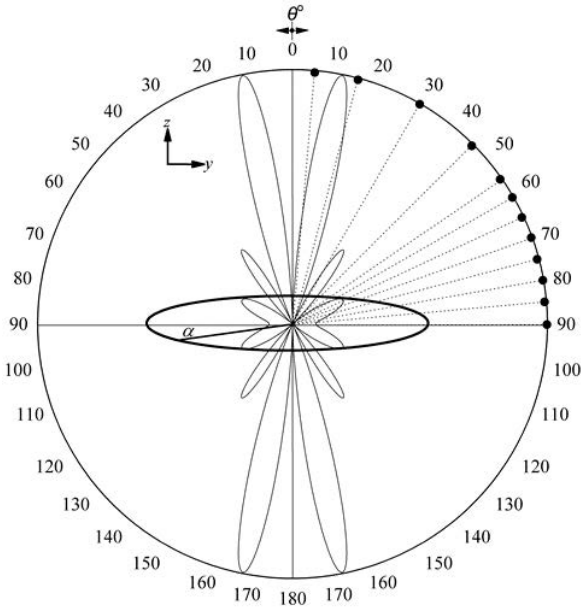

Figure 1. Circular loop antenna geometry and representative radiation pattern (ϑ-plane, $a = 3\lambda/2$, I=1A). The dots represent the observers.

The φ-component of the electric field intensity serves herein as input to the NN. It may be expressed as *Werner (1996)*:

$$E_{\varphi}(r,\theta,\varphi)=\frac{\eta\beta^2 a}{4}\sum_{\substack{v=1\\ v-u=2q\\ q=0,1,\ldots}}^{\infty}\sum_{u=1}^{v}\left[\cos(u\varphi)\left(\frac{\beta^2\alpha r\sin\theta}{2}\right)^{v-1}\left(C_{vu}^{6}\frac{h_v^{(2)}(\beta R)}{(\beta R)^{v}}-C_{vu}^{2}\frac{h_{v-1}^{(2)}(\beta R)}{(\beta R)^{v-1}}\right)\right] \quad [1]$$

where (r,θ,φ) are the spherical coordinates of the field point, $R=\sqrt{r^2+a^2}$, η stands for the free space wave impedance, β is the wavenumber and $h_v^{(2)}(\beta R)$ represents the spherical Hankel function of the second kind and *v*-th order. Data generated from [1] have been grouped in three distinct datasets and were used for training, validating and testing the neural network model, respectively.

Calculations are performed for specific field points denoted as Pn ($r=400\lambda$, θ_n, φ), where n=1,2,...,N and λ stands for the wavelength. The observation points are depicted as dots in Figure 1; the maximum number of observers considered herein is 12. As regards the loop radius, it is allowed to take values in the range [0.1λ, 8λ].

Simulations have been performed in MATLAB environment, where the NN toolbox has been used *Beale et al (2016)*. Three different NN architectures have been implemented in this study: The Multilayer Perceptron (MLP)-NN, the Radial Basis Function (RBF)-NN and the Generalized Regression (GR)-NN. An extensive trial-and-error process has been applied.

3. RESULTS AND DISCUSSION

A comparison of the loop radius predicted from the three NN models with the theoretical data extracted from [1] is given in Figure 2; where the single case for a specific observer, placed at 30^o, is shown. The size *M* of the training dataset as well as the number of the observers *N* are given in the inset.

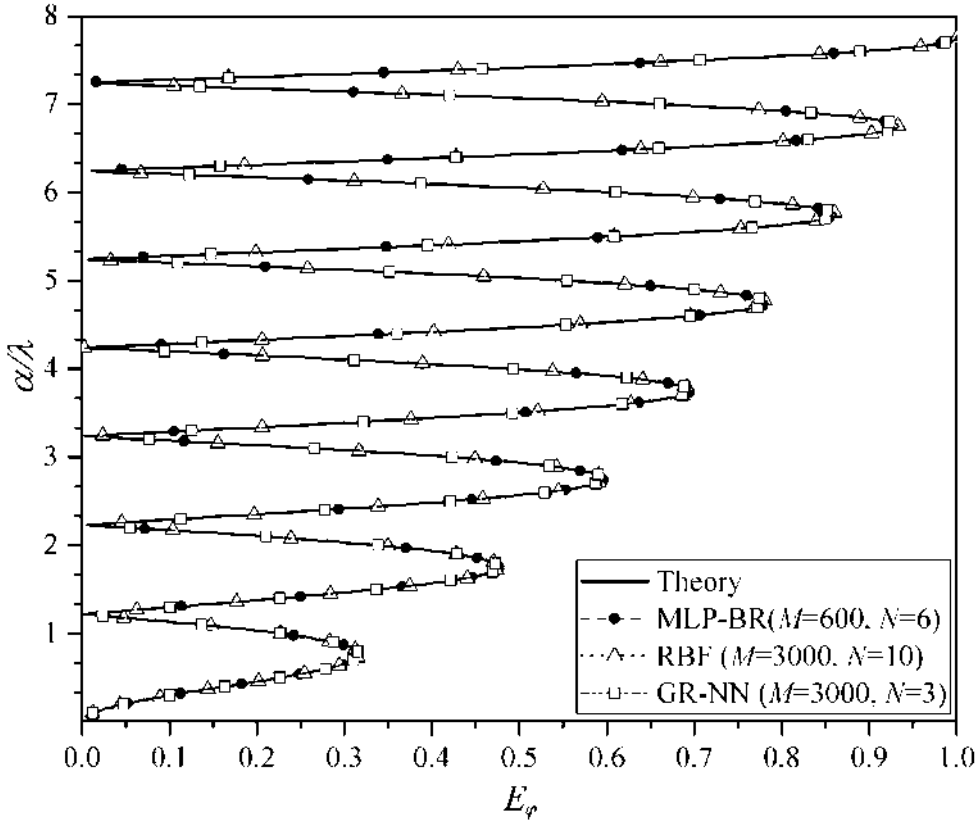

Figure 2: Normalized loop radius (output) against the normalized electric field intensity $|E_\varphi(400\lambda, 30°, \varphi)|$ (input). Dots, triangles and squares represent the NN predicted values p_k, whereas the continuous line represents the exact theoretical target values t_k^{te}.

4. CONCLUSION

The inverse problem of a circular, loop antenna that carries uniform current and radiates in free space has been successfully solved by neural networks. The values of the electric field intensity at specific observation points have served as inputs to the NNs. The numerical tests have revealed that important parameters that affect the accuracy of the results are the number and the location of the observers as well as the size of the training dataset. The selection of the appropriate NN configuration for the solution of the inverse loop antenna radiation problem is a task that involves several parameters and should take into consideration all the existing constraints such as the size of the datasets and the number of the observers available.

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HEART RATE TIME SERIES PREDICTION DURING EXERCISE USING NEURAL NETWORKS

A. Lampou[1], M. Zakynthinaki[1], T.N. Kapetanakis[1], M.P. Ioannidou[2], and I.O. Vardiambasis[1]

[1] Department of Electronic Engineering, Hellenic Mediterranean University
[2] Department of Information and Electronic Engineering, International Hellenic University

ivardia@hmu.gr

1. INTRODUCTION

The heart rate (HR), defined as the number of heart beats per minute) is the simplest and most informative cardiovascular variable *Whipp et al (1972)*, *Wilmore et al (2007)*, *Zakynthinaki et al (2007)*. The analysis of the HR response to exercise is very important in the areas of physiology, fitness and sport *Zakynthinaki (2016)*, but also in cardiovascular health, prediction and rehabilitation, as it can detect hidden physiological responses or abnormalities and also provide important information regarding cardiovascular condition *Astrand et al (2003)*, *Davies et al (1972)*, *Linnarsson (1974)*, *Zakynthinaki et al (2011)*.

Here we use artificial neural networks (NNs) to predict the heart rate response to exercise based on a given initial set of HR data *Zakynthinaki (2016)*, *Zakynthinaki (2015)*.

2. MATERIALS AND METHODS

A healthy male athlete served as the test subject preforming a set of four constant intensity exercises followed by a 10 minute static recovery period. The experiment was carried out on a tartan track *Zakynthinaki (2015)*, *Zakynthinaki et al (2008)*, *Zakynthinaki et al (2007)*. The data recording resulted to four sets of heart rate data, each including the HR response to an exercise of constant intensity and its subsequent recovery *Zakynthinaki (2015)*, *Zakynthinaki et al (2008)*, *Zakynthinaki et al (2007)*. The velocities of each exercise were: v_1=13.4 km/h, v_2=14.4 km/h, v_3=15.7 km/h, and v_4=17.0 km/h.

3. RESULTS AND DISCUSSION

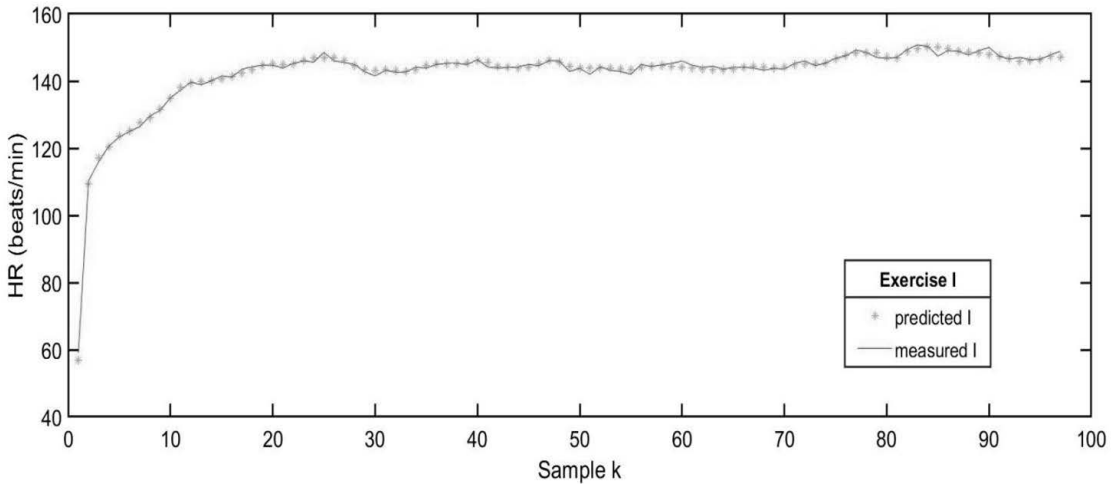

Figure 1: Predicted and measured HR (in beats/min) in the case of exercise velocity v_1.

The performance of the NN model was evaluated through the calculation of the statistical measures of the mean absolute error

$$MAE_{te} = \frac{1}{K}\sum_{k=1}^{K}|p_k - t_k| \quad [1]$$

and the relative mean square error

$$RMSE_{te} = \frac{1}{K}\sum_{k=1}^{K}\left(\frac{p_k - t_k}{t_k}\right)^2 \quad [2]$$

Here we present the results in the case of exercise velocity v_1=13.4 km/h. The obtained MAE_{te} was 0.649, while the $RMSE_{te}$ was 4.6297×10^{-5}. Figure 1 shows a very close agreement between the predicted and the measured heart rate values (in beats/min) in this case.

4. CONCLUSION

The heart rate predictions can be applied to provide data for analysis in population groups for which direct HR recordings at intense exercises would not be possible or allowed, such as elderly or pregnant women. The close agreement between the measured and the predicted HR values, verifies that the proposed neural network model can be used successfully for the solution for the HR prediction problem.

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Link Budget and Capacity study for LTE ground to air system

Valmas George[1] and Kokkinos Evangelos[1]

[1]Hellenic Mediterranean University

E-mail: george458354@yahoo.com

ekokkinos@chania.teicrete.gr

1. INTRODUCTION

Using the characteristics of LTE (Long Term Evolution) technology for wireless communication, parameters were adapted to design, study and taking conclusions to a ground-to-air communication system. Some parameters such as frequency, distance, speed, transmitted power, antenna gain etc. of this system differ from a ground system. Ground-to-air communication is between base station, located on the ground and passenger aircraft, through an antenna at the bottom of the aircraft.

Surveys has shown that aircraft passengers consider internet access, during the flight, more important than phone calls. The majority of passengers consider that the Wi-Fi in flight is important for entertainment and it is more necessity than a luxury. Passengers have adopted the convenience of staying connected. Passengers need this connectivity, stay up-to-date on social media, banking, or work online.

2. LTE GROUND TO AIR LINK BUDGET

The network planning for the direct ground-to-air system is quite similar with the terrestrial network. First is calculated the noise level and then the received signal. Depending on SINR (Signal to Interference plus Noise Ratio) conditions, the LTE choose the appropriate modulation scheme. QoS depends on the number of the aircrafts. The data speed is shared to all aircrafts in each antenna sector and QoS is reduced accordingly. For better QoS there should be more ground stations. Passengers are supported with WiFi onboard. The antenna at the bottom of the aircraft receives the signal. In some aircrafts there is a diversity antenna in order to improve the signal reception.

Direct air to ground vs Satellite

A satellite-based equipment is heavy, bulky and expensive, and latency is high in regions with heavy air traffic. Ka band and Ku band satellite antennas are difficult to install on continental aircraft, requiring significant investments in the aircraft infrastructure [1].

Margin

Set a margin of 10 dB and add it to the sensitivity of the receiver. This will be a protection, due to weather conditions, from the bad antenna targeting etc. It increase the noise, so the sensitivity and the link availability decreases. The signal received at the receiver must be greater than the value of Sensitivity plus margin.

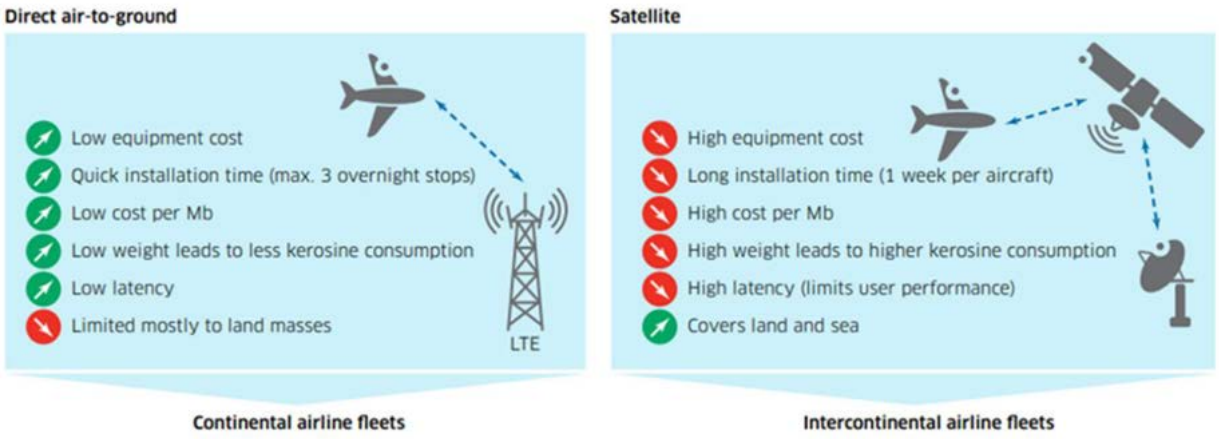

Figure 1. Direct air to ground vs Satellite [1]

Interferences

There are two types of interference, the intersystem interference and the outside cell interference, for example if there is another broadcast. If the transmitter of the aircraft transmits with high power at low altitudes, this will increase the interference issues in ground stations at neighbor zones of the systems.

2.1 Forward Link Scenario

Forward Link is the data transmission from the base station to the aircraft. One scenario is examined, according to the power distribution within the cell and the distance between the ground station and the aircraft. The antenna elevation, is 10^o (The vertical pattern of the antenna is 8^o), depends on the characteristics of the antenna and the cell radius to be covered. The value of cell radius which used here, is suitable for large cells. For cells with a shorter radius, the main lobe should have larger elevation. In this scenario we use a typical value of 90km. The antenna of the base station has 3 sectors. Each sector has 120 degrees, with the main lobe and side lobes at -7 dB of the transmitter antenna gain. The altitude that the aircraft flies most of the time in flight ($H_{aircraft}$), is 10 km and the antenna height ($h_{antenna}$) is 50 m.

Base station-aircraft distance:

$$\sin\varphi^o = \frac{(\mathrm{H_{aircraft}} - \mathrm{h_{antenna}})}{\mathrm{d}} => d = \frac{(\mathrm{H_{aircraft}} - \mathrm{h_{antenna}})}{\sin\varphi^o} = 57.183\mathrm{Km} \quad (1)$$

So, the horizontal distance is 56.3Km.

Free-space path loss (FSPL):

$$FSPL(dB) = 20\,log(d) + 20\,log(f) + 32.45 = 133.62 \qquad (2)$$

d = 57.18 Km (distance between the transmitter and the receiver in km)
f = 2GHz (=2000MHz - signal frequency in MHz)

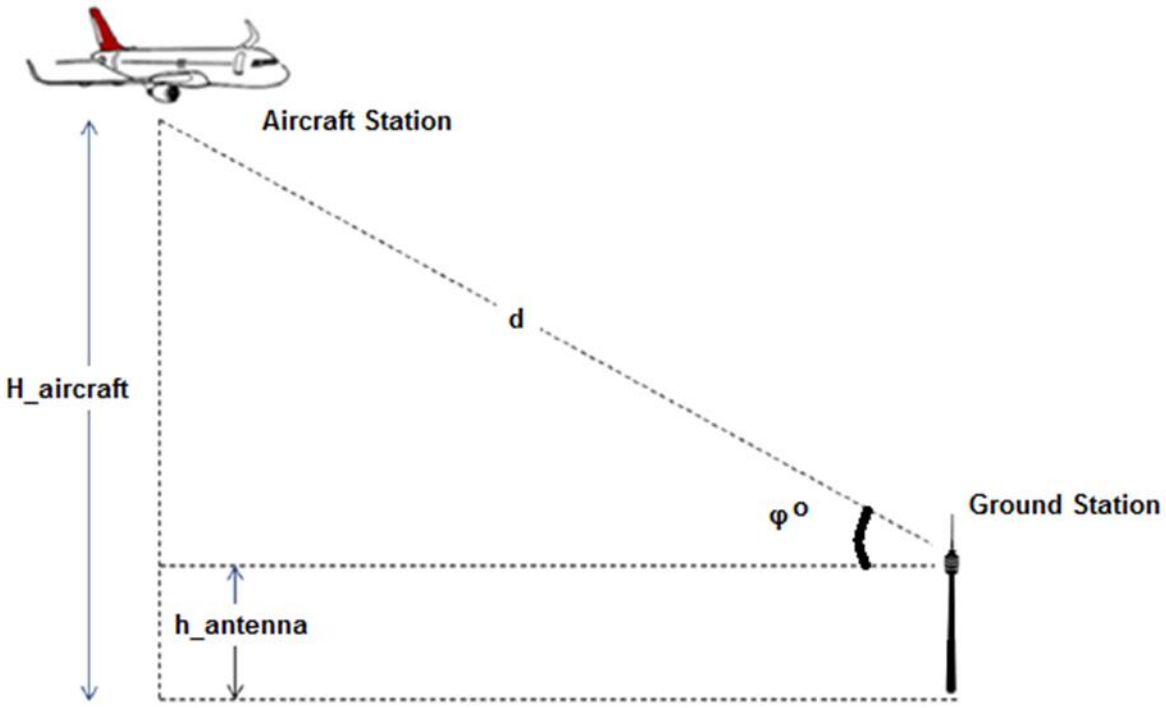

Figure 2. Scenario 1 for direct ground to air communication [2]

Effective Isotropic Radiated Power (EIRP)

G_T : Transmission gain is 15 dBi

P_T = 47 dBm per polarization (The input power of the base station transmitter antenna)

$Loss$: Cable losses are 1 dB

$$EIRP(dBm) = G_T\ (dBi) + P_T(dBm) - Loss(dB) = 61 \qquad (3)$$

The signal at the receiver

G_R : Reception gain is 3 dBi [2]

$$P_r(dBm) = EIRP(dBm) + G_R\ (dBi) - FSPL(dB) = -69.62dBm \qquad (4)$$

Noise power of the receiving system

$k = 1.3806488 \times 10^{-23}\ (J/K)$: Boltzmann constant (physical constant)

$T_s = 290$ K : Noise temperature at receiver input

For B = 10MHz

N : Noise power of the receiving system: $Noise\ power\ in\ the\ band \times Receiver\ noise\ figure$

$$N = N_0 B \cdot NF = -96dBm \qquad (5)$$

N_o : Thermal Noise $= k \cdot T_s \approx -174\ \frac{dBm}{Hz}$

$N_o B$: Noise power in the band$= -104\ dBm$

NF : Receiver noise figure. Typical value of the aircraft receiver is $NF = 8dB$

Thermal Noise

Johnson–Nyquist noise (sometimes thermal, Johnson or Nyquist noise) is unavoidable, and generated by the random thermal motion of charge carriers (usually electrons), inside an electrical conductor, which happens regardless of any applied voltage. Thermal noise is approximately white, meaning that its power spectral density is nearly equal throughout the frequency spectrum.

Noise Figure

Noise figure (NF) is a measure of degradation of the signal-to-noise ratio (SNR), caused by components in a signal chain. It is a number by which the performance of an amplifier or a radio receiver can be specified, with lower values indicating better performance. NF is the ratio of input SNR to the output SNR of a device or receiver chain. It is expressed in dB [3], [4].

3. Sensitivity of the receiver

Sensitivity of the receiver is defined as the minimum signal strength required ensuring a certain quality of service and is expressed in dBm. Sensitivity is an indicator showing how well a device receive the signal and decode it within a satisfactory error rate. The LTE sensitivity power level is the minimum mean power received at the antenna connector. The power reaching at the receiver of the aircraft should be higher than its sensitivity. If the power level which reaching at the receiver is less than the sensitivity then the probability of bit error rate (BER) increases. [5].

3. 1. Sensitivity Calculation

The LTE sensitivity power level is the minimum mean power received, at the antenna connector and determined as

$$Sensitivity\ (dBm) = N + SNR \qquad (6)$$

From SNR table,

For SNR=-5 and B = 10MHz, So Sensitivity = -101 dBm

For SNR= 0 and B = 10MHz, So $Sensitivity$ = -96 dBm

For SNR= 5 and B = 10MHz, So $Sensitivity$ = -91 dBm

For SNR= 10 and B = 10MHz, So $Sensitivity$ = -86 dBm

For SNR= 16 and B = 10MHz, So $Sensitivity$ = -80 dBm

Required Base Band SNR		
SNR Requirements Versus Coding Rate and Modulation Scheme		
Modulation	Code Rate	SNR [dB]
QPSK	1/8	-5.1
	1/5	-2.9
	1/4	-1.7
	1/3	-1.0
	1/2	2.0
	2/3	4.3
	3/4	5.5
	4/5	6.2
16 QAM	1/2	7.9
	2/3	11.3
	3/4	12.2
	4/5	12.8
64 QAM	2/3	15.3
	3/4	17.5
	4/5	18.6

Figure 3. Required SNR for different type of LTE signal [6]

4. Capacity calculation of LTE system

$$C(bits/s) = B \cdot \log_2(1 + SNR) \qquad (7)$$

- For SNR=-5dB and B = 10 MHz, $SNR = 10^{SNR_{dB}/10} = 0.316$

So $C(bits/s) = B \cdot \log_2(1 + SNR) = 3.96\, Mbits/s$

Modulation: QPSK, Code Rate 1/8, So the Payload= 495k$bits/s$

- For SNR=0dB and B = 10 MHz, $SNR = 10^{SNR_{dB}/10} = 1$

So $C(bits/s) = B \cdot \log_2(1 + SNR) = 10\, Mbits/s$

Modulation: QPSK, Code Rate 1/3, So the Payload = 3.33M$bits/s$

- For SNR=5dB and B = 10 MHz, $SNR = 10^{SNR_{dB}/10} = 3.162$

So $C(bits/s) = B \cdot \log_2(1 + SNR) = 20.57\, Mbits/s$

Modulation: QPSK, Code Rate 2/3, So the Payload = 13.716M$bits/s$

- For SNR=10dB and B = 10 MHz, $SNR = 10^{SNR_{dB}/10} = 10$

So $C(bits/s) = B \cdot \log_2(1 + SNR) = 34.594\, Mbits/s$

Modulation: 16QAM, Code Rate 1/2, So the Payload = 17.297M$bits/s$

- For SNR=16dB and B = 10 MHz, $SNR = 10^{SNR_{dB}/10} = 39.811$

So $C(bits/s) = B \cdot \log_2(1 + SNR) = 53.509\, Mbits/s$

Modulation: 64QAM, Code Rate 2/3, So the Payload = 35.673M$bits/s$ [6].

5. Conclusions - Future work

The power received in this Scenario is $P_r = -69.62dBm$ and the Sensitivity with those SNR values is from −101 dBm to −80 dBm". So the received signal can be detected from the receiver and we can set a margin. At the cell edges, where already signal level is low, thus aircrafts equipment are assigned lower modulations to maintain the connectivity with the base station and thus with lower modulation at the cell edges, the throughput of aircrafts equipment also decreases. At the cell edge, additional interference will increase noise. Excessive noise in the system can significantly reduce system capacity. 5G communication techniques, such as, large antenna arrays, multi-users beamforming systems and higher-order modulation systems will improve DA2GC systems to provide 1.2 Gbps per aircraft. The largest capacity of the 5G DA2GC network is mainly achieved through the use of MU-MIMO, which allows the spatial division multiple access (SDMA). This allows any aircraft to be served with its own signal beam. This leads to full usage of bandwidth [7], [8].

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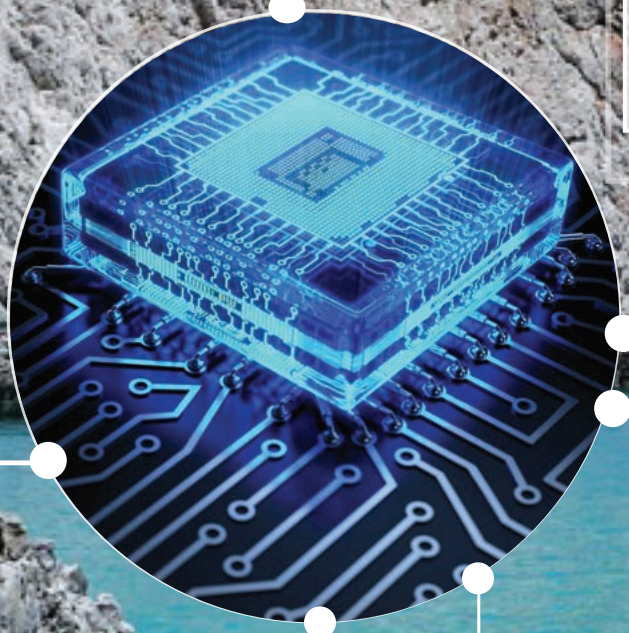

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