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Athens Journal of Technology & Engineering

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The current issue is the first of the tenth volume of the *Athens Journal of Technology & Engineering (AJTE),* published by the Engineering & Architecture Division of ATINER.

Gregory T. Papanikos, President, ATINER.

Athens Institute for Education and Research
A World Association of Academics and Researchers

13th Annual International Conference on Civil Engineering
19-22 June 2023, Athens, Greece

The Civil Engineering Unit of ATINER is organizing its **13th Annual International Conference on Civil Engineering, 19-23 June 2023, Athens, Greece** sponsored by the Athens Journal of Technology & Engineering. The aim of the conference is to bring together academics and researchers of all areas of Civil Engineering other related areas. You may participate as stream leader, presenter of one paper, chair of a session or observer. Please submit a proposal using the form available (https://www.atiner.gr/2023/FORM-CIV.doc).

Academic Members Responsible for the Conference

- **Dr. Dimitrios Goulias**, Head, Civil Engineering Unit, ATINER and Associate Professor & Director of Undergraduate Studies Civil & Environmental Engineering Department, University of Maryland, USA.

Important Dates

- Abstract Submission: **21 March 2023**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **22 May 2023**

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- Greek Night Entertainment (This is the official dinner of the conference)
- Athens Sightseeing: Old and New-An Educational Urban Walk
- Social Dinner
- Mycenae Visit
- Exploration of the Aegean Islands
- Delphi Visit
- Ancient Corinth and Cape Sounion

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A World Association of Academics and Researchers

11th Annual International Conference on Industrial, Systems and Design Engineering, 19-22 June 2023, Athens, Greece

The Industrial Engineering Unit of ATINER will hold its **11th Annual International Conference on Industrial, Systems and Design Engineering, 19-23 June 2023, Athens, Greece** sponsored by the Athens Journal of Technology & Engineering.The aim of the conference is to bring together academics, researchers and professionals in areas of Industrial, Systems, Design Engineering and related subjects. You may participate as stream leader, presenter of one paper, chair of a session or observer. Please submit a proposal using the form available (https://www.atiner.gr/2023/FORM-IND.doc).

Important Dates

- Abstract Submission: **21 March 2023**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **22 May 2023**

Academic Member Responsible for the Conference

- **Dr. Theodore Trafalis**, Director, Engineering & Architecture Division, ATINER, Professor of Industrial & Systems Engineering and Director, Optimization & Intelligent Systems Laboratory, The University of Oklahoma, USA.

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The Possibilities of Developing STEM Skills in Higher Education

By Ildikó Holik[*] & István Dániel Sanda[±]

The development of information and technology in recent decades has entailed a change of attitudes in higher education. In addition to academic knowledge, it is becoming increasingly important for students to acquire up-to-date, practical knowledge that will help them find their place in the world of work and in everyday life. Based on international analyses, the following characteristics, so-called soft skills, are essential on the labour market: higher-level thinking, communication skills, cooperation, self-control and a positive self-image. In our paper, we examine the possibilities of skills development in the field of STEM, especially in engineering education. In our university's engineering teacher training, we strive to develop our students' STEM skills using a variety of methods, and prepare them for the teacherly task of being able to effectively develop their own students' skills and motivate them in STEM areas. This requires students to view their own learning process not as passive onlookers but as active participants. In our paper, we present some methods that can be effectively applied in STEM areas (e.g. discussion, collaborative learning, cooperative methods, project method, problem-based learning, inquiry-based learning, gamification, the use of robots in education).

Keywords: *STEM, skills development, educational methods, teacher training*

Introduction

STEM includes the areas of **S**cience, **T**echnology, **E**ngineering and **M**athematics. Its essential feature is the use of scientific, technical and mathematical knowledge to solve everyday tasks or social problems. It is characterised by a complex and interdisciplinary approach.

"STEM competency refers to an individual's ability to apply STEM knowledge, skills and attitude appropriately in his or her everyday life, workplace or educational context" (Boon 2019, p. 11).

STEM competency includes the "know-what", i.e., the knowledge, attitudes and values attached to the areas of science, as well as the "know-how", i.e., the skills necessary for the application of this knowledge (Boon 2019). It is important not to treat these components in isolation but rather in a holistic way.

The aim of teaching STEM areas is not only to develop cognitive skills, but also to develop soft skills such as problem solving, collaboration and communication skills. This is extremely important because nowadays, as a result of the 4th industrial revolution, the range of expected skills and abilities on the

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labour market has changed, and the demand for the development of soft skills has come to the fore (Kersánszky and Nádai 2020). STEM teaching is key in the preparation of students for the world of work (Kefalis and Drigas 2019). Improving STEM skills is possible through varied teaching methods.

The Skills Necessary on the Labour Market

The development of information and technology in recent decades has entailed a change of attitudes in higher education (Wolhuter 2020). In addition to academic knowledge, it is becoming increasingly important for students to acquire up-to-date, practical knowledge that will help them find their place in the world of work and in everyday life. This also necessitates knowing the demands of the labour market (Alter and Kocsis 2021, Szabó and Barta 2020).

Several studies explore what characteristics are expected by employers besides professional knowledge.

On the basis of national and international analyses, Daruka (2017, p. 10) lists the five most important soft skills which can be considered critical from the aspect of labour market preferences:

- Higher-level thinking (critical thinking, problem solving, decision making).
- Communication skills (oral and written, in one's mother tongue and in foreign languages).
- Cooperation (e.g., context-dependent behaviour, conflict management).
- Self-control.
- Positive self-image (self-confidence, self-knowledge, self-effectiveness, self-worth).

Between 1997 and 2002, a large-scale competency survey was conducted in 12 OECD countries, during which researchers compiled a competency list. Organised into three groups, the list contains a total of 23 competencies that, based on research in the Member States, are specific to the employee who can ensure the future competitiveness of the organisation (cited by Karcsics 2007, p. 62).

Key Competencies:

- Communication.
- Quantification skills.
- Teamwork.
- Problem solving skills.
- Learning and performance development.

Work Competencies:

- Flexibility.
- Creativity.
- Initial independent decision.
- Ability to act.
- Foreign language skills.
- Self-confidence.
- Critical approach.
- Exploring possibilities.
- Responsibility.

Leadership Competencies:

- Leading.
- Motivating other people.
- Learning from mistakes.
- Building and maintaining relationships.
- Influencing other people.
- Decision making.
- Focusing on results and completing processes.
- Setting up a strategy.
- Ethical attitude.

A particularly important question in engineering education is what abilities and skills are essential for an engineer in a rapidly changing information society (Conlon 2008, Lappalainen 2009, Williamson et al. 2013).

Already during their studies, engineering students face a variety of challenges to successfully complete their education. For example, critical thinking and technical skills are considered essential (Noonan 2017, Szabó and Bartal 2020).

There is a growing demand on the labour market for flexible, adaptable and communicative engineers (Kolmos 2006). Employers expect fresh graduate engineers to have not only professional knowledge but also qualities such as problem solving, openness and creativity so that they can deal with people as well as work in a team.

Engineers need to collaborate with other engineers, their subordinates, marketing and financial experts, merchants, and many other corporate employees, as well as representatives of other companies, foreign partners, and even communicate with users (e.g., when presenting products) (Bajzát 2010). Soft skills provide the basis for the effective handling and management of problem situations (Schulz 2008).

Engineering education focuses primarily on the development of professional competencies and technical skills, but it would also be important to prepare students for the demands of the workplace. Schomburg (2007) draws attention primarily to the lack of social, communicative and personal competencies. Other studies have highlighted the importance of interpersonal skills in engineering (Direito et al. 2012, Berglund and Heintz 2014), and emphasise the need to rethink "traditional pathways" in engineering education as a result of technical changes, and to develop competencies which meet the expectations of the labour market.

Literature sources also point out that personality traits play an important role in terms of working ability and job satisfaction, and are therefore regarded as key characteristics of the engineering profession. According to the research results of Williamson et al. (2013), the studied engineers differ from the research subjects of other occupations in that they have more intrinsic motivation and are more persistent, but less characterised by the following qualities: self-confidence, conscientiousness, extroversion, emotional stability and optimism.

Other studies (Lappalainen 2009, Direito et al. 2012) have also drawn attention to the weaknesses of engineers: effective communication, cooperation, teamwork, project management and lifelong learning tend to pose difficulties for them.

According to the reports issued by the World Trade Form, the skills preferred by the labour market are continually changing. The priority has shifted towards soft skills. Based on the ranking of the 2020 report, the most important skills on the labour market in 2025 will be the following (World Economic Forum 2020):

1. Analytical thinking and innovation.
2. Active learning and learning strategies.
3. Complex problem-solving.
4. Critical thinking and analysis.
5. Creativity, originality and initiative.
6. Leadership and social influence
7. Technology use, monitoring and control.
8. Technology design and programming.
9. Resilience, stress tolerance and flexibility.
10. Reasoning, problem-solving and ideation.
11. Emotional intelligence.
12. Troubleshooting and user experience.
13. Service orientation.
14. Systems analysis and evaluation.
15. Persuasion and negotiation.

Analytical thinking, innovation, active learning and complex problem solving are essential in the future labour market. Therefore, an emphasis should be placed on the development of these skills in higher education.

In Hungary, several studies have examined how the demands and expectations of employers appear in job advertisements.

In his study published in 2006, Híves analysed what aspects the labour market considered most important on the basis of 954 job advertisements targeting graduate employees.

The results of his research showed that foreign language skills, informatics and professional experience are outstanding among the expectations. Firstly, employers expect a number of professional competencies that can be acquired through study or employment. Secondly, they also require general competencies related to work activities, which in many cases are related to the personality traits of employees. Thirdly, they expect qualities that are related to fellow employees, the company and working conditions. The results of the research call attention to the fact that a good demeanour and good communication skills are essential. In addition, problem-solving skills, organisational skills and leadership skills are emphasised. The expectation of independent work is of paramount importance.

Bajzát (2011) analysed in her research 1000 job advertisements for mechanical engineers. She found that all advertisements contained foreign language skills requirements. 60.5 per cent of job advertisements also included expectations of other competencies. Based on the results, it can be stated that companies are primarily looking for engineers who have good communication, problem-solving and teamwork skills.

Selmeczy (2006) assessed the needs of the labour market divided into different job areas. In his research, he came to the conclusion that the most important skills in the evaluation of graduates are:

- Accurate work.
- ICT knowledge.
- High workload capacity.
- Foreign language skills.
- Teamwork.

Besides the above, the following are also important:

- Working independently.
- Foundational professional knowledge.
- Professional experience.
- Organisation skills.

In Selmeczy’s research, what repeatedly surfaced in interviews with experts was that engineers did not have a good enough demeanour or enough knowledge about practical applications and the operation of companies and also that their foreign language skills were often inadequate. On the other hand, they had a strong idea that what they wanted to do, they were calm and would persevere in a company and an occupation.

Some of the responding employers emphasised the lack of work experience and foreign (mainly professional) language knowledge in the case of graduate career starters. The first expectation raises the important question of how career starters can be expected to have (several years of!) work experience.

The dual training introduced at our university seeks the resolution of this antagonistic contrast in the scheme that, in addition to their university student status, students also gain work experience with partner companies in parallel with their higher education.

In a study by Kiss (2010), he compared the opinions of new graduates and employers about the competencies needed by career starters. Based on the data obtained, a striking difference can be observed: recent graduates rated precise and independent work, high working capacity and interpersonal and communication skills as the most important, while employers rated entrepreneurship, foreign language skills, analytical approach and professional theoretical foundations as key.

The study of Ablonczyné and Tompos (2007) also showed that companies value in career starters high-level foreign language communication competencies, reliable work, creativity, teamwork skills, flexibility, problem-solving skills and initiative.

In her research based on the analysis of the Hungarian press, Czenky states that what employers value is "the so-called marketable knowledge, expertise and professional knowledge, which can be used directly in practice, rather than purely theoretical knowledge" (Czenky 2006, p. 124).

According to a survey of the Northern Great Plain region, corporate experts drew attention to the importance of the following competencies: responsibility at work, independent work and problem-solving skills, followed by professional competence (Polónyi 2007).

Pénzes et al. (2012) assessed labour market expectations among organisations operating in Central and Eastern Hungary. According to the results of the research, the surveyed organisations considered good communication skills to be the most important requirement for career-starting graduates. Possession of a high level of theoretical knowledge and the ability to utilise it, as well as high-quality foreign language communication were also among the most important requirements. The companies surveyed also stated which areas they were most dissatisfied with when employing young career-starters. The standard of oral communication came first, followed by the lack of negotiation-level foreign language skills and that of professional experience. Another problem identified was the lack of a goal-oriented approach and strategic thinking, and a low level of motivation, willingness, self-knowledge and independence. In contrast, they were satisfied with the graduates' professional theoretical knowledge and its effective application in practice.

The current challenge for higher education institutions is to train students in a way that they would be able to stand their ground on a labour market with changing demands.

STEM Skills

A degree in STEM fields appears as a competitive advantage in the job market. According to Noonan (2017), students studying in STEM courses and employees performing jobs in STEM-related workplaces are of paramount importance to the economy and industry.

However, a number of problems arise in this area. For example, there are not enough applicants for some engineering courses, there is a high drop-out rate during the programme, especially in the first and second semesters, and there is a large gap between the theory taught at university and the practice of corporate industrial production.

The main goal of STEM courses is not to educate intellectuals in the classical sense, but professionals with the specific knowledge and the greatest chance to satisfy the needs of the labour market (Alter and Kocsis 2021). In order for the student or employee to succeed in the STEM fields, in addition to theoretical knowledge and cognitive skills, emphasis must also be placed on the development of soft skills, which requires deliberate preparation.

The skills required to perform tasks in STEM areas include cognitive, manipulative, technological, as well as collaborative and communicative skills (Boon 2019).

Cognition refers to the mental process of understanding through thinking and experience. Cognitive skills include: information management and processing; identifying, collecting, processing and using relevant data to make decisions; critical, creative and analytical thinking; problem solving; scientific investigation; creativity and computational thinking.

Manipulation and technological skills refer to psychomotor skills, which are required for the correct and safe use and operation of scientific and/or technical equipment and the correct and safe handling of various substances.

Collaboration and communication skills can be developed and improved through effective teamwork. Effective collaboration is achieved when team members set common goals, are given equal opportunities to participate and communicate ideas, and everyone takes equal responsibility for their work.

Also important in STEM areas are the so-called transversal (cross-curricular, inter-curricular) competencies, which are general skills that are independent of school subjects and cannot be linked to a specific discipline, but can be widely applied. They enable adaptation to change and also contribute to motivation and job satisfaction that affect the quality of work (Säävälä 2011).

Transversal competencies (Lukácsné Ujhegy 2013) are the following:

- Learning to learn independently.
- Social competencies.
- Cooperative activity.
- Critical thinking and reflection.
- Digital competency.

In its report, the UNESCO separated the following transversal competency areas (Care and Luo 2016, p. 11, Sheffield and Koul 2021, p. 5).

- Critical and innovative thinking (creativity, entrepreneurship, resourcefulness, application of skills, reflective thinking, reasoned decision-making).
- Inter-personal skills (presentation and communication skills, leadership, organisational skills, collaboration, initiative, sociability, collegiality).
- Intra-personal skills (self-discipline, engagement, perseverance, self-motivation, compassion, integrity, commitment).

- Global citizenship (awareness, tolerance, openness, respect for diversity, intercultural understanding, ability to resolve conflicts, civic/political participation, conflict resolution, respect for the environment).

These competencies deserve special attention in the STEM areas.

Some characteristics of the development of transversal competencies (Lukácsné Ujhegy 2013):

- They improve through teamwork.
- They require verbal and/or written communication in the mother tongue or in a foreign language.
- Their development and improvement are supported by the application of communication techniques and computer technology.
- Their development and improvement also require and assumes decision-making and problem-solving strategies and techniques.
- During their development and improvement, individual and social characteristics and differences are respected and the opportunities provided by multiculturalism are valued.
- Its objectives include autonomous learning, entrepreneurship, initiative and openness to innovation.
- Professional ethics and values are respected.

Research into Soft Skills Necessary in the STEM Areas

In the following, we outline the results of two of our own studies. Both are related to engineering education. The first was conducted among engineering students and the second among employers. Both studies aim to assess the soft skills needed on the labour market. Our research question was which soft skills were considered to be the most important in the labour market by students and which by employers.

Our attention was drawn to the need for skills development by our empirical study of 475 first-year engineering informatics students, in which we examined on one hand, how important students considered a given competency to be for their future profession and on the other hand, to what extent they currently had that competency.

Respondents evaluated 24 characteristics on a 5-point scale. We examined the reliability of both competency lists: their Cronbach’s alpha values were: 0.8160 and 0.8720, respectively, which we regarded as good results.

Table 1. *Means, Standard Deviations (SD) and Differences between the Perceived Importance and Self-Reported Proficiency Level of Competencies (N=475)*

	Importance (Mean)	Own level (Mean)	Difference	Wilcoxon (Z)
Oral communication	3.80	3.31	0.49	-8.525*
Problem solving	4.90	3.81	1.09	-17.678*
Ability to work precisely	4.76	3.75	1.01	-16.325*
Cooperation	4.22	3.90	0.32	-6.912*
Teamwork ability	4.25	3.88	0.37	-7.488*
Working independently	4.53	3.91	0.62	-12.402*
Analytical thinking	4.69	3.80	0.89	-15.110*
Learning ability	4.66	3.60	1.06	-16.008*
Innovation	4.64	3.68	0.96	-16.154*
Conflict resolution	3.23	3.53	-0.3	-4.694*
Organisation	3.53	3.28	0.25	-4.878*
Persistence	4.18	3.67	0.51	-8.686*
Written communication	2.97	3.33	-0.36	-6.179*
Openness	3.86	3.81	0.05	-1.275**
Goal orientation	4.57	3.91	0.66	-12.834*
Self-knowledge	3.20	3.65	-0.45	-6.994*
Stress tolerance	4.22	3.53	0.69	-10.324*
Responsibility	4.31	3.93	0.38	-8.036*
Adaptation to change	4.37	3.93	0.44	-8.887*
Concentration	4.74	3.65	1.09	-16.510*
Understanding causal relationships	4.80	3.95	0.85	-16.208*
Appling knowledge	4.77	3.97	0.8	-15.397*
Flexibility	4.29	3.82	0.47	-9.428*
Evaluation and self-evaluation	3.54	3.55	-0.01	-0.420**

*p=0.000
** Not significant

In students' opinion, the skill of problem solving is the most needed for their future profession (4.9 mean value on a 5-point scale). This is in keeping with the results of international studies which highlight the fact that the skill of problem solving is indeed one of the most important skills on the labour market (Daruka 2017, Karcsics 2007, Híves 2006, Bajzát 2011). In second place was the understanding of causal relationships (context) (4.8) and in third, the ability to apply the acquired knowledge (4.77). The students believed that the least necessary skills on the labour market were writing (2.97), self-knowledge (3.2) and conflict resolution (3.23) (Table 1).

Examining the relationship with the background variables, we found that while 90.7% of women consider the ability to learn to be very necessary in the labour market, this ratio for men is only 69.2% (based on the Chi-squared test performed on the data: p=0.029). The ability to understand context is also considered more important by women: according to 97.7% of them it is very necessary in the labour market, while 81.5% of men were of this opinion (p= 0.042).

In their own opinion, respondents had the most skills in applying knowledge (3.97) and in understanding context (3.95). Responsibility and adaptability occupied the 3rd and 4th places, both with a mean value of 3.93. Based on the results, we found that students perceived shortcomings in all areas, as none of the average scores given to the assessed characteristics reached a value of 4 on the five-point scale. The results highlighted the importance of skills development.

Students often drop out because they are not able to adapt to the challenges of higher education, to process the material, to apply theoretical knowledge during their practice, they cannot understand context, cannot concentrate, are not accurate enough and are not persistent. The first-year students interviewed in the research consider themselves to have serious deficiencies in these areas. Solving this problem is a serious challenge for higher education institutions. Student mentoring programmes can be highlighted as good practice, the purpose of which is to provide assistance to students in navigating the world of higher education: studying as well as socialization.

Examining the relationship with the background variables, we found significant correlations in the following area: according to their own assessment, women possess stronger writing skills (41.9% to a great extent, 18.6% to a very great extent; while men have this skill 28.2 % to a great extent and 13.8% to a very great extent; Chi-squared test: p=0.034). Regarding responsibility, women are also better in their own opinion: 48.8% of them consider themselves responsible to a great extent, 25.6% to a very great extent; while 40.3% of men consider themselves to have this characteristic to a great extent and 29.4% to a very great extent (p=0.017).

The biggest differences between students' current competencies and those needed on the labour market were found in the areas of concentration of attention, problem-solving skills and the ability to learn, so development is especially necessary in these areas.

It is interesting to point out that in four cases (realistic self-esteem, self-knowledge, writing skills and conflict resolution), the students believed that they possessed the given competence to a greater extent than necessary on the labour market.

Our second study examined the other side: it assessed the demands of employers. Our university's 27 corporate partners identified the soft skills that they expected engineering students/fresh graduates to possess. Responding to the open-ended questions in the questionnaire, they articulated their expectations in three major areas: key competencies, work-related competencies and management competencies.

In the area of key competencies, 25 companies responded, naming a total of 103 non-professional skills. Most of them identified communication skills (14 mentions), followed by teamwork (11 mentions), problem solving (5 mentions), reliability (3 mentions), and accuracy (3 mentions).

17 respondents listed work-related competencies, giving a total of 25 answers to this question. Most of them mentioned independent work (11 mentions), followed by problem solving (5 mentions), teamwork (3 mentions), and proactivity (3 mentions).

14 respondents identified management competencies, giving a total of 41 answers. Most of them mentioned decision-making (8 mentions), followed by project-related skills such as project management (4 mentions) and problem solving (3 mentions).

Our study drew attention to those soft skills that are indispensable on the labour market (Holik 2019, Holik and Sanda 2022). By mapping employers' relevant competence requirements, our research contributes to content development: to the creation and launching of the university's new training programs, as well as to the development of the range of educational skills and the identification of critical needs. The results can also be useful for other higher education institutions in the STEM areas.

Development Possibilities and Methodological Recommendations

Although the frontal, knowledge-based form of education is also prevalent in STEM areas, it actually works better in groups with more homogeneous abilities and cannot take into account the individual abilities and skills of learners. It is not interactive, so it is unsuitable for the development of certain skills.

In the field of STEM subjects, a particularly important question arises as to how to motivate students, as math, physics, chemistry and biology usually seem scary to students. However, in order to make STEM subjects attractive, "traditional" frontal teaching is no longer an appropriate strategy – education requires constant renewal. The development of STEM competencies requires the use of methods by which participants recognise and identify their abilities and characteristics and consciously shape them through experiential learning and interactions (Seetha 2013).

In our university's engineering teacher training programme, we strive to develop our students' STEM skills using a variety of methods, and prepare them for the teacherly task of being able to effectively develop their own students' skills and motivate them in the STEM areas. This requires students to view their own learning process not as passive onlookers but as active participants.

In our training programme, we emphasise the following areas.

Methodological Competencies

- Pedagogical methodological readiness.
- Planning of pedagogical processes and activities and self-reflections related to their implementation.
- Planning, organising and evaluating the problem-solving teamwork.
- Usage of simulation software in order to reinforce theoretical knowledge (laws and connections).
- Summary and presentation of the results of the problem-solving groups in front of the plenum while applying an interactive whiteboard and video recording.

Competencies Related to the Renewal of Pedagogical Work

- Planning and organising learning process (experience-based learning, supported digital teaching methods).
- Modern methods of pedagogical evaluation.
- Well-motivated and effective teaching-methodologies.
- Gamification methods, their use in the teaching of STEM subjects.
- Designing an e-learning process, developing learning organisation and support skills.
- Content development of e-learning materials for self-study.
- Self-monitoring, control and evaluation, learning support solutions.
- Supporting the processing of STEM teaching materials with digital teaching tools (software, videos).

Additional Skills and Competencies

- Cognitive skills, information management and processing (identifying, collecting, processing and using relevant data to make decisions).
- Critical, creative and analytical thinking.
- Problem solving skills.
- Scientific investigation.
- Creativity and computational thinking.
- Manipulative and technological skills.
- Collaboration and communication skills (teamwork).
- Self-knowledge.
- Evaluation.
- Systems analysis.
- Creativity.
- Independent learning.
- Environmentally conscious (Novák 2020).

Attitude Characteristics

- Openness.
- Creativity.
- Self-expression.

In the following, we present some methods which can effectively be applied in STEM areas.

Teamwork, and discussion within a group, provides an excellent opportunity for students to express their thoughts, elaborate their own views, to argue and pay attention to the other party. **Dispute**, a game from the English language area that develops players' debating culture, can be very effective in developing discussion techniques (Hunya 1998). It aims to teach students the techniques that are essential for becoming a successful, critical, active citizen in an open, democratic society. It enriches one's culture as well as entertains. The primary goal of the dispute is learning, which takes precedence over victory. Disputes can be made, for example, about a healthy lifestyle or the characteristics of different energy sources, the effects of littering, the environmental problems of using plastics, or even about the technical, legal and ethical aspects of obtaining and using information. In addition to reasoning, this method teaches attention to others, self-discipline, tactfulness and logical thinking.

Collaborative learning is an active and interactive process, an excellent opportunity to develop soft skills, as it aims to give students an active learning experience. In collaborative learning, the result of co-learning is the successful achievement of a common goal. Students achieve this through a joint activity that also indirectly develops their collaborative skills.

The use of **cooperative methods** also serves the development of soft skills because these methods are based on the cooperation of learners. The four basic principles of cooperative learning (Kagan 2015) are constructive interdependence, individual responsibility, equal participation and parallel interaction. In addition to increasing learning motivation and performance, this method promotes the building of positive relationships among students, strengthens cognitive development, and develops social and management skills (leadership skills, communication skills, conflict resolution, decision making, etc.) (Kagan 2015). Research results suggest that the use of cooperative learning techniques and courses to develop social skills have had a positive effect on cooperation at work and on personal relationships (Smith et al. 2005). In engineering teacher education, students are introduced to several cooperative methods and have an opportunity to try them out in small group sessions.

The application of the **project method** builds on the interest of students and the joint activities of teachers and students. Therefore, it is suitable for developing cooperation, empathy, conflict-management and communication skills. The focus of the project is generally a practical problem, so it provides an excellent opportunity to develop problem-solving skills. When applied, the traditional teacher-student relationship also changes. This is also important because proper cooperation between students and faculty is an essential condition for both academic and social integration. A study by Berglund and Heintz (2014) reports that project-based learning in a real workplace environment develops skills that facilitate students' employment, such as teamwork, communication, problem solving and conflict-management.

Problem Based Learning (PBL) can be particularly effective in STEM areas as it confronts students with practical problems, thereby preparing them for creative, critical and analytical thinking and for finding their own sources of learning. Students solve complex problems in group-work, using self- and peer assessment (Epstein 2004). The development of the ability to assess oneself improves the ability to assess one's peers, which in turn makes for an increasingly realistic self-evaluation, so the two abilities develop in parallel. Furthermore, students working in a group not only develop their problem-solving skills, but also their communication, cooperation and leadership skills.

In **Inquiry-Based Learning** (IBL), students conduct experiments, model and research, often in collaboration with each other. The method assumes the active involvement of students in the learning process, in the construction of knowledge. Inquiry-based learning contributes to students' understanding of the nature of science and the research methods of the natural sciences. They acquire general research skills (for example: formulating research questions, setting up hypotheses, planning and managing the research, analysing and publishing results) and specific research skills (for example: the use of microscopes, physiological and field research methods). Research activities can help to understand scientific content and apply scientific knowledge. Students can gain first-hand experience in research, scientific discoveries, which can help develop their interest in science, a willingness to research and positive subject attitudes (Nagy and Nagy 2016).

In **design-based learning** (DBL), also known as design-based education, students are involved in the design and even the development of scientific experiments. Students are not presented a ready-made curriculum, but have to design and then create an object, model, or other product themselves. Here, the processes of design and creation together create the opportunity for development (Schoenfeld 2006). This method allows students to explore and develop different technologies, consider limitations, security, and risks, and seek alternative solutions (Guzey at al. 2016).

Gamification refers to the application of games and game elements to non-game areas of life. The goal of gamification is to make educational processes more interesting and effective by helping students engage with the task, by activating both intrinsic and extrinsic stimuli. Initially, it arouses the curiosity of students and learning becomes an experience for them. Its motivating factor is rewards, which are the classic elements of gamification, such as completing levels, collecting reward points, competing and achieving rankings. Points are key indicators of performance, feedback tools, the quantified markers of win-states. Based on the main components of the reward system of computer games, we can talk about the Points, Badges, Leaderboards (PBL) models (Módné et al. 2022). Using gamification, participants are happy to complete the tasks. They are driven by the desire to overcome the challenges and solve the problems posed by the game. Furthermore, gamification can excellently be used in education to increase motivation as well as to develop skills (Duchon 2021, Frohmann and Damsa 2016). Nowadays, a number of online applications based on many aspects of gamification are available, which helps the work of the teacher. In our engineering teacher education programme, students try out a curriculum built on gamification aspects.

An innovative method is the use of **teaching robots** in education. Robots can be used as teaching assistants and pedagogical assistants in almost any field of science, but they can also play a role specifically in the teaching of computer programming (Nagy 2020). Educational robots help to master the basics of programming in a playful way, as well as developing logical thinking, spatial and temporal orientation, observation skills, attention, social skills, creativity and digital competence. The use of teaching robots can contribute to the development of students' problem-solving skills and algorithmic thinking. Educational robots play a role in motivating students and arousing their interest. They provide space for experimental learning and contribute to the connection of STEM areas. During the training, our students become acquainted with the application possibilities of robots in the field of education. We plan to enable our students to gain their own experience in the future by using a teaching robot during classes.

The above methods contribute to making learning and teaching an experience. The roots of experiential pedagogy go back to the work of John Dewey, who believed that the student's own learning experience should be at the heart of any teaching-learning process. Methods that build on **experience-based learning** leverage the effective teaching power of direct experience and, through the processing of subjective experience, make experiences and learning permanent. When the new knowledge of the learning process can be linked to a relevant experience, it greatly helps to deepen and subsequently recall knowledge. Freund writes: "**It is** a very important, if not **the most important**, **task of teachers to stamp a positive emotional seal on the knowledge they want to share** (Freund 2014).

Mihály Csíkszentmihályi called it **flow experience** when we consider the majority of our work to be not really work because we find it interesting, it is a challenge for us, and the difficulties inspire us to find solutions. The solution and implementation fill us with joy and pride, making learning an enjoyable adventure. Flow "is the phenomenon when we are dissolved in an activity to such an extent that everything else dwarfs in comparison, and the experience itself becomes so enjoyable that we want to continue the activity at any cost, just for its own sake" (Csíkszentmihályi 2010, p. 22).

Summary

Nowadays, as a result of the 4th industrial revolution, the range of abilities and skills expected on the labour market has changed, and the need to develop soft skills has come to the fore. In higher education, in addition to the development of cognitive skills, the development of soft skills (such as problem solving, cooperation or communication) is becoming increasingly important. An essential feature of STEM areas is the use of scientific, technical and mathematical knowledge to solve daily or societal problems. STEM teaching is characterised by a complex approach and an interdisciplinary approach. STEM education is key in preparing students for the world of work. The development of STEM skills is possible through a variety of teaching methods, and this requires methodological renewal in higher education. Our paper presented the diversity of STEM skills and the possibilities for their development.

In Hungary, the lack of teachers in the STEM subject areas is a serious problem. The promotion of STEM subjects and the renewal of (subject-specific) methodology, on the basis of the above examples, will hopefully help to ensure the supply of teachers by increasing the number of candidates choosing these subjects when entering teacher education.

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The UPMQube: An Academic/Educational PocketQube Proposal for the EU2Space Challenge

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In the present paper, the UPMQube PocketQube proposal for the EU2Space challenge is described. This proposal has been developed by a group of master's degree students led by Ph.D. students and professors from the Instituto Universitario de Microgravedad "Ignacio Da Riva" (IDR/UPM) at Universidad Politécnica de Madrid (UPM). PocketQube is a recent new picosatellite concept, which is currently under development. Its reduced size and mass require a significant effort to reduce the characteristic size of the elementary subsystems. One of the subsystems that offers the greatest capacity for improvement is the Attitude Determination and Control Subsystem (ADCS), since most PocketQubes do not usually have one due to lack of space. The most relevant technical aspect of this proposal is the development of a new ADCS which fits the high restrictive size and mass requirements, and it is based on Commercial Off-The-Shelf (COTS) components. This ADCS is composed by: (i) a purely Autonomous Magnetic Controller (AMC) based on magnetorquers and magnetometers on board the spacecraft (S/C platform; (ii) an Attitude Determination System (ADS) based on solar sensors and thermal sensors on board the S/C and an On Ground Attitude Determination Algorithm (for post processing the sensors flight data. The work carried out by Master s degree students is integrated within the academic program of the UPM's Master in Space Systems as a Case of Study. It also provides an excellent training program for the Ph.D. Assistant Professors included in the proposals Team. The tasks assignments and responsibilities of all members of the Team are fully described in the paper. Additionally, it should be underlined that this proposal is quite well balanced in terms of gender, as 40% of the Team (including the Principal Investigator) are women. This figure is higher than the mean percentage of women present in STEAM Sciences, Technology, Engineering, and Mathematics careers (29% of the workforce, 19% of company board members, 3% industry CEOs).

Keywords: *UPMQube, PocketQube, MUSE, magnetic ADCS, space engineering challenge*

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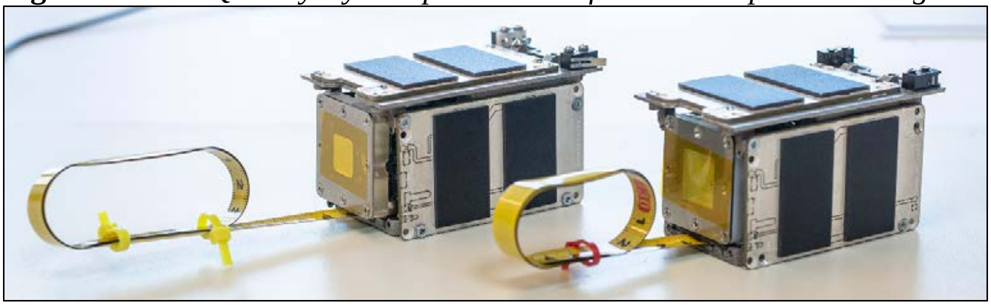
Introduction

The PocketQube (see Figure 1) is a recent concept of picosatellite currently under development. Its main advantage is its small size, with dimensions of only 5x5x5 cm in its smallest version (one unit). Due to its limited size, the mass is also very small, barely 250 g per unit. The concept was devised in 2009 for educational purposes, and the first PocketQube was launched into space in 2013. By mid-2021, 13 missions had been launched into space, with more than 40 in development (Yost et al. 2021). Its main advantage lies in its low mission costs, which can be in the $20k range including development, testing, and launch (other formats such as CubeSats multiply that price by at least 8). Due to this reduced cost, they have become popular for start-up companies or academic projects. PocketQubes also have some drawbacks. For one, they are less popular than the standard CubeSat, so there is much less hardware available on the market. Most of the one used is Commercial Off-The-Shelf (COTS). They also have much less space to place it, so the capabilities of these satellites are still much smaller.

Figure 1. *PocketQube by Hydra Space Studied for the EU2Space Challenge*



PocketQubes have a very promising potential for use in space education. On the one hand, its prices are more affordable than other larger Cubesat standards. But its main advantage would be that the project times, between one and two years, are very suitable to be integrated within the academic deadlines of a university master's degree. Being able to include all phases of the project, from design to operation, including integration and testing, within a single academic promotion.

The master's degree in space systems at UPM has recently had the opportunity to become familiar with this new standard thanks to the EU2Space program, a challenge for Spanish students that encourages them to build their own satellite and put it into operation in space. Several of the MUSE teachers, belonging to the educational innovation group INNAERO (*Innovación Educativa en Ingeniería Aeroespacial*) have decided to test the possibilities of this standard within the academic program of the master. This document puts the activity in context, explaining the characteristics of the master and the challenge. As well as the way in which the challenge has been integrated with the various subjects of the master. All this with the idea of multiplying the chances that students will be able to successfully put the satellite into space and motivate them with exciting projects and tangible results within a project-oriented educational program.

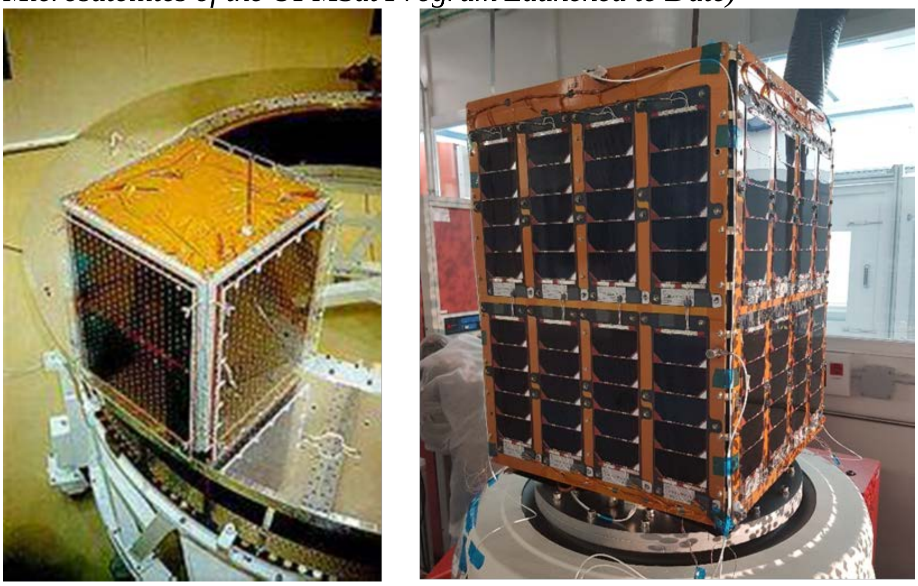
Overview of the Master in Space Systems (MUSE)

The Master's degree in Space Systems (MUSE) is a 120 ECTS (two years) master designed to provide a practical approach to space systems technology and research activities in space sciences (Pindado Carrion et al. 2017, Pindado et al. 2016, 2018).

MUSE is organized, managed, and supported by the *Instituto Universitario de Microgravedad "Ignacio Da Riva"* (IDR/UPM). The IDR/UPM Institute is one of the 5 Research Institutes of the *Universidad Politécnica de Madrid* (UPM), and its main activities include applied aerodynamics, wind engineering and space technology. The IDR/UPM Institute has participated in several space missions including NASA and ESA's interplanetary spacecrafts. The contributions made frequently include the thermal and structural design of instruments and subsystems. More recently also mission analysis and attitude determination and control subsystem (ADCS) design have been included among the priorities of the institute. Among the historical missions in which the IDR/UPM Institute has participated, the ESA Rosetta – Osiris mission stands out, the first mission to land on a comet. Missions currently in operation in which the institute has participated include Solar Orbiter, such as the PHI and EPD instruments, ExoMars (TGO - NOMAD). Some of the future missions that the IDR/UPM Institute participates in are Euclid and Ariel (Sanz-Andrés and Meseguer 2006).

Another of the space engineering activities carried out at the IDR/UPM Institute is the launch and operation of microsatellites oriented to educational, scientific, and technological demonstration applications (see Figure 2). These satellites are usable as an in-orbit technology demonstration platform. These missions improve and expand the knowledge of teachers, students participating in the project, and demonstrate the capacity of the UPM in the field of space technology (Pindado Carrion et al. 2017, Sanz-Andrés et al. 2003).

Figure 2. Left: *UPMSat-1 (1995)* and Right: *UPMSat-2 (2020) (The Two Microsatellites of the UPMSat Program Launched to Date)*



A key aspect of the Master in Space Systems (MUSE) is the use of a Project Based Learning (PBL) approach, taking advantage of the experience of the IDR/ UPM Institute in space projects and microsatellite development. PBL main goal is to provide students with the opportunity to apply their knowledge, not just acquire it (Brodeur et al. 2002), focused on the students learning, making them co-creators of their own education. PBL also prepares students with some specific skills, such as curiosity, creativity, and collaboration, and is especially interesting for master students, who have already acquired a solid theoretical foundation.

The master course is classified into theoretical and practical lessons related with space technologies, classified into five different group (see Table 1).

Table 1. *The Five Groups of Subjects Included in the Master of Space Systems (UPM), Classified by Type of Learning (Mono-Disciplinary or Multidisciplinary + PBL)*

Group	**Total ECTS**	**Learning methodology**
Advanced Mathematics	12.0	100% Mono-disciplinary
Spacecraft Subsystems	28.5	53% Multidisciplinary + PBL
Space Projects Definition	22.5	60% Multidisciplinary + PBL
System Engineering	25.5	30% Multidisciplinary + PBL
Case Studies and Final Project	31.5	100% Multidisciplinary + PBL
	120	**55% Multidisciplinary + PBL**

In Table 2 and 3 a list of the subjects that make up each semester of the muse can be found. Those that will take part in the EU2Space challenge are highlighted in bold.

Table 2. *Subjects of the First Course of the Master MUSE*

Semester	Subject	ECTS
1st	Advanced mathematics 1	6.0
	Space environment and mission analysis	3.0
	Systems engineering and project management	6.0
	Vibrations and aeroacoustics	4.5
	Graphic engineering for aerospace mechanical design	4.5
	Space propulsion and launchers	4.5
2nd	Advanced mathematics 2	6.0
	High speed aerodynamics and reentry phenomena	3.0
	Heat transfer and thermal control	6.0
	Electric power generation and management	3.0
	Spatial use structures	4.5
	Case study (1)	1.5
	Communications	4.5
	Data management	4.5

Table 3. *Subjects of the Second Course of the Master MUSE*

Semester	Subject	ECTS
1st	**Orbital dynamics and attitude control**	4.5
	Space Use Materials	4.5
	Quality guarantee	4.5
	production technologies	4.5
	Integration and tests	4.5
	Case study (2)	7.5
2nd	Seminar on space industry and institutions	1.5
	Case study (3)	9.0
	Master's thesis	18.0

MUSE's students participate in real-life projects of IDR/UPM. This has the advantage of providing hands-on experience and motivation to the students. But also has certain challenges, like the harmonization of the education and projects.

One of the difficulties that a PBL-based master is finding motivating ideas for student projects, which are also realistic and prepare them for their professional activity. When choosing these projects, the IDR/UPM Institute has usually resorted to its experience in projects, highlighting two types of activities:

Academic Projects based on IDR/UPM Institute's Activities in Scientific Instrumentation

The inclusion of students in the international projects in which the IDR/UPM Institute participates is usually reserved for individual work and the most advanced Study Cases. Normally in the second year of the master. These projects have important pros: students are highly motivated to work on important missions; and represent a more realistic approach to the labor market (including handling requirements, regulations, etc.). But it also has some cons: there are not always enough projects for all students; it is difficult to adjust deadlines to the master academic times; and the topics covered in these projects do not include all the themes of the master.

Increasingly frequently, students carry out these individual and advanced case studies in companies or institutions other than the IDR. This possibility is encouraged in the master and has similar advantages to the aforementioned projects. With the additional advantage that the topic can be much more varied. Although this is only applicable for individual case studies.

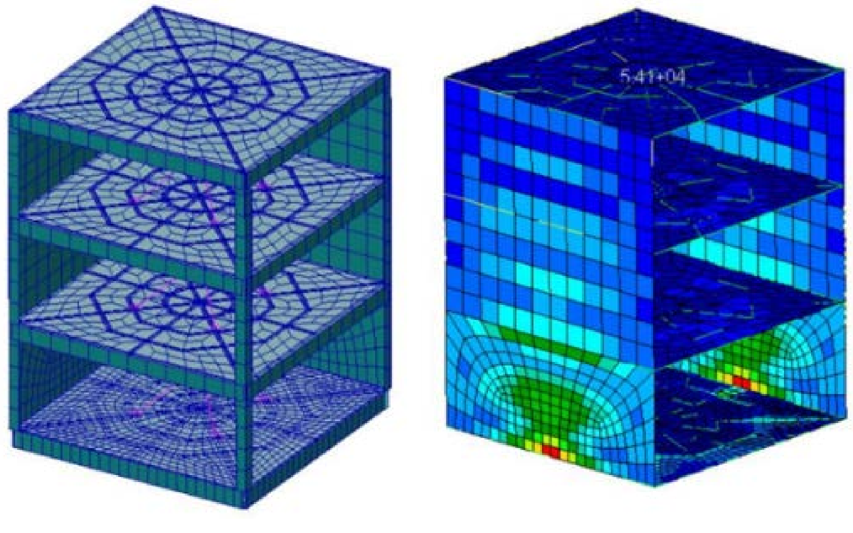
Academic Projects Based on the IDR/UPM Institute's Microsatellites Program

The second main source of student projects for MUSE is the UPMSat project. The IDR/UPM Institute microsatellite project was resumed in 2014 at the same time as the MUSE master was organized, with the intention of involving students in the development of UPMSat-2. From the beginning of MUSE to the present, all MUSE promotions have participated in the development of UPMSat-2. The first promotions participated in the design, the following ones in manufacturing and testing. Since its launch, the latest promotions have participated in its operation. This project has turned out to be one of the successes of the Master, and its results have been commented on in several publications (Pindado Carrion et al. 2017). Among the advantages of this project is that students are motivated to know that they are contributing to something that will be in space; and unlike other projects at the IDR/UPM Institute, this one includes all the topics of the master, and it includes all phases of a project (design, manufacturing, qualification...). Finally, the microsatellite program has contributed to train both students and teachers in an overview of space systems. Since without their help, many of the master's teachers would only have had a theoretical approach to the subject they taught.

Specific problems in the development of the UMSat-2 such as thermal design, access analysis to the ground station, mechanical tests, etc. were a source of individual work for many MUSE's case studies. But on the other hand, the lessons learned, and the procedures developed have also been a source of inspiration for the PBL group projects of the MUSE subjects. Notable examples are satellite integration, satellite wiring, solar panel testing, structural design (see

Figure **3**), or the development of attitude control laws; all these activities have been proposed as group projects for different subjects to the master's students in several successive years.

Figure 3. *Finite Element Method Model of the UPMSat-2 and Structural Analysis Results Obtained by MUSE Students. Project Proposed to Students in the Subject Space Structures (Cubas et al. 2022)*



Academic Projects Based on Academic Challenges

There is a third source of projects for students who participate in MUSE: the Challenges or international competitions for students. On a recurring basis in the

MUSE master, different competitions have been integrated into the academic program. These competitions, whenever possible, have been held with universities from other countries. In this way, a double effect has been achieved on the students. On the one hand, the challenges have had the ability to motivate students and provide them with typical PBL skills. On the other hand, by participating with students from other universities and countries, it has allowed them to contact groups of other nationalities and cultures. Improving their interaction skills in international environments and languages other than Spanish (the language in which the master is taught).

This point, and how it is integrated into the master, will be further explored in this article.

Academic Challenges Conducted in the MUSE

Some of the most representative activities in which MUSE students have participated are listed below.

The 1st ESA Academy Concurrent Engineering Challenge

Between September 12th and 15th of 2017, ESA Academy conducted the 1st *ESA Academy Concurrent Engineering Challenge* as an extension of ESA educational programs oriented to concurrent engineering. The objective of the challenge was to design a satellite to look for Moon Surface areas that could be used as locations for a future human base. Students of four different institutions were invited to participate simultaneously in different CDFs. MUSE students from *Universidad Politécnica de Madrid* (Spain) were one of the selected groups, the other groups were from the ESA Academy's Training and Learning Centre at the European space Security and Education Centre (ESEC) in Belgium, students from *Politecnico di Torino* (Italy) and students from University of Strathclyde (United Kingdom). The challenge itself was not a competition but an opportunity to share the progress, raise any difficulties receive helpful input from the other participants. At the end of the challenge each group presented their final design. The result of this challenge was the mission MEOW presented in Figure 4 (Roibás-Millán et al. 2018a).

Additionally, a MUSE student participated in the 2nd *ESA Academy Concurrent Engineering Challenge*, which was held from 22nd to 26th October 2018 (see figure 5). This student was invited to be part of the ESA Academy's team. After coming back this student said "This event gave me and other 29 students from different nations the opportunity to preliminary design a mission following ESTEC procedures. The work carried out by us was not only focused on each subsystem but also harmonized with the whole group of them and directed towards one single final objective: the success of the mission. Although in the Master in Space Systems (MUSE) the Concurrent Design (CD) concept is embraced, during this week working in ESA facilities I managed to understand the basics of the philosophy that remains behind the CD procedures. This was possible thanks to the experts from the European Space Agency (ESA) that dedicated all their attention to us from the first iteration till the last modification of the designed mission. We developed SANTA mission (Satellite for Airborne and Naval Transmission in the Arctic) using 12 subsystems. I had to study the power requirements, analyze the different options related to the power subsystem (solar panel, battery…) and select the best viable option. This was, in my opinion, the best experience directly related to space engineering I have had".

Figure 4. *MEOW Spacecraft. (1) Main thruster, (2) Attitude Control Thrusters, (3) Deployable Solar Panels, (4) Orientable X-band Antennae System, (5) Launch Adapter Ring. S-band Patch Antennas and Sensors are not Shown in the Image (Roibás-Millán et al. 2018a)*

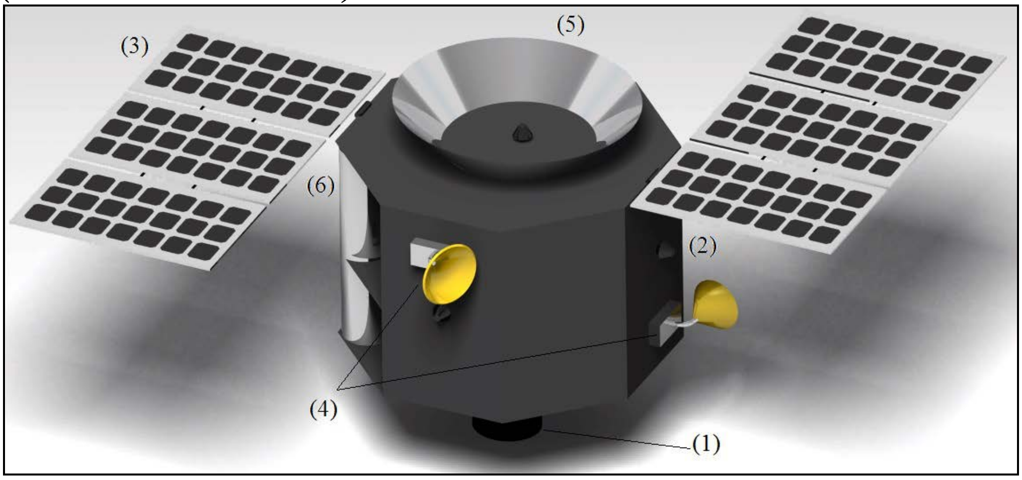


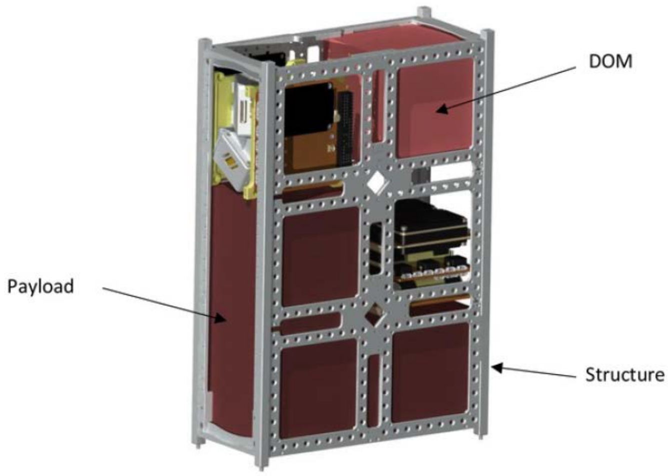
Figure 5. *The MUSE Student Borja Cobo López at the ESA Academy during the 2nd ESA Academy Concurrent Engineering Challenge*

The NANOSTAR's Challenges

NANOSTAR (Monteiro and Guerman 2020) was a project funded by the *Interreg Sudoe Programme* for creating a network of excellence among universities, the regional industry, and the scientific ecosystem in order to increase the European knowledge on nanosatellites. The consortium was composed of 7 universities and 2 aerospace clusters, plus 3 ESA Business Incubation Centers as associates, in France, Spain and Portugal. All the results of the project are open source and can be found in Gitlab repositories (Nanostar 2021a, 2021b).

Among the activities of the consortium was the organization of two challenges in which groups of students from most of the participating universities competed. The first NANOSTAR challenge (2019) consisted in the predesign of a nanosatellite/small satellite space mission to the Moon. The second one (2020) aimed at predesigning a nanosatellite that is built around a scientific based space mission. In each of the editions, around four teams of MUSE students participated (see figure 6) obtaining various awards.

Figure 6. *Image of the nanoMUSE Mission, One of the Missions Proposed by the MUSE's Students During the Second NANOSTAR Challenge. The Objective of the Mission was to Maintain Alive a Colony of Roscoff Worms*



The 2021 Challenge: EU2Space

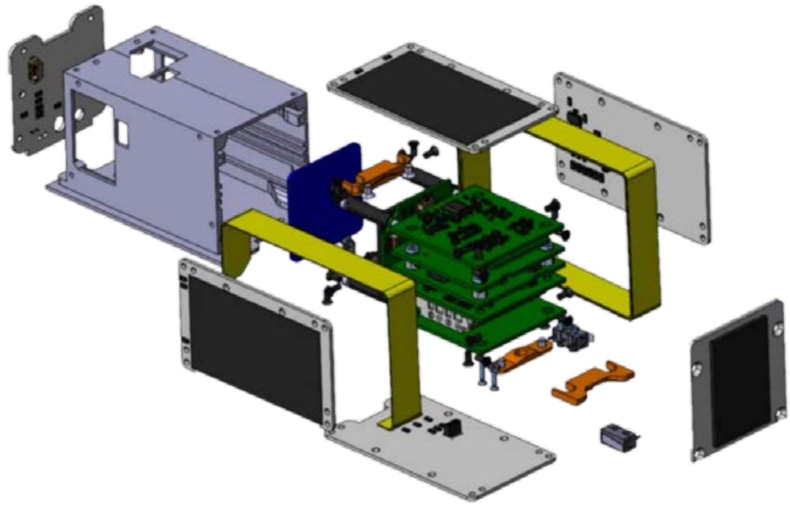
The Europe to Space (EU2Space) Challenge[1] allows university students to work on a real satellite development mission in all its phases, including launch and subsequent operations. This Challenge, promoted and organized by UARX Space, Hydra Space and AMSAT EA, started its first edition in September 2021 and has three stages. The first is a course with specific content, which serves as support at an introductory level for those who have no experience in space. It will give

[1]https://www.eu2space.com/.

students the necessary tools to understand and design a real mission. In the case of MUSE students, this has served to reinforce their knowledge. At the end of this phase the students propose different mission concept, and the selected groups go to the next phase.

The second phase focuses on the creation of the mission. Organizers provides with an educational kit (see Figure 7), based on the PocketQube standard, satellites weighing about 350 grams. The kit includes everything needed to have a platform capable of going into space, which will allow students to learn, modify, test, expand or even replace components to achieve the mission they propose. It will consist of an on-board computer (OBC), a communications system, including radio frequency and antenna components, a satellite structure, a power subsystem to generate, regulate and store energy, a well-defined interface to enable the inclusion of a payload and the necessary ground support equipment. Currently, the challenge is at the beginning of this second phase.

Figure 7. *Preliminary Design of the Satellite's Kit (UARX Space n.d.)*



The third phase will focus on obtaining the funds to pass the exhaustive tests to reduce the risk of failures and bear the launch costs. For this phase, the students will have to look for sponsors, until covering the costs of the mission. Which will also be an important challenge and will certainly help students to acquire truly relevant skills. For example, if they decide to entrepreneurship. The IDR/UPM Institute will support the master's students in this work, and it is expected that part of the costs can be reduced by carrying out certain tests in the IDR's testing facilities.

This challenge is organized by the following Spanish entities: UARX Space, a space logistics company that provides shared and dedicated launch solutions for small satellites; Hydra Space, a company specialized in PocketQubes and CubeSats, developed entirely in Spain to provide solutions for global IoT, and AMSAT EA, a non-profit cultural association dedicated to the study, dissemination of information and the promotion and development of space satellites for the communication of the Amateur Radio Service.

Although the EU2Space challenge was attended by more than 400 students, only 10 teams have been selected to participate. Of the 10 selected teams, three are made up entirely or mostly of students from the ETSIAE of the Universidad Politécnica de Madrid. The selected teams that belong to the UPM are UPMQube, Horizon and Caronte Crew.

MUSE Students' Proposal to EU2Space

The project corresponding to the students of the MUSE master is the UPMQube (see Figure 8) whose characteristics are detailed below.

Figure 8. *Mission Patch for UPMQube Project*

Mission Concept

As mentioned before, the reduced size and mass of PocketQubes require a significant effort to reduce the characteristic size of the elementary subsystems. One of the subsystems that offers the greatest capacity for improvement is the Attitude Determination and Control Subsystem (ADCS), since most PocketQubes do not usually have one due to lack of space. In addition, adapting commercial ADCS (even the one for CubeSats) for its use in PocketQube platforms is a meaningful challenge. In fact, even the smallest ADCS are too heavy and large to be used on PocketQube platforms.

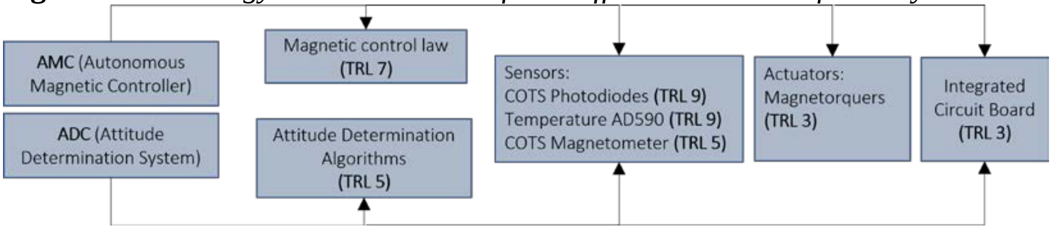
Among all existing ADCS strategies, magnetic attitude control is one of the most attractive alternatives for the attitude control of small satellites with not-too-demanding orientation requirements. This strategy significantly saves overall power and reduces weigh, cost, and the system's complexity compared to other attitude control options. In addition, the risk of failure is reduced, making the system more reliable. All advantages make magnetic attitude control well suitable for picosatellites operating in Low Earth Orbits (LEOs).

For those reasons, the proposal of UPMQube is an ADCS based on Commercial-Of-The-Shelf (COTS) elements that can be adapted to PocketQubes as small as 1.5P. To achieve this goal, the complete ADCS is divided into two payloads: (i) an autonomous magnetic controller (AMC) based on magnetorquers and magnetometers on board the S/C platform and (ii) an attitude determination system (ADS) based on solar sensors and thermal sensors on board the S/C.

The AMC main characteristics are the following: (1) only magnetorquers are required as actuators, (2) only magnetometers are required as sensors, (3) it does not need an on-orbit Earth magnetic field model, (4) it does not need to be externally activated with information about the orbital characteristics, and (5) it allows automatic reset after a total shutdown of the attitude control subsystem.

The attitude control proposal is closely related to the teaching of the subjects taught in the master, since it is a master in space systems. The students took many lessons learned from the UPMSat-2 project and its attitude control (Zamorano et al. 2017). The use of the UPMSat microsatellite program in the MUSE has already been treated in other papers in other editions of ENGEDU (Pindado Carrion et al. 2017). This program has not only laid solid foundations in the training of students and teachers of the master but has also managed to raise the Technology Readiness Levels (TRLs) of many of the technologies that will be used in this mission (see Figure 9). Including magnetic attitude control laws (Cubas et al. 2015), magnetometers calibration (Rodríguez-Rojo et al. 2019a), magnetorquers essays (Rodríguez-rojo et al. 2019b), solar sensors design and operation (Porras-hermoso et al. 2021b), an others.

Figure 9. *Technology Readiness Level of the Different Elements of the Payload*



Team Composition

Most of the group is composed by 15 members with a bachelor's degree in Aerospace Engineering and one with bachelor's degree in Mechanical Engineering. All of them currently enrolled in the first year of the master's degree in Space Systems at the Universidad Politécnica de Madrid (UPM).

The group is completed by three doctoral students, former students of the MUSE master's degree, who are currently carrying out research work at the IDR institute. In this way, most of the work will be carried out by the first-year students, but the various shortcomings that they may still suffer from due to not having completed all the subjects, are complemented by the greater experience of the doctoral students.

This combination of first-year students with second-year or doctoral students tutors is a strategy that we have used very frequently in the MUSE's case studies and has always given us satisfactory results.

As all the members of the Team are currently enrolled in a MSc in Space Systems, or are PhD students in Aerospace Engineering, all the technical aspects for the payload design, manufacturing and testing can be overcome by the Team members. In terms of gender, the Team is well balanced. The number of women participating in the Team is even higher than the mean percentage of women present in STEM careers. Indeed, the principal investigator is a woman (Professor) of the UPM with extensive experience in the space sector.

Integration of the Challenge with the Academic Activities of the Master

As aforementioned, MUSE's academic program is centered around a Project-Based Learning (PBL) methodology, as a comprehensive perspective focused on teaching by engaging students in research and resolution of authentic problems. Involving students in actual engineering projects allow them to learn by doing, taking advantage of the two essential components of a project: they require to solve a question or problem that serves to organize and drive activities, and then these activities result in a series of products, or solutions, which culminate in a final product that addresses the driving question.

An observed effect of PBL application is that students connect with their own learning process, gaining ownership over their learning. Consequently, the student's interest and motivation are highly increased. Another advantage of applying PBL is that enable an effective collaboration between industry and universities. This collaboration has mutual benefits because it has the potential of create a steady talent pipeline, providing graduates with a direct pathway to the workforce.

Within MUSE academic program, students participate in research projects conducted by IDR/UPM professors and staff. However, it is usual that they can only contribute in some project phases due to time limitations. Traditionally, space projects had extremely long-duration development stages, from identifying the need up to place the satellite in the right orbit to perform its operation. The new space era has changed this paradigm and the new goals are to be agile, responsible, and therefore far less expensive. One consequence is the reduction of the project size by using, for example, CubeSat platform or even the smaller PocketQubes.

The latter are interesting platforms to be using in an academic environment. On one side, the development times are short and on the other, the project cost is affordable for research institutions and universities. In this context, participating in the EU2Space challenge is a fantastic opportunity for MUSE students, as they can take part of an entire satellite project from the conception up to the launch and operation.

Furthermore, after the launch of UPMSat-2 in 2020, and pending the completion of the new mission for UPMSat-3, the IDR/UPM is currently without an ongoing development of a satellite on which the students can work. The

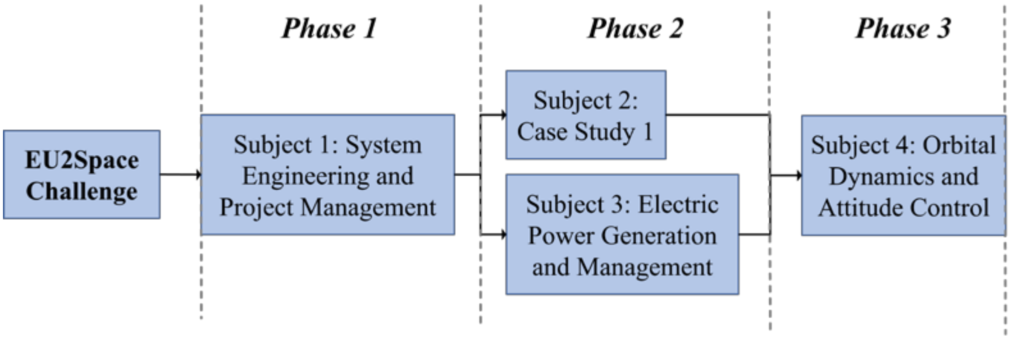
EU2Space project has therefore been an interesting opportunity to provide a more detailed practical component to the formation of the master's students.

However, integrating a real industry-led project in an academic environment is a major challenge. First, the time that students can dedicate to the challenge is limited as they are immersed in their respective subjects. To be able to give students the time to participate in the challenge without compromising the acquisition of competencies, a great adaptation effort must be performed by the professors regarding the subject's schedule and planning. One of the greatest successes has been the adaptation of the subjects, so that the theoretical contents can be taught within the framework of the challenge. Therefore, the EU2space challenge has been incorporated into the activities of the master, as a motivating element for the projects proposed to the students.

For this reason, several of the master's subjects, which extend over three semesters, have adapted the activities proposed to students to be complementary to the challenge. In this way, it is expected to reduce the workload, already very extensive without counting on the challenge, that the students have; in addition to academically rewarding the effort of the students.

To integrate the challenge schedule within the academic MUSE program, the activities are articulated around certain subjects, in a three-step process that is shown in Figure 10.

Figure 10. *Three-Step Process to Integrate the EU2Space Challenge in MUSE Academic Program*



The process is described as follows:

- *Phase 1*: This phase is carried out within the 1st year, 1st semester MUSE subject "System Engineering and Project Management" (see Table 2). In the last years, this subject has included relatively new concepts and trends in space mission predesign and feasibility phases (Roibás-Millán et al. 2018b).
  Between others, Concurrent Engineering (CE) has revealed as a design philosophy that facilitates the design process by using tasks parallelization (instead of the traditional sequential design), and therefore improving the flux of information between disciplines by working in a collaborative environment.

IDR/UPM has its own Concurrent Design Facility (CDF), which includes the technology and resources needed to perform parametric studies, aiming to find a mission solution that fulfils the technical requirements in a brief period (usually less than a week).
Within this subject, students are guided in a Concurrent Engineering process within the CDF (Pindado et al. 2021a). A mission is proposed in base of a set of requirements, so a preliminary design is requested as an output of the work. Usually, students are distributed in two or three teams, each one of them performing the same mission design. Therefore, the results obtained by each team can be compared and analyzed by collaborative sessions within the classroom.
This academic year, the CE project was oriented to the PocketQube mission, so students were divided in two groups, each one of them developing a proposal for the PocketQube payload. Results and conclusions of both teams were analyzed and condensed into a single proposal to be presented to the challenge call.

- *Phase 2:* The second phase of the process is devoted to the development of the payload by transforming the preliminary design of the previous phase into a detailed design. This phase is articulated around two MUSE subjects, both of 2nd year and 2nd semester, "Case Study 1" and "Electric Power Generation and Management" (see Table 2).
Within "Electric Power Generation and Management" students must perform an analysis of the behavior of the PocketQube under operating conditions (see next section) to derive the in-orbit power availability for the payload. Then, "Case Study 1" is oriented to define the interfaces between the payload and the PocketQube platform kit and develop the electric/electronic design of the proposed payload. This analysis includes selection of sensors (thermal sensors, magnetometers, and photodiodes) and actuators and the design of the signal conditioning circuits.

- *Phase 3:* Finally, the objective of this phase is to develop the experiments of the payload, in this case the control laws that will be tested onboard the satellite. This task will be carried out in the subject Orbital dynamics and attitude control, first semester of the second year (see Table 3). By this time students are expected to have a good understanding of the satellite's attitude control system. Therefore, after receiving training in this regard, they will be able to develop control laws, model their operation and anticipate their behavior in flight. The students will be distributed in groups and the project that will be carried out during the subject will include tasks such as the modeling of the ADCS, the environment, and the behavior of the control laws. As a result of the students' work, it is expected that several control laws, adequate for a satellite with the characteristics of the PocketQube, will be obtained. These laws will be tested during the mission.

Detailed Example for One Subject: Electric Power Generation and Management

This section summarizes the project based on the EU2Space project proposed to the students of the subject Electric Power Generation and Management. This will allow the reader to get an idea of the detail of the proposed problem, the evaluation criteria, as well as the skills that are intended to be fostered with the proposed work. It also summarizes how the work is included within the rest of the projects of the subject.

Students of the power systems course (Pindado et al. 2018) will perform an analysis of the behavior of the HydraSpace PocketQube under certain operating conditions and will seek to analyze the effects of the different parameters considered in the mission.

This work has been preceded by three others:

- Analysis of the maximum power extractable from the Sun by a microsatellite similar to UPMSat-2 (Pindado et al. 2017), placed in a sun-synchronous orbit. It was proposed to study the maximum extractable power as a function of the angle between the plane of the orbit and the solar direction, the altitude of the orbit, and the energy efficiency of the solar cells that make up the solar panels.
- Simulation of the behavior of a solar panel as a function of its operating point, radiation, and temperature.
- Simulation and analysis of the behavior of a battery, applying the models developed at the IDR/UPM Institute (Pindado et al. 2021b).

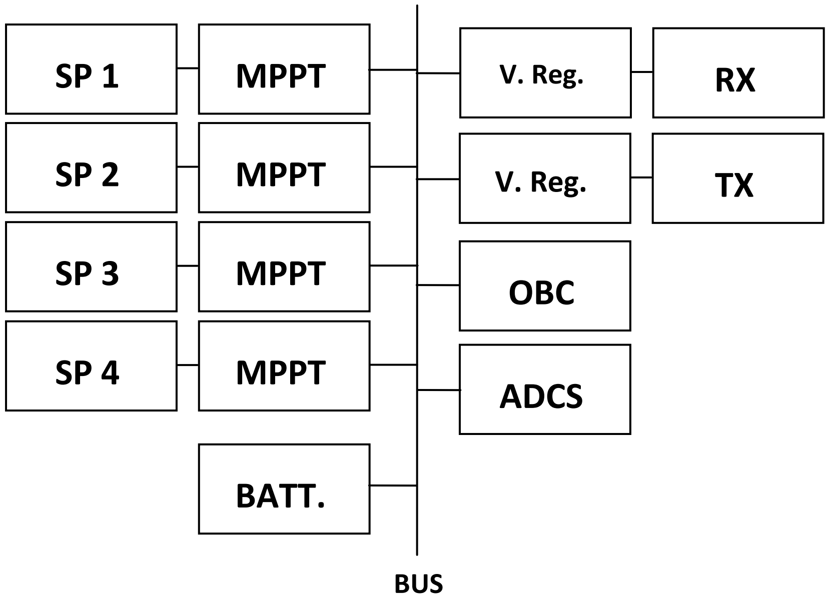
The power subsystem of the PocketQube from HydraSpace has been simplified into the following parts (see Figure 11):

- 4 Solar panels, each one with its own Maximum Power Point Tracking (MPPT) system.
- 1 Li-ion battery.
- 1 signal transmitter and 1 signal receiver, both equipped with its own voltage regulator.
- 1 On-Board Computer (OBC)
- 1 Attitude Determination and Control Subsystem (ADCS).

Operation conditions are grouped are organized in the following group of constraints:

- Orbit and attitude.
- Solar panels and MPPT.
- Battery.
- Attitude Determination and Control Subsystem (ADCS).
- Voltage regulators.
- Power consumption.
- Operational modes.

Figure 11. *Sketch of the Power Subsystem of PocketQube by HydraSpace Studied for the EU2Space Challenge*



Orbit and Attitude of the Mission

The PocketQube will flight in a 550 km altitude helio-synchronous orbit, the angle between the orbit's plane and the Sun direction being 0º (noon orbit), 22.5º and 45º. Three different attitudes are considered:

- Case 1: Passive (i.e., no power consumption is considered), the *Z* axis of the spacecraft being aligned with the Earth magnetic field. Rotation rate around *Z* axis is considered at ω = 0.01, 0.02 and 0.1 rad/s.
- Case 2: Active, the *Z* axis being perpendicular to the orbit's plane. Rotation rate around *Z* axis is considered at ω = 0.01, 0.02 and 0.1 rad/s. This is similar to the attitude of the UPMSat-2 within its orbit (Cubas et al. 2015).
- Case 3: Active, the solar panels (2 deployable) are oriented towards the Sun during the day period of the orbit.

Details of the Subsystems of the Mission

<u>Solar Panels and MPPT</u>

The solar panels are made of 2 parallel-connected IXOLAR™ SM141K06L solar cells. These high efficiency (25%) monocrystalline solar cells are connected to a ST Microelectronics SPV1040 high efficiency solar battery charger with embedded MPPT. The efficiency to be used in the calculations is η = 0.95 and η = 0.90, the performance being calculated with a 1st order system and an output characteristic current to be defined based on the available literature (Porras-Hermoso et al. 2021a). Depending on the attitude case (see subsection above) different number of solar panels needs to be considered:

- Case 1 and Case 2: 4 solar panels located at $+X$, $-X$, $+Y$, and $-Y$ lateral sides of the PocketQube.
- Case 3: 3 solar panels, 2 of them deployable.

Battery

The battery selected is a commercial Li-ion battery similar to Duracell DR9714 or Sony NP-BG1, with 1240 mA·h and an output voltage ranging from 4.2 V to 3.2 V. The battery will be modeled based on the data from Li-ion batteries (discharging-charging curves) used for the simulations carried out previously by the students.

Attitude Determination and Control Subsystem (ADCS)

Only the power consumption of the ADCS needs to be considered. Students will have to review the available literature to estimate a reasonable consumption.

Voltage Regulators

The voltage regulators will have an efficiency of $\eta = 0.3$, 0.4, 0.5 and 0.6.

Power Consumption

The power consumption in the nominal mode during 1 working period, T, will be:

- Receiver (RX): 40 mW 100% of the working period.
- Transmitter (TX): 200 mW, 50% of the working period.
- OBC: 350 mW, 33% of the working period.

3 different values of T will be considered, $T = 30$ s, 5 min., and 10 min.

Operational Modes

Two modes will be analyzed:

- Nominal, which is described above.
- Emergency. TX and OBC consumptions are reduced to 8% and 1% of the working period. This emergency mode is activated in three different scenarios.
    - It is activated at 3.5 V battery voltage and deactivated at 3.7 V battery voltage.
    - It is activated at 3.0 V battery voltage and deactivated at 3.2 V battery voltage.
    - It is activated at 2.7 V battery voltage and deactivated at 2.9 V battery voltage.

Academic Skills Developed

This challenge is intended to help students to be able to acquire certain competencies and skills. First, the students must organize themselves as groups, assign tasks to each other, and establish processes of analysis of the results that impose new tasks. And thus establish an iterative work process that leads to an acceptable solution.

Also, students must decide whether the available (or starting) information is good or complete enough. If the information is not good enough, either academic sources or a reasonable extrapolation of the results of other projects and studies carried out in the master's program should be used.

Once an acceptable solution has been achieved, the students must write up the work done in a report. In itself, a report is a summary of the work done and an exercise in organizing and transmitting information. Thus, students should pay attention to:

- The writing of the text and the appropriate formats (e.g., variables in italics, use of the International System of Units...).
- Proper writing of equations and their numbering.
- The appropriate use of figures and graphs. In the case of the latter, care must be taken in the choice of scales and the use of dimensionless variables.
- Use of tables in combination with the information displayed in the graphs.

Conclusions

This article explains the way in which the EU2Space Challenge has been integrated into the academic program of the MUSE master's degree at UPM.

Challenges and competitions for students are a regular resource that has been used in the MUSE master to create exciting projects for students. However, the EU2Space challenge starts from an unusual premise in the case of space projects: it allows condensing an entire space project, from design to operation, in a period compatible with the duration of a master's degree. This is due to the use of a new type of satellite standard, the PocketQubes, with an unusually reduced scale and simplicity. And, also quite important, a very small budget.

Some of the teachers of the master have decided to explore the opportunities offered by this standard, integrating the challenge within the PBL approach of the master. The main challenge has been to adapt the requirements imposed by the EU2space challenge to the MUSE academic program. In this sense, MUSE professors have made a great effort to modify the projects that were usually carried out in their subjects, to focus on a whole satellite project that cuts across a high number of MUSE subjects. The adaptation has been a success, so the students have been able to follow up and continue the challenge within the workload of the master itself.

Although the activity is not over yet, the results so far look promising.

- It has been possible to find a sequence of subject projects with a theme and complexity appropriate to the evolution of the project.
- The students have successfully passed phase 1 of the challenge.
- Student motivation is high, as are their work levels.

For the next academic year, it is expected to verify if the satellite can be successfully launched and operated. The total costs of the project will be analyzed, as well as the feasibility/convenience of implementing the development of a PocketQube for each academic promotion as a regular activity within the master's program.

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Evaluation of the 3D Reconstruction Performance of Objects in Meshroom: A Case Study

By Indrit Enesi[*] & Anduel Kuqi[±]

3D reconstruction of objects is with interest nowadays, mainly in production industry. The field of photogrammetry realizes the 3D reconstruction of objects through 2D photos. Different software, free or non-free exist, providing different quality and performance. Accurate 3D reconstruction is important in cloning objects, especially in the industry of spare parts or in the production of prostheses in medicine, etc. Determining accurately the sizes of the object, especially those with complex geometric shapes is very important in the 3D printing process. The purpose of this paper is the analysis of the accuracy of 3D reconstruction of objects against the number of its photos and the time evaluation of this process. The 3D reconstruction will be performed by free Meshroom software, measurement will be done in MeshLab one. Experimental results show that quality and performance of 3D reconstruction depends on the number of photos of the object, concluding in finding the optimal balance between these parameters.

Keywords: *Meshroom, MeshLab, 3D reconstruction, sizes accuracy, time analysis*

Introduction

Undoubtedly the use of 3D computer vision finds massive use in many different fields, such as archeology, 3D printing etc. As a result of the massive uses of today and the premises for the future, research in this field can be a valuable asset for improving the future vision for new applications in computer vision or even for improving existing ones.

The work here deals with the study of a software that serves for the reconstruction of 3D objects from images taken with cameras of different types. The software used in the paper is Meshroom. Meshroom is a free, open-source 3D reconstruction software based on Alice Vision framework. Alice Vision is a Photogrammetric Computer Vision Framework which provides 3D reconstruction and camera tracking algorithms. Meshroom software is designed as a nodal engine. It is developed in Python while Alice Vision framework is developed in C ++ (Alice Vision Inc 2021). What makes this software very special both in terms of research and in terms of practical use is the fact that the parameter configurations can be changed in each of the nodes. The nodes can be added or removed from the pipeline regarding the type of processing. The aim of the paper

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is the visual quality and the processing time of the reconstructed object from its images taken from a usual camera.

Different sets of photos of the same object will be used as input in the Meshroom software, for each set, the quality and processing time of the reconstructed object will be evaluated. Measurement of object sizes will be determined in Meshlab software (Meshlab 2021).

The object rebuilt in Meshroom from sets of photos, will be extracted in MeshLab software to determine its sizes. MeshLab is a software that serves for processing and editing messages. It is an open source and offers various edited tools (Meshlab 2021).

Methodology

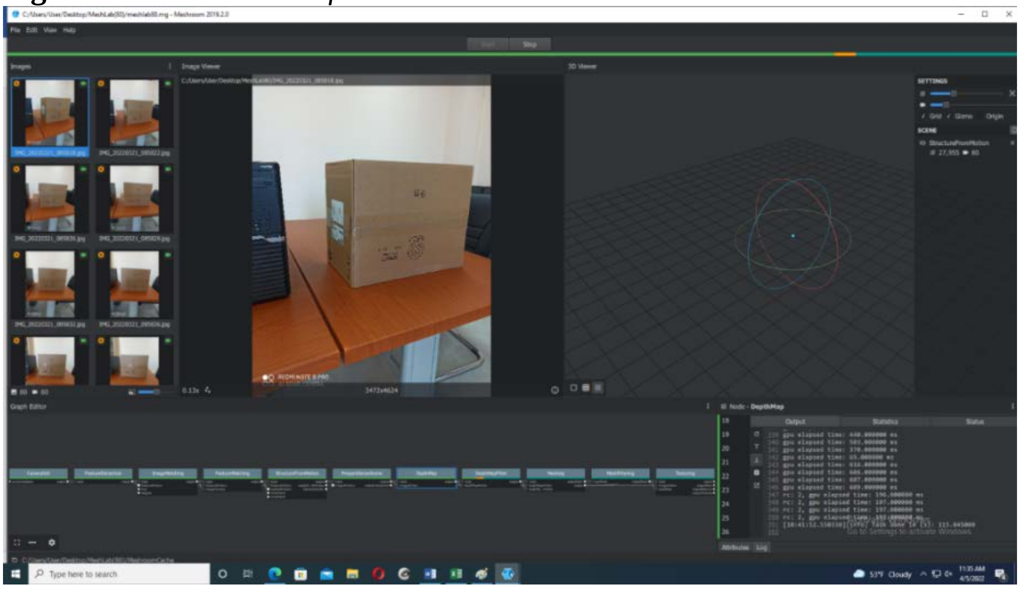
Photogrammetry

Photogrammetry is the process of creating 3D models from images taken from real-world objects in different positions and different angles. Reconstructing 3D objects from its photos would require a huge work if modern software did not exist. In the paper a combination of software's Meshroom and MeshLab will be used and evaluated.

Meshroom Software

The Meshroom interface is shown in Figure 1.

Figure 1. *Meshroom Interface*



The inputs are located in the upper left part, and right part serves to show the reconstructed 3D object, the output of special nodes such as meshing, or structure from motion stands in the right part of the workspace. The left-bottom part is the actual nodes that will take part in the execution flow. Nodes can be easily configured, giving Meshroom a lot of flexibility. The photos for the implementation and testing are taken through the Xiaomi ReadMe note 8 pro mobile phone.

The implementation consists in measurement and analysis of five cases, in case one a set of 100 photos is taken, the 3D object will be created based on the set and the dimensions of the object are measured and analyzed, in case two 80 from 100 photos create the set 2, in case three 60 from 100 photos create the set 3 and respectively 40 and 20 out of 100 photos creates sets 4 and 5.

In set 5, one out of five photos are chosen, it consists in photo indexes: 1,5,10,15,20,25,30,35,40,45,50,55,60,65,70,75,80,85,90,95. In set 4, one out of five photos are chosen, practically the photo indexes are: 1,2; 5,6; 10,11; 15,16; 20,21; 25,26; 30,31; 35,36; 40,41; 45,46; 50,51; 55,56; 60,61; 65,66; 70,71; 75,76; 80,81; 85,86; 90,91; 95,96. Increasing by one the number of samples creates set 3, 4 and 5. On every case, object dimensions are obtained and compared with the real ones.

Finally, a comparison between the five cases is made in terms of processing time, the quality of the reconstructed object as well as the accuracy of the measurements.

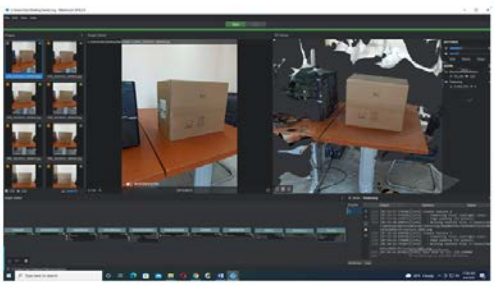
MeshLab Software

Meshlab is an open-source software for 3D image processing and preparing models for 3D printing. It works based on point clouds or in meshes. A set of tools are provided from Meshlab software as rendering, meshes, texturing, measurement of distances, cleaning, healing etc. (Meshlab 2021).

<u>Case A</u>

This case consists of a set with 100 photos. The workspace in Meshroom is given as illustrated in Figure 2.

Figure 2. *3D Reconstruction Based on Default Pipeline*



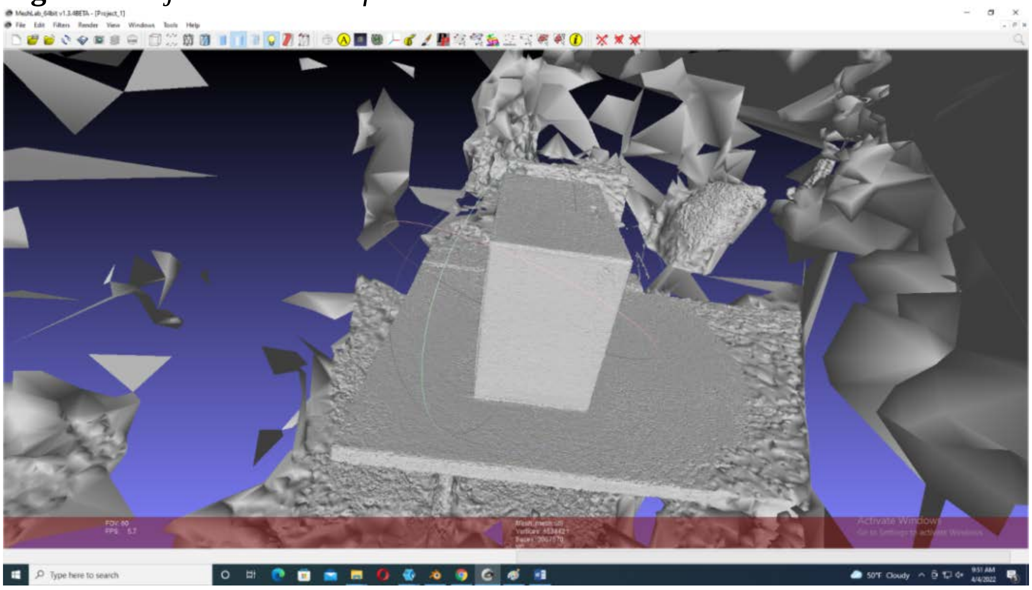
In this case the default nodes of the Meshroom are used, which are camera initialization, feature extraction, image matching, structure from motion, depth map, depth map filter, meshing, mesh filtering and texturing. Camera Init loads image metadata, sensor information and generates viewpoints.sfmcameraInit.sfm (Alice Vision Inc 2021). Feature Extraction extracts features from the images as well as descriptors for those features (Alice Vision Inc 2021). Image Matching is a processing step which figures out which images make sense to match to each other. Feature Matching finds the correspondences between images using feature descriptors (Asadpour 2021). Structure from motion will reconstruct 3D points from the input images. Depth Map retrieves the depth value of each pixel for all cameras that have been resolved by SFM (Alice Vision Inc 2021, Shilov et al. 2021). Certain depth maps will claim to see areas that are occluded by other depth maps (Stark et al. 2022, Berio and Bayle 2020). The Depth Map Filter step isolates these areas and forces depth consistency. Meshing generates mesh from sfm point cloud or depth map. Mesh Filtering filter out unwanted elements of your mesh. Texturing projects the texture, it changes the quality and size/file type of texture (Matys et al. 2021, Lee and Yu 2009).

As can be seen from Figure 2, the quality for the target object is at a good level, but the processing time of the nodes for this set and for the total time of the object generation process is quite high, the total processing time is 120 minutes (2 hours). Details of the time processing are given in the summary table 1.

The actual dimensions of the object are width = 27.5 cm, length = 48.5 cm and height = 39.5 cm (in MeshLab the width is referred to the x axis, length is referred to the y axis and height is referred to the z axis).

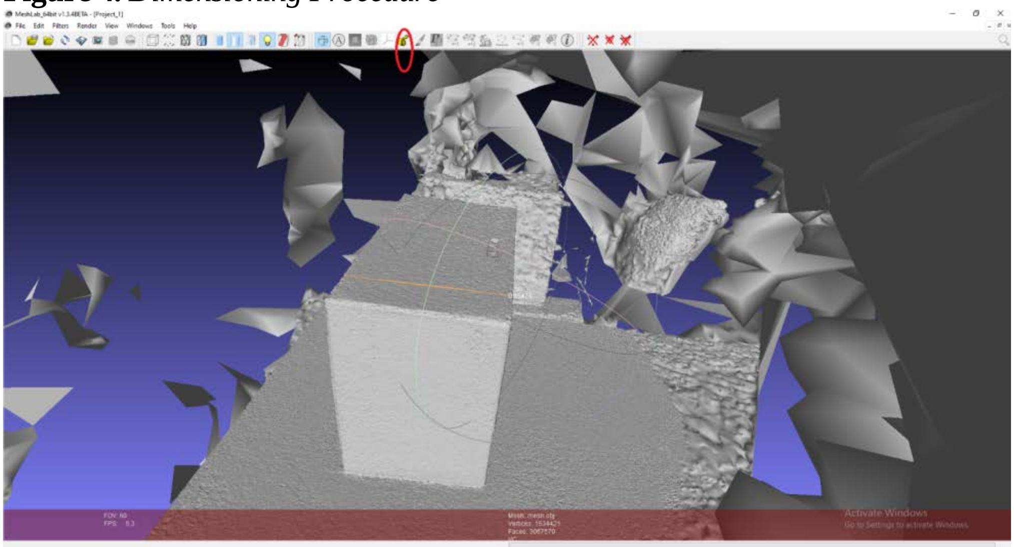
To find the dimensions of the reconstructed 3D object, MeshLab software will be used. The meshing generated by Meshroom software will be exported to MeshLab (Alice Vision Inc 2021, Berio and Bayle 2020). The workspace in MeshLab is illustrated in Figure 3.

Figure 3. *Object in Meshlab for Measurements*



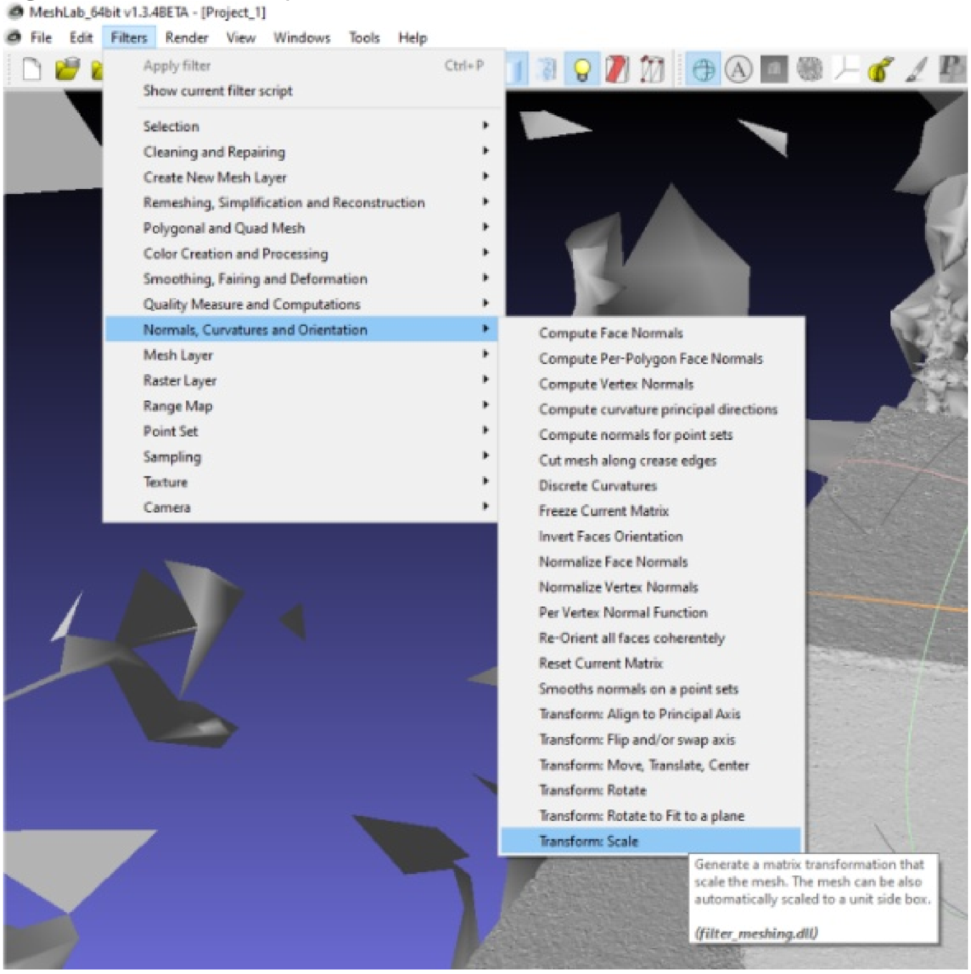
The target object, as can be seen from Figure 3, is complete, it is in the same condition that was generated in the Meshroom. MeshLab in addition to sizing can also serve to eliminate the parts of the background that as noted from Figure 3 are in a large quantity, but this is out of our focus since it is done in the Meshroom software. Therefore, in this paper, MeshLab will be used only to determine the dimensions of the object.

Figure 4. *Dimensioning Procedure*



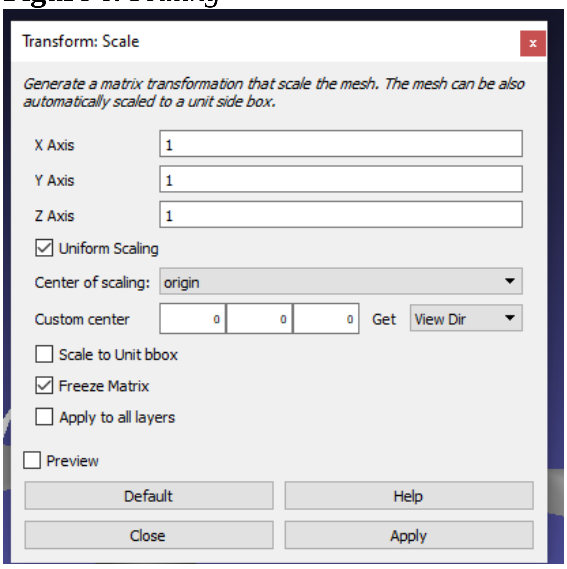
To determine the object sizes, the box marked in red will be checked, as shown in Figure 4, it stands for the measurement option. To find the object dimensions, two points, for which the distance is needed, are specified, it is illustrated by the orange line in Figure 4. The result is around the value of 0.55 but nothing is specified if this unit belongs to meters, centimeters, millimeters, etc. The scaling information is missing. One way to convert it to real world measurement units is: knowing the dimensions of the real object that corresponds to the two ends of the orange line, then the real size of the object is divided by the value generated by the orange line above, their ratio is calculated. The result that is obtained is exactly the value of the scale. This value replaces the corresponding parameter that corresponds to the real distance between two points, so it can be in the x plane, y plane or z plane. The Transform: Scale is filled with the calculated value, as shown in Figure 5.

Figure 5. *Conversion of Units into Real Units*



Scaling parameters window is shown in Figure 6.

Figure 6. *Scaling*



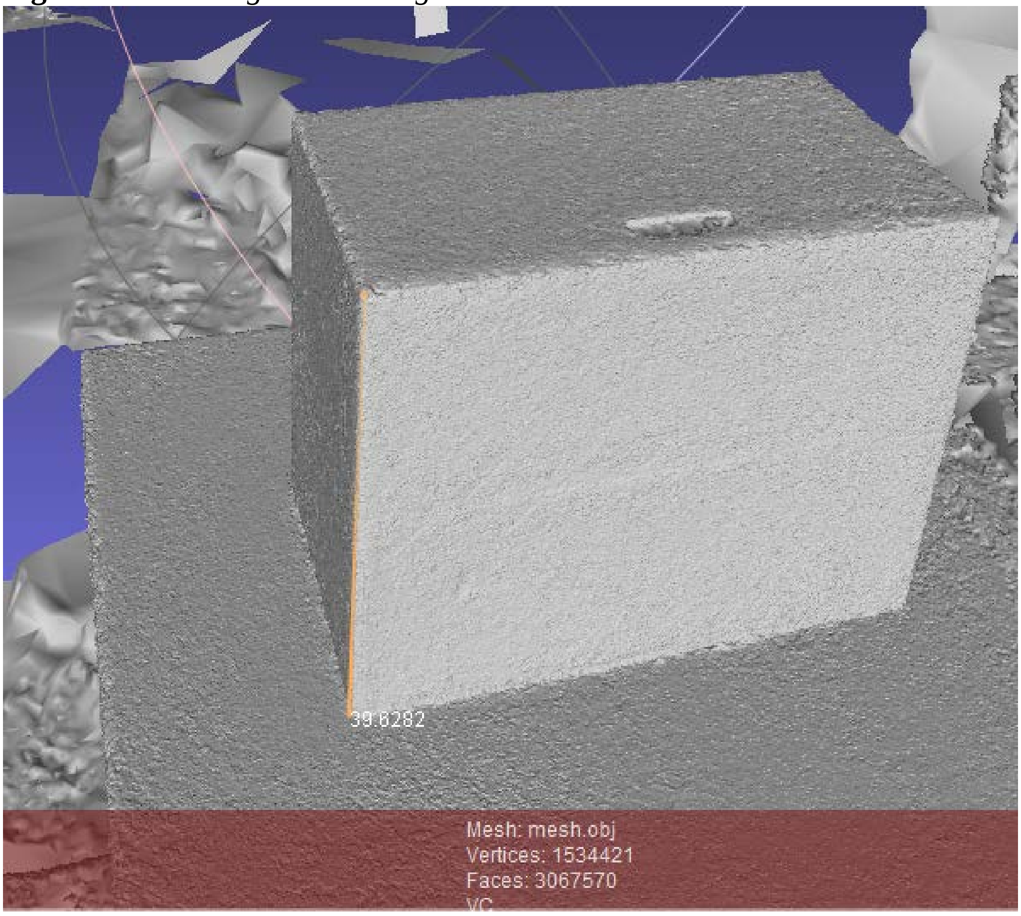
The values x, y and z will be set exactly the new values as indicated in Figure 6. Measuring only the width corresponds to the x coordinate, only the x value will be changed, it is the same for the other two coordinates.

Based on the real values and the measured ones, the scales will be determined. For X dimension, the ratio is calculated as 27.5/0.575 = 47.8, where 27.5 cm is the real size of the width of the box, 0.575 is the number that was generated from the initial measurement of the width of the box in the meshing (inside MeshLab) and 47.8 is the new value of scale to be set for X.

For Y dimension, the ratio is 48.5/1.01 = 48.01, where 48.5 cm is the real size of the box width, 1.01 is the number generated by the initial measurement of the box width in the meshing (inside MeshLab) and 48.01 is the new value of the scale that will be set for Y.

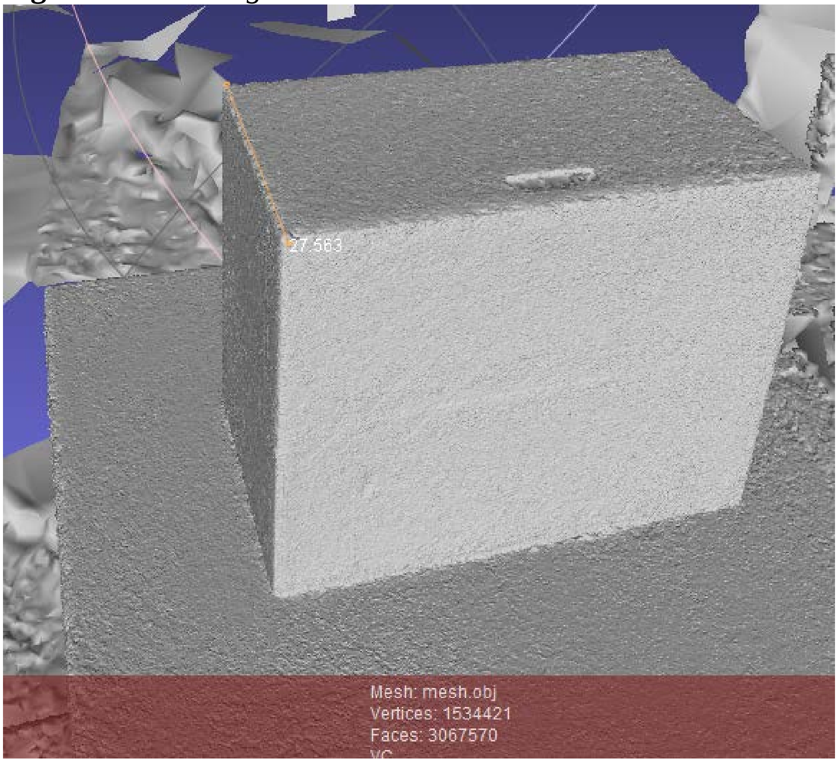
For Z dimension, the ratio is 39.5/0.82 = 48.17, where 39.5 cm is the real size of the width of the box, 0.82 is the number that was generated from the initial measurement of the width of the box in the meshing (within MeshLab) and 48.17 is the new scale value to be set for Z. The three new values in X, Y and Z are replaced in Transform: Scale. The dimensions that will be measured in the target object will be of the same unit as those of the real object.

Figure 7. *Measuring the Box Height*



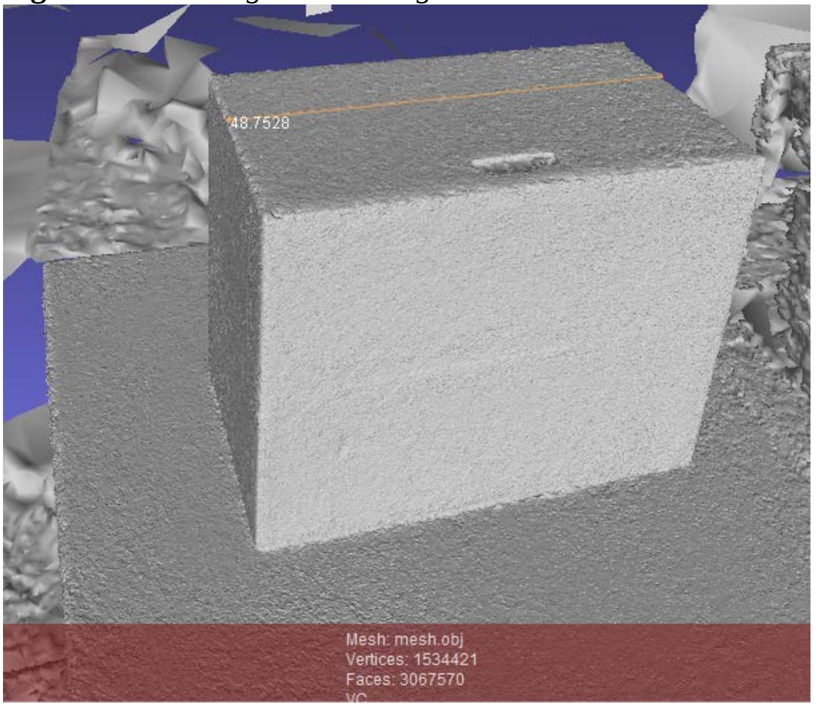
From Figure 7 it is noticed that the height is 39.6282 cm.

Figure 8. *Measuring the Box Width*



From Figure 8 it is noticed that the width is 27.563 cm.

Figure 9. *Measuring the Box Length*

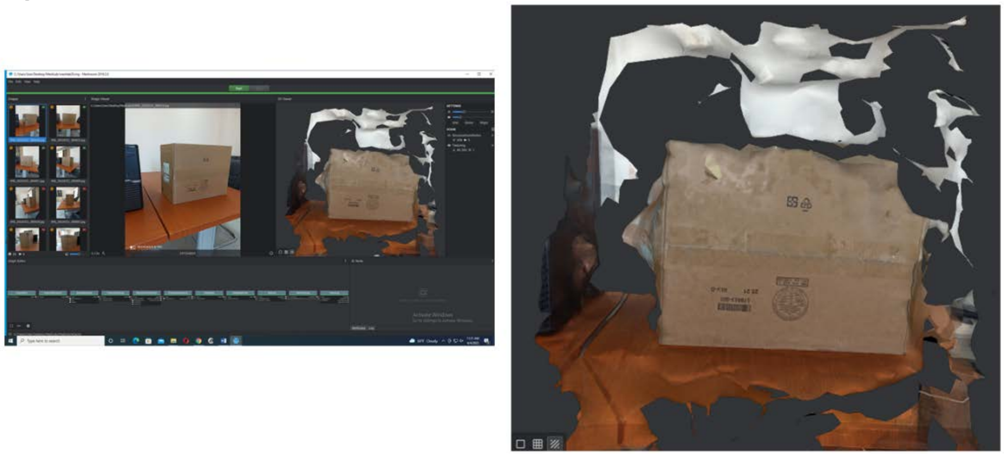


From Figure 9 it is noticed that the length is 48.7528 cm. From measurement results that the width is 27.573 (x axis), the length is 48.7528 (y axis) and the height is 39.6282 (z axis). A very accurate precision has been achieved for the width, for the length an error of only 0.25 mm and for the height an error of only 0.12 mm.

Case B

The set with 20 photos is used, within the initial set with 100 photos according to the rule: choose the photo with index 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90 and 95. The proposed procedure is performed again and the result in Meshroom is obtained as shown in Figure 10.

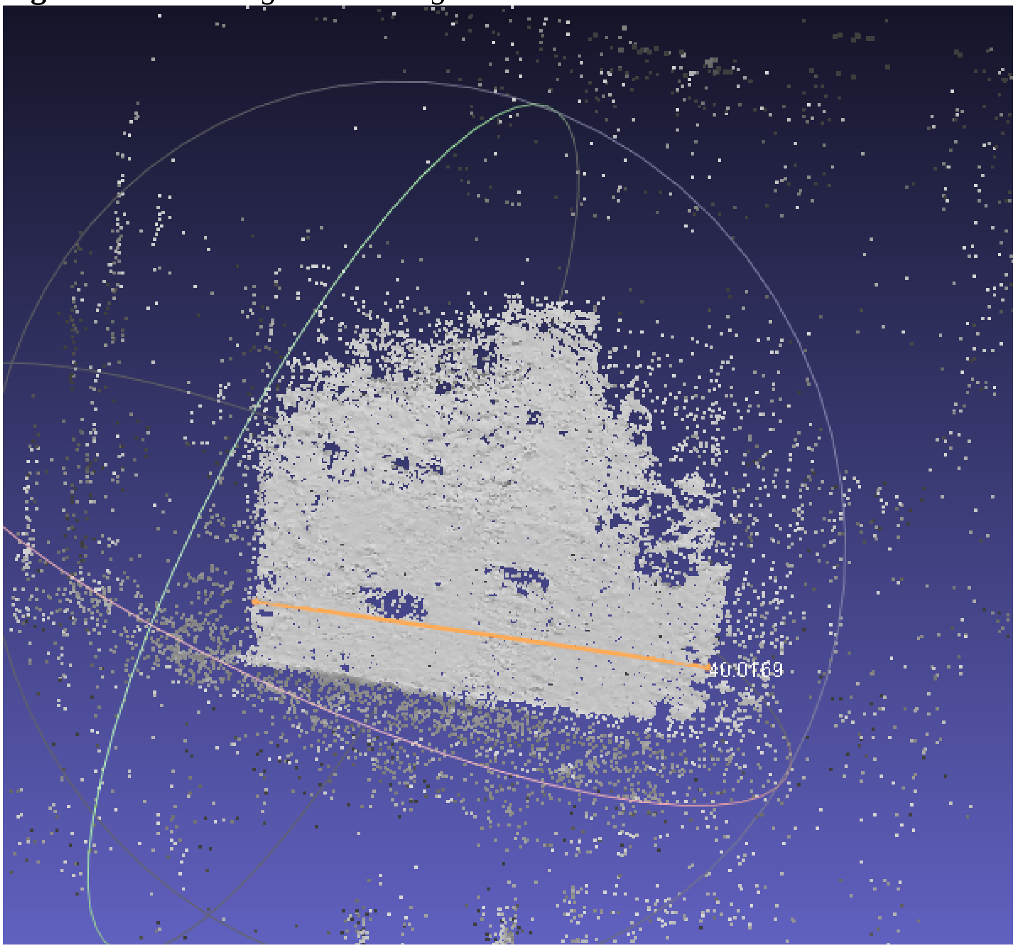
Figure 10. *3D Reconstruction Based on Default Pipeline*



The 3D object reconstructed with this selection of photos has many shortcomings in terms of quality, which can be seen from Figure 10, where the biggest problems are seen in the contours. The number of photos is relatively enough to generate a 3D object more complete than the obtained results, but the selection of photos according to the specified rule led to the conclusion that out of 20 photos as input only 5 of them are recognized and processed further in subsequent nodes to generate the 3D object. In terms of time the result is generated for about 2 minutes. Details of the processing time are given in Table 1.

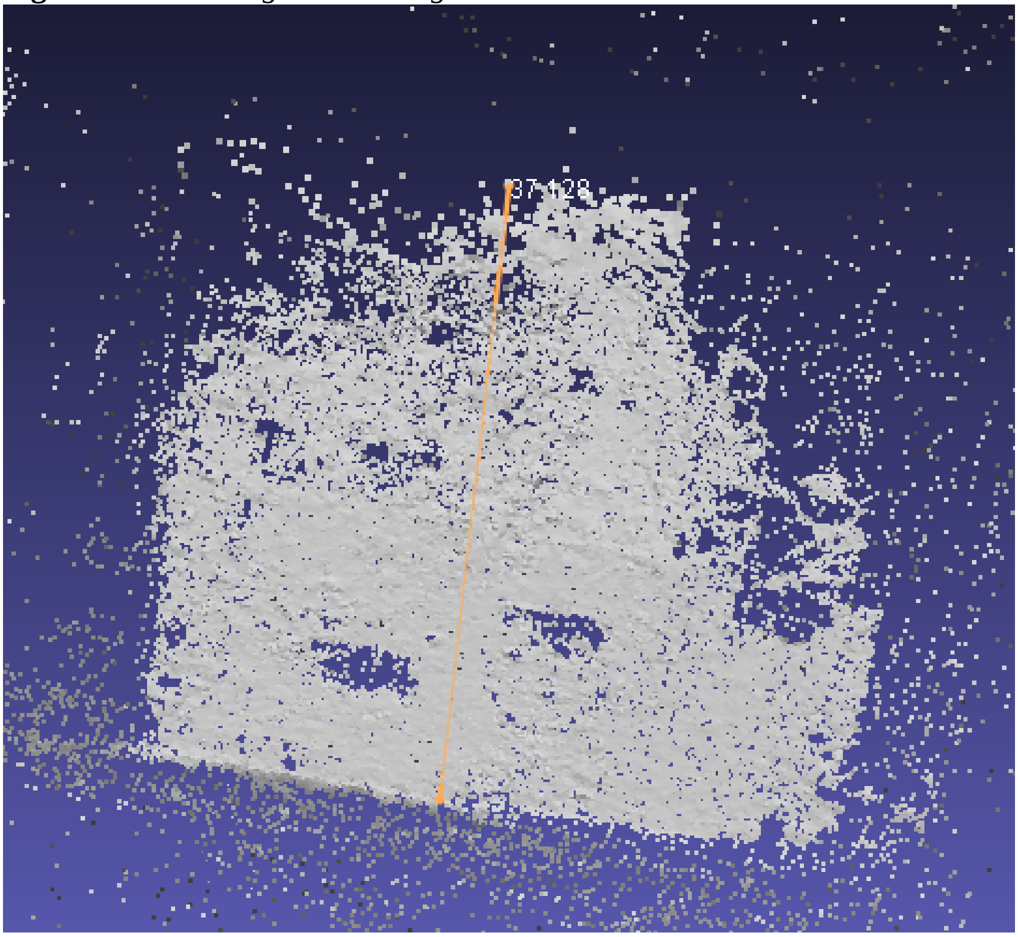
To determine the dimensions of the reconstructed object, the meshing generated by Meshroom software for the set of 20 photos will be exported to MeshLab. The result is shown in Figure 11.

Figure 11. *Measuring the Box Length*



The width, as it is seen from Figure 11, is 40.01 cm, about 8.5 cm less than the real width of the object.

Figure 12. *Measuring the Box Height*



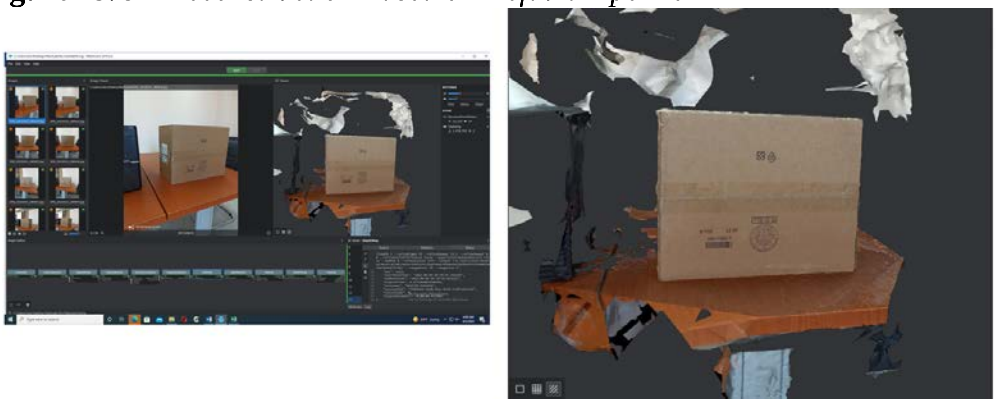
As indicated in Figure 12, the height results about 37.12 cm at the farthest distances between the two points. This distance is in the center of the object, but the rest of the object is incomplete so a fixed value for the height cannot be determined. But even the value 37.12 is 2.4 cm smaller than the real size of the object.

The depth of the target object is not possible to determine since many parts are missing from the side and rear views.

<u>Case C</u>

The set with 40 photos is chosen, the photo indexes are: 1,2; 5,6; 10,11; 15,16; 20,21; 25,26; 30,31; 35,36; 40,41; 45,46; 50,51; 55,56; 60,61; 65,66; 70,71; 75,76; 80,81; 85,86; 90,91 and 95,96. The proposed procedure is repeated and the result in the Meshroom software is shown in figure 13.

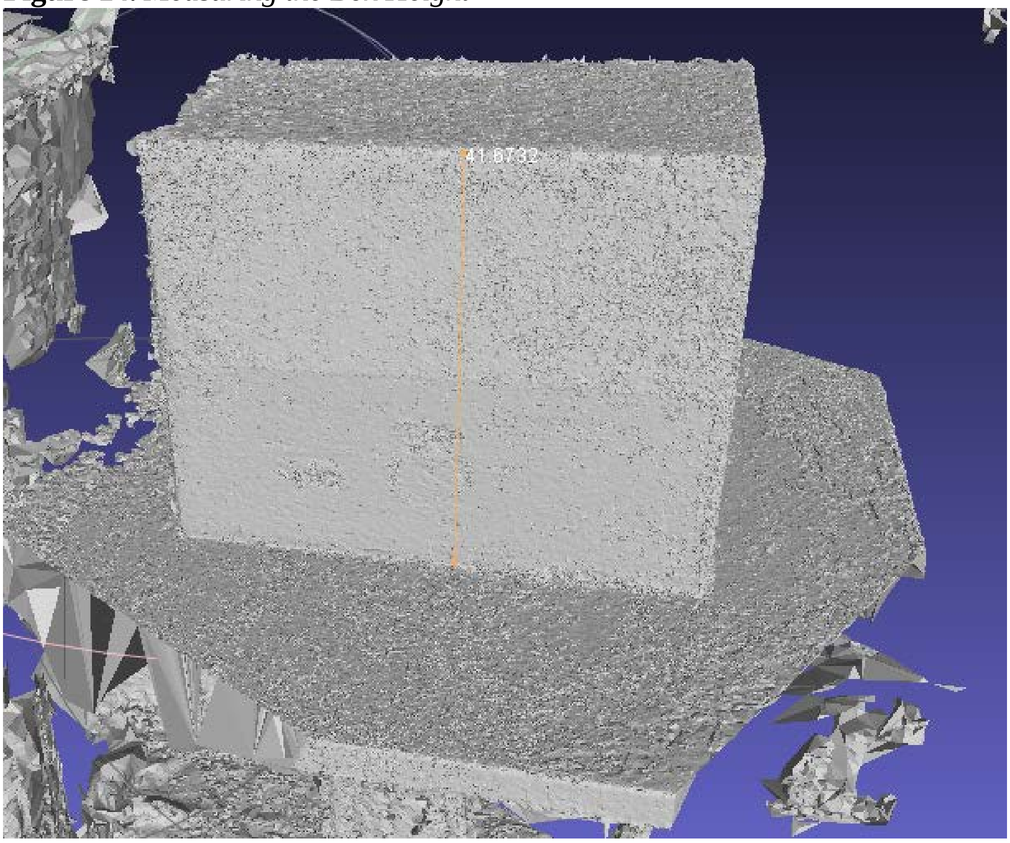
Figure 13. *3D Reconstruction Based on Default Pipeline*



From the set of 40 photos, 34 of them are recognized for further processing. After the processing in the Meshroom pipeline, the 3D reconstructed object is obtained in a good quality, as shown in Figure 13. The object is visually clear, the contours are also quite clear and the content part is complete from all sides. The total processing time to generate the 3D object is about 32 minutes. Details of the time processing are given in Table 1.

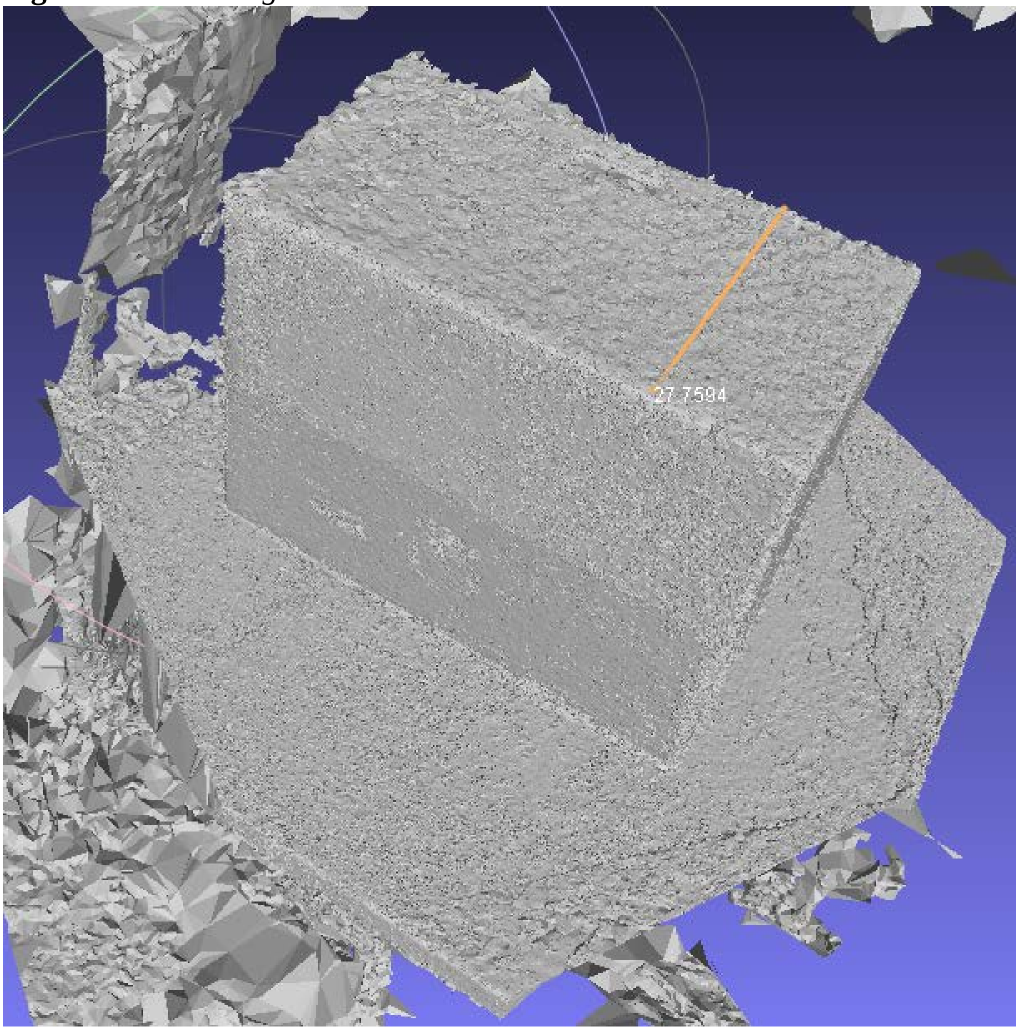
To find the dimensions of the reconstructed 3D object, MeshLab software will be used. Meshing generated by Meshroom software will be exported to MeshLab. Result from the MeshLab measurements are shown in Figure 14.

Figure 14. *Measuring the Box Height*



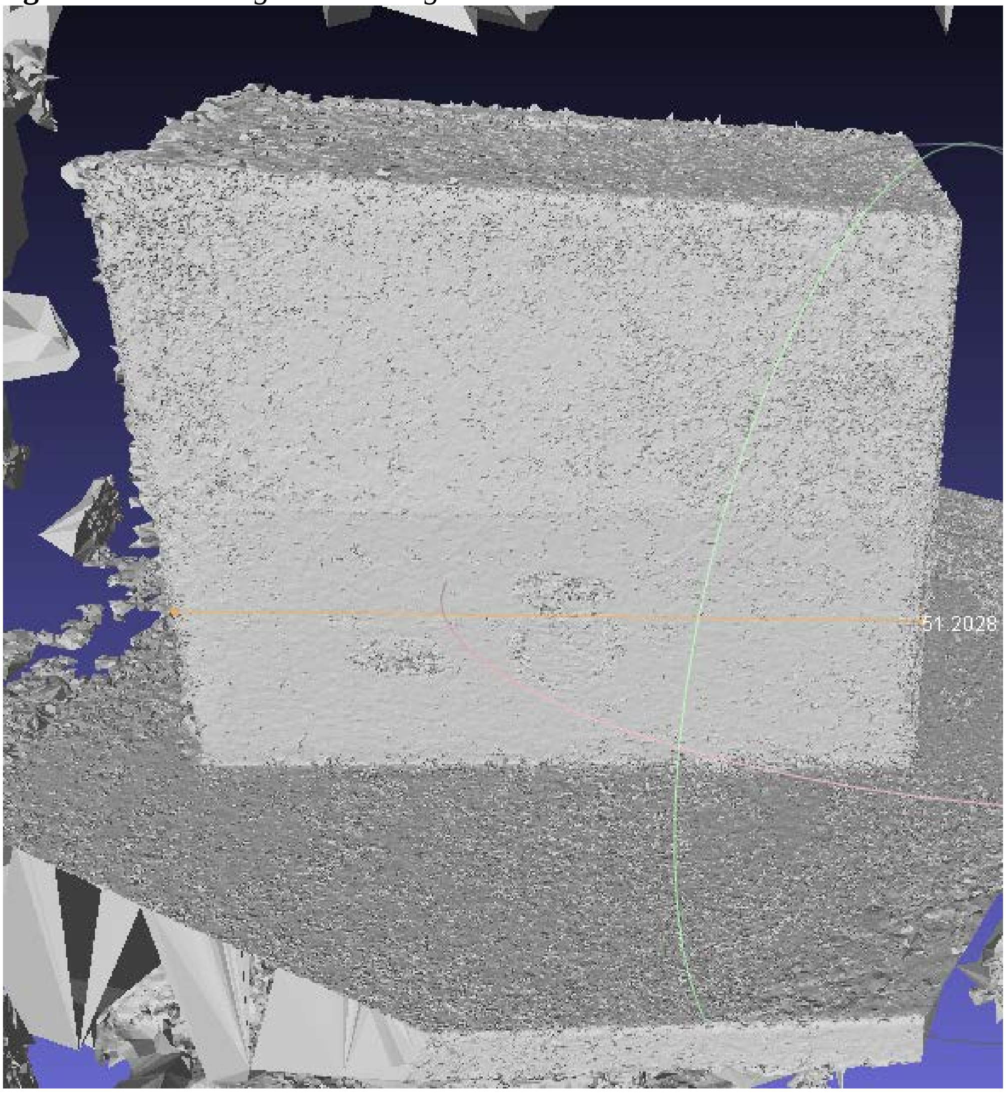
The measured height for the reconstructed object, as shown in Figure 14, is 41.67 cm. Comparing it with the height of the real object, which is 39.5 cm, yields a measurement error of 1.17 cm.

Figure 15. *Measuring the Box Width*



Regarding Figure 15, the measured of the width of the reconstructed object is 27.75cm, while the width of the real object is 27.5 cm. The error is very small, only 2.5 mm.

Figure 16. *Measuring the Box Length*

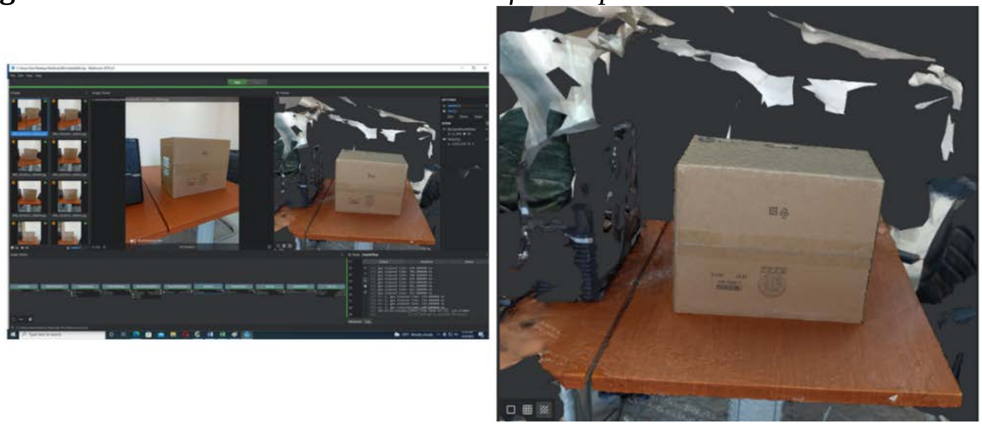


Regarding Figure 16, the measured length for the reconstructed object is 51.2 cm, while the width of the real object is 48.5 cm. The measurement error is about 2.7 cm.

<u>Case D</u>

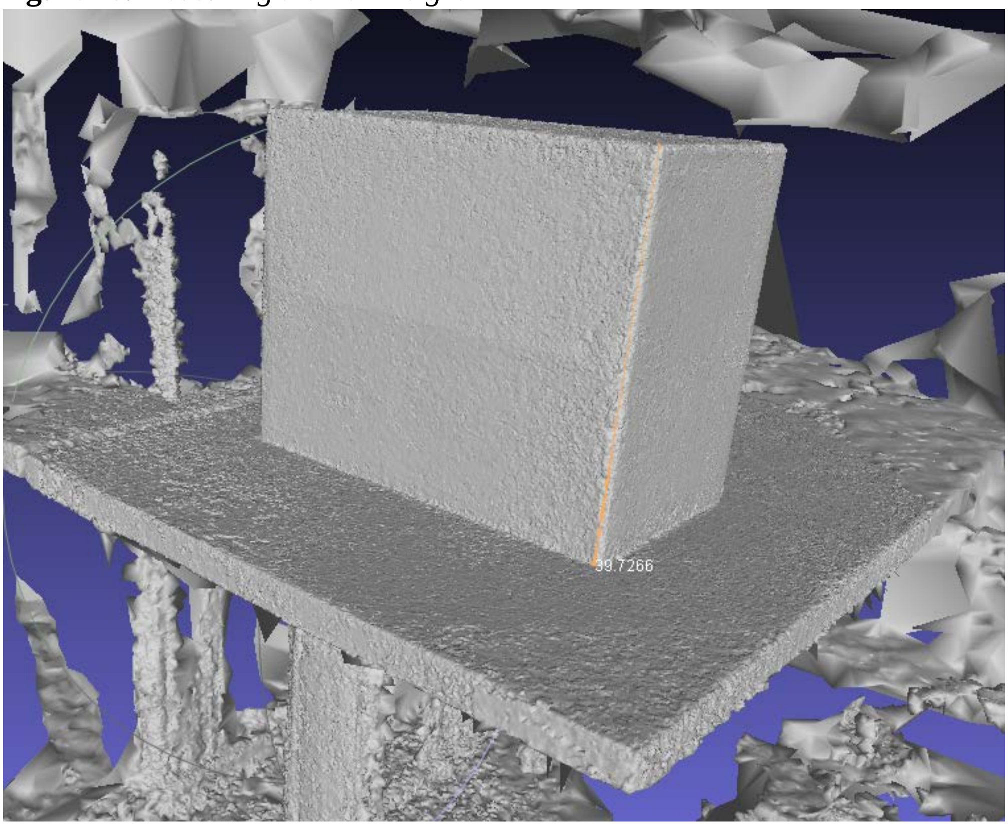
The set with 60 photos is chosen, the photo numbers are: 1,2,3; 5,6,7; 10,11,12; 15,16,17; 20,21,22; 25,26,27; 30,31,32; 35,36,37; 40,41,42; 45,46,47; 50,51,52; 55,56,57; 60,61,62; 65,66,67; 70,71,72; 75,76,77; 80,81,82; 85,86,87; 90,91,92 and 95,96,97. Repeating the procedure, the result in the Meshroom software is given in Figure 17.

Figure 17. *3D Reconstruction Based on Default Pipeline*



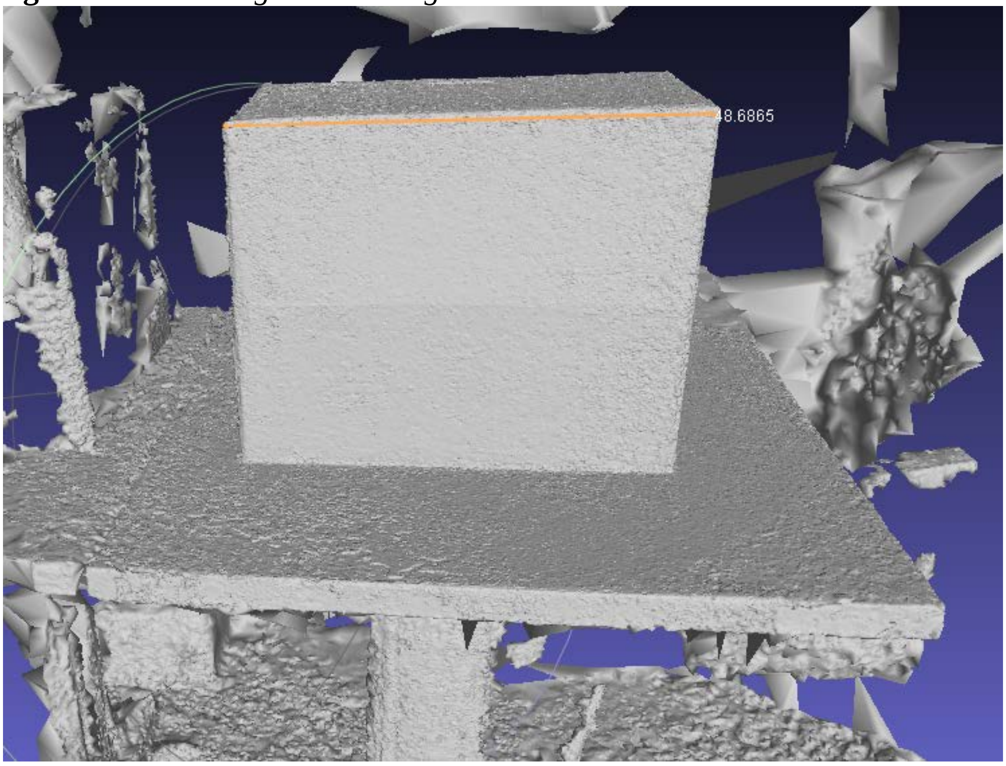
Regarding Figure 17, the reconstructed 3D object is in the same quality as the reconstructed object with the initial set of 100 photos, the contours clear, the content part has no shortcomings and is visually very clear. From the input of 60 photos, 59 of them were recognized for the processing and the total processing time in the default pipeline nodes of the Meshroom software (given as the sum of processing time in each node) is about 97.6 minutes. Details of the time processing are given in Table 1.

Figure 18. *Measuring the Box Height*



The dimensions of the 3D reconstructed object will be measured. The height, as can be seen from Figure 18, results 39.726 cm, while the real dimension of the object is 39.5 cm. The measurement error is only 2.26 mm.

Figure 19. *Measuring the Box Length*



Regarding measurement shown in Figure 19, the length resulted 48.68 cm, while the real value is 48.5 cm. The error is only 1.8 mm.

As indicated in Figure 20, the width of the reconstructed object resulted in 27.08 cm, while the real width of the object is 27.5 cm. There is an error of 4.2 mm.

<u>Case E</u>

The set with 80 photos is chosen, the photo indexes are 1,2,3,4; 5,6,7,8; 10,11,12,13; 15,16,17,18; 20,21,22,23; 25,26,27,28; 30,31,32,33; 35,36,37,38; 40,41,42,43; 45,46,47,48; 50,51,52,53; 55,56,57,58; 60,61,62,63; 65,66,67,68; 70,71,72,73; 75, 76,77,78; 80,81,82,83; 85, 86,87,88; 90,91,92,93; 95,96,97,98. The procedure is repeated and the result in the Meshroom is shown in Figure 21.

Figure 20. *Measuring the Box Width*

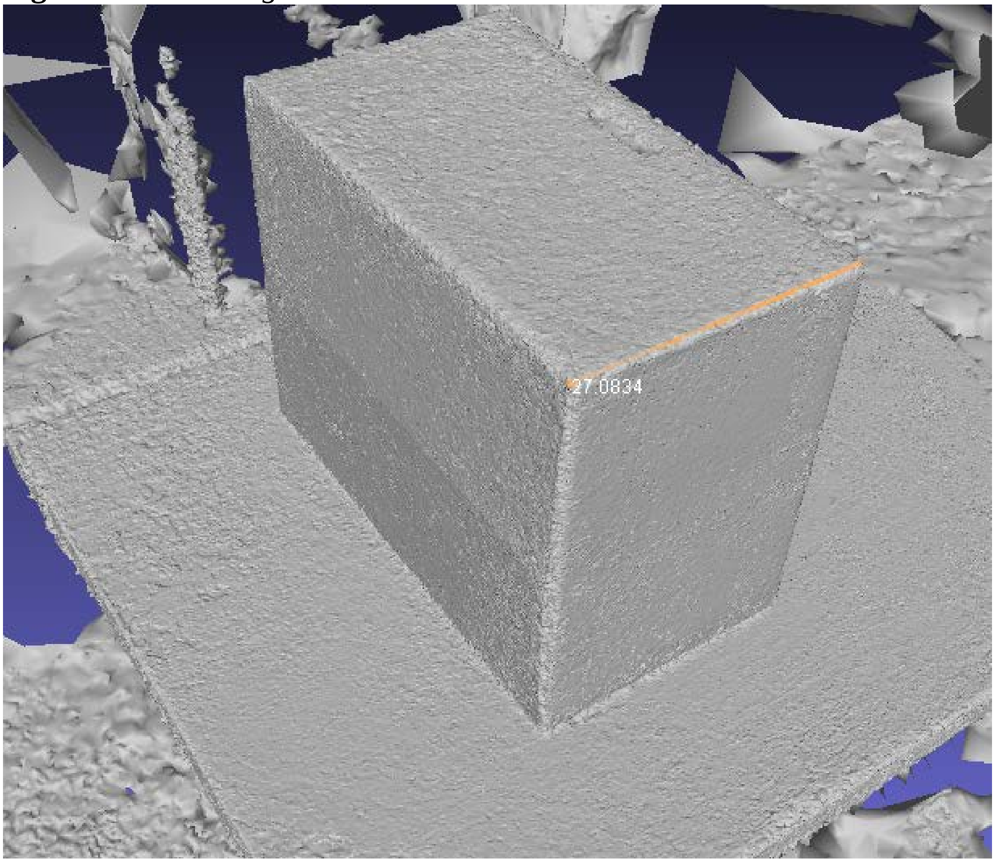
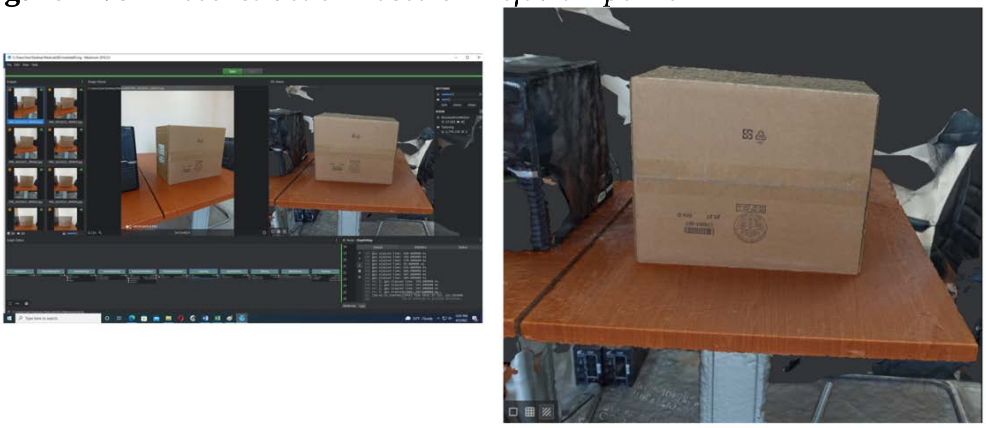
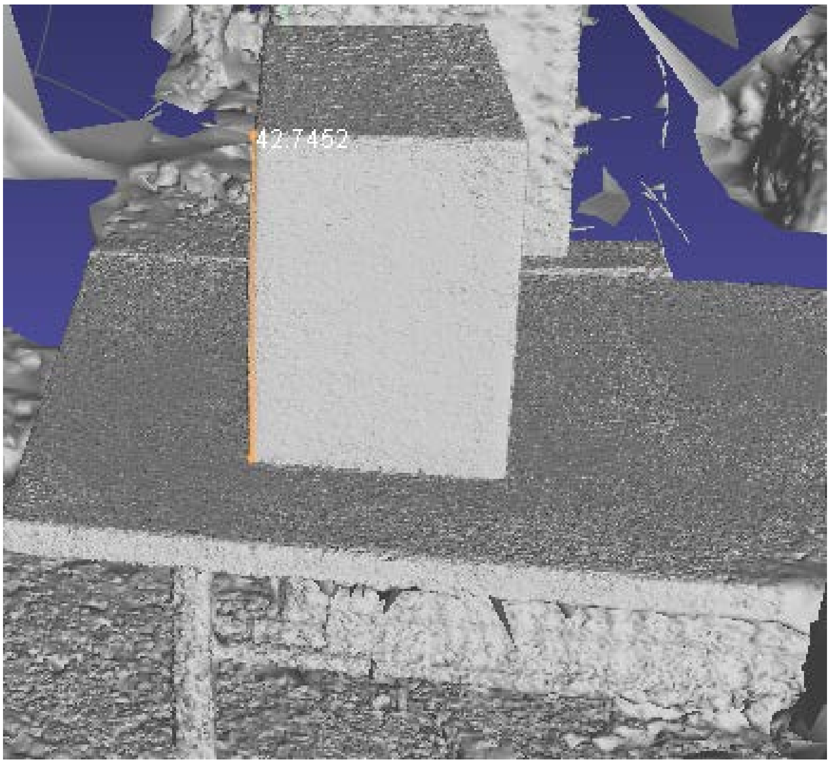


Figure 21. *3D Reconstruction Based on Default Pipeline*



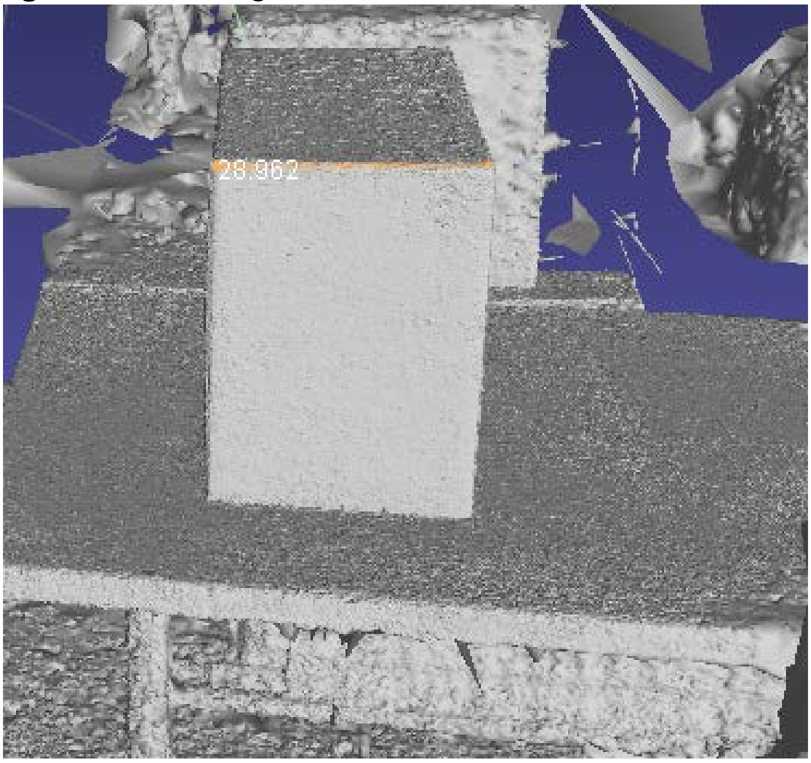
Regarding Figure 21, the reconstructed 3D object is in the same quality as the reconstructed object with the initial set of 100 photos, the contours are well reconstructed, the content part has no shortcomings and is visually very clear. From the input of 80 photos, all were recognized for processing and the total processing time in the default nodes in Meshroom software (given as the sum of processing time in each node) is about 84 minutes. Details of the time processing are given in Table 1. The dimensions for the generated object will be measured.

Figure 22. *Measuring the Box Height*



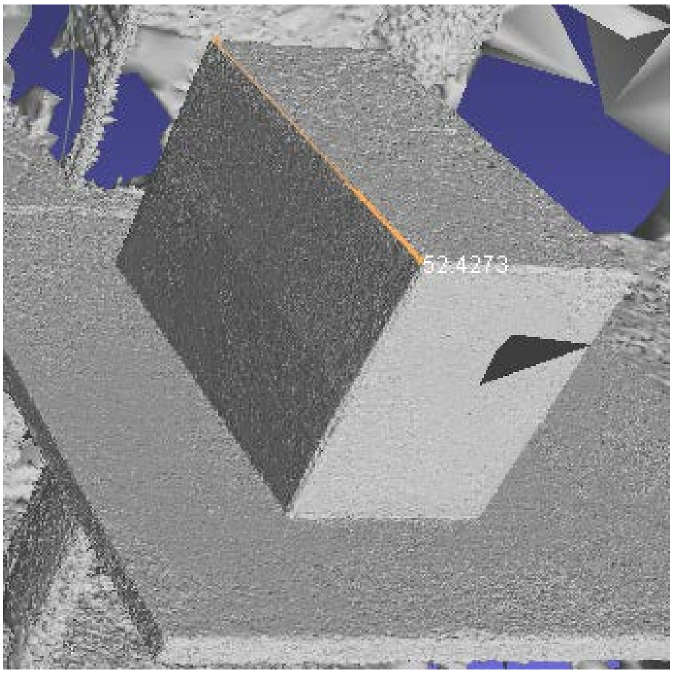
The height as indicated from Figure 22 is 42.74 cm, while the real value of the object is 39.5 cm. The measurement error results in 3.2 cm.

Figure 23. *Measuring the Box Width*



Referring to Figure 23, the width of the reconstructed object resulted in 28.962 cm, while the real width of the object is 27.5 cm. There is an error of about 1.46 cm.

Figure 24. *Measuring the Box Length*



Referring to Figure 24, the length is 52.427 cm, while the real value is 48.5 cm. It resulted in a measurement error in the value of about 4 cm.

Time processing results for each case is shown in Table 1.

Table 1. *Results of Processing Time Measurements for Each Case*

Procesing statistics															
Test	Input images	Camera calibrated	CameraInit	FeatureExtraction	ImageMatching	FeatureMatching	StructureFromMotion	PrepareDenseScene	DepthMap	DepthMapFilter	Meshing	MeshFiltering	Texturing	Total time (seconds)
1	100	100	0.21	94.37	0.2	165.76	83.17	35.37	4697.83	511.5	1053.74	34.67	531.03	7207.85
2	80	80	0.23	33.34	0.3	103	103.1	30.84	3250	390	645.34	27.79	456.37	5038
3	60	59	0.21	36.34	0.19	68.1	73.75	47	3776	471	962.22	23.68	401.9	5861.8
4	40	34	0.19	36.63	0.33	22.07	31.04	28.28	1284	168.83	235.65	11.68	103.1	1920
5	20	5	0.19	19.39	0.1	7.84	3.11	5.02	52.54	11.36	15.48	0.66	19.61	135

As indicated in Table 1, case 5 gives the best result for processing time. Performance comparison for each case is shown in Table 2.

Table 2. *Performance Comparison*

Experiment	Processing time	Quality	Size measurements
Case 1	5	1	1
Case 2	3	3	4
Case 3	4	2	2
Case 4	2	4	3
Case 5	1	5	5

Regarding results shown in Table 2, the reduction of the number of photos from 100 to 60 (case 3) yields the optimal performance in terms of visual quality and processing time.

Cignoni et al. (2008) deal with the strategy and support for development and the capacities offered by the proposed system, but not the measurement of the size of the objects and the accuracy in the measurement. Sá et al. (2019) proposed a methodology for replica of public sculptures of modern period. In this work discussion is presented about various options for access, augmented reality applications and 3D printing of replicas. The proportions of the components of the objects under consideration are analyzed, but not their measurement and accuracy. In the article of Djuric et al. (2021) the results of the 3D reconstruction in the open-source software Meshroom and the commercial one Agisoft Metashape are compared, highlighting the advantages of the commercial software and the level of accuracy obtained from the open-source software, in this case Meshroom.

Conclusions

In this paper the trade-off between number of photos and processing time in the 3D reconstruction is analyzed. Meshroom software is used for reconstruction and Meshlab is used for dimensioning. The full quality is obtained from input of all the photos, but processing time is too large. Five cases are considered, with 100, 80, 60, 40 and 20 photos, quality of reconstruction and time processing are analyzed for each case.

Experimental results show that reducing the number of photos decreases the processing time but at the same time also the quality of the reconstructed object. On the other hand, a very large reduction of photos can give a poor quality, as demonstrated in the case five with the set of 20 photos, only 5 of them were processed by the nodes.

Based on the experimental results it is concluded that the optimal case in terms of quality and processing time is the case three, where the number of photos is equal to 60. The processing time is 97.6 minutes and the dimensions accuracy is about 1-2 mm.

Acknowledgments

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Machine Learning Solutions in Combating COVID-19: State of the Art and Challenges

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COVID-19 is a toxic virus that emerged in China and caused an epidemic globally. COVID-19 virus patients are placed in isolation so that the virus does not blow out widely. The only approach to secure people from this deadly virus is by maintaining social distance among people, wearing gloves and masks, and sanitizing and washing hands regularly. The law enforcement agencies and Government are included in prohibiting people movement in varied cities to control the virus spread. It is not feasible for government to supervise all places namely hospitals, shopping malls, banks, government offices and direct people to following the safety guidelines prescribed by government. The COVID-19 virus has been spreading in a drastic way with the feasibility of a restricted amount of testing kits rapidly. Therefore, the diagnosis of COVID-19 model is important to recognize the occurrence of disease from radiological images. The major aim of the research is to review different machine learning solutions in combating COVID-19. Various machine learning models are implemented to combat COVID-19 virus. The proposed models with the along computer vision algorithm are used as a corresponding device to be fixed at varied places and supervise people to adopt secure guidelines which are suggested by the government. By following the precautionary steps and using the solutions of machine learning, people are capable to succeed with the fight against COVID-19 virus.

Keywords: *COVID-19, machine learning, social distancing, face mask, hand hygiene, deep learning*

Introduction

The disease of Corona Virus (COVID-19) is spreading and affecting people globally in present times. It is a malicious and highly severe disease affected by virus that belongs to Beta Corona Virus family known as SARS-CoV-2 (severe acute respiratory syndrome Corona Virus 2) which is a new Corona Virus in 2019 (Liu et al. 2020). COVID-19 is a deadly virus which impacts the lungs and respiratory tract of people severely and causes pneumonia and causes several other diseases related to lungs. There is no vaccination or medicine available for COVID-19 in November and December 2019 (Subhalakshmi et al. 2021). The Corona Virus initiated from China in 2019 December but the spread of virus initiated in January and it was recognized first on January 2020. Since it is

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increasing vastly from China to other nations, World Health Organization declared COVID-19 as a pandemic (Cohen and Normile 2020). COVID-19 is a big family of viruses which causes huge number of deadly diseases. People affected by this virus would have moderate or mild illness in respiratory. The most common symptoms of COVID-19 are cough, difficulties in breathing, head ache and fever. Sometimes this virus causes serious syndrome of acute respiratory, pneumonia, failure in kidney, blindness and even death (Majumder et al. 2021). The toxic virus is spreading widely from the transmission of human to human. The non-occurrence of virus makes the circumstance much challenging. The only approach invented to secure this transmission of human to human is to break all kinds of commuting or travelling (Wang et al. 2020).

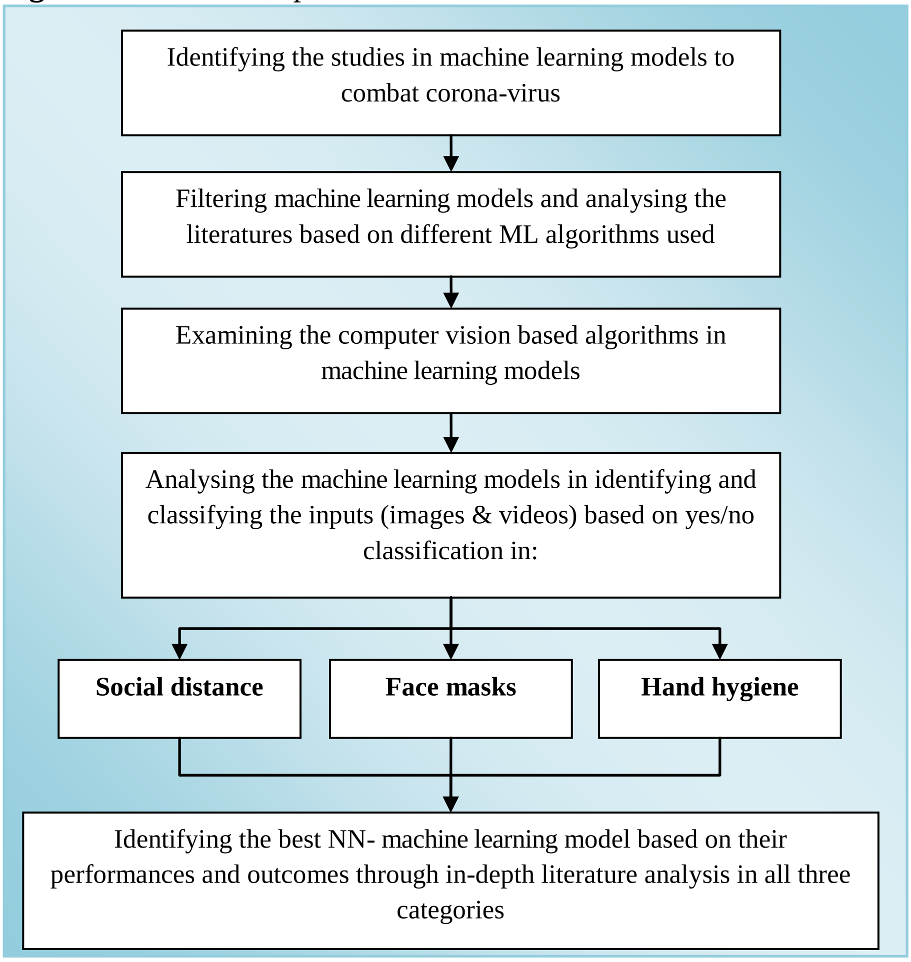
According to Stokes et al. (2020) the Centers for Diseases Control and Prevention's (CDC) report 2019-2020 on corona-virus informs that it takes about minimum 2-14 days for corona-virus to spread in human after they are exposed. Once the affected individual suffers from symptoms like fever, cough, breathing discomfort, tastelessness, loss-of-smell, sore throat, headache, body-aches and muscle cramps, they are advised by medical practitioners to prevent or recover from COVID-19. The method for combating corona-virus includes, social distancing, timely vaccination, avoiding crowded commutes, transportation and places, avoiding outing or travelling with families, wearing masks, washing hands frequently, coughing into elbow, not touching one's face often and maintaining minimum 3-feet distances between people prior diagnosed and post diagnosed one should combat the infection with plenty of rest, hydration, medication (like: Tylenol, Paracetamol, Advil, Motrin). Though the symptoms vary from one to another, it has been advised by the CDC that when an individual has similar symptoms they are to be checked by medical practitioners within 3 days.

An Artificial Intelligence system has predicted the unknown kind of pneumonia disease outbreak in China before the world was aware of the damage posed by COVID-19 virus. Though the pneumonia outbreak has become a worldwide pandemic, the technologies and tools of artificial intelligence can be used to assist efforts of medical community, policy makers and society at large to handle each crisis stage and its consequences (OECD 2020). The health sector is looking for new techniques and technologies to control and track the development of the COVID-19 epidemic in this global crisis of health. One of the biggest global techniques now is artificial intelligence which can predict the growth rate and track the speed of Corona patients (Li et al. 2020). Corona patients have been developing every day an efficient model named Artificial Intelligence is an automatic prediction method that is considered to be essential towards a dense limitation of testing duration. Artificial Intelligence can also expect the death possibility by examining the earlier data of patient (Pathak et al. 2020). Machine learning is a helpful technique and this can be seen in different areas to recognize the existing drugs which seem beneficial for COVID-19 patient's treatment. Machine learning is advantageous to find the risk in healthcare during the Corona situation. Machine learning also examines the threat factors as per climate, age, location and social habits (Kushwaha et al. 2020). Several applications of machine learning have been evolved to manage different problems associated to the virus.

Several solutions of software based on AI are presently in use to trace the virus spread. Machine learning has been employed to direct scientists to new inventions in pharmacology (Kamalov et al. 2021). AI is an automatic method of prediction that is considered to be essential towards a dense restricting of testing (Togacar et al. 2020). AI is used in combating the virus by verifying individuals, information and data, medical support and suggestions regarding control of disease. In order to solve the complex issues in people lives artificial intelligence is a wide term that comprises of searching, learning, preparation and thinking. The subset of artificial intelligence is machine learning that comprise of many algorithms that offers intelligent models to cluster or recognize specific tasks (Alafif et al. 2020). The Corona Virus liable for COVID-19 has made havoc among people presenting a huge number of complications in compelling healthcare researchers around the world to discover new solutions of technology and treatment plans.

A machine learning technique is playing an essential part in solving these complications and many healthcare firms are adopting and customizing them in response to the barriers posed by the COVID-19 virus (Syeda et al. 2020). The pandemic has made negative influence on health, political and socioeconomic surroundings globally. The ways of handling the COVID-19 spread are identifying initially, putting in quarantine, quick management, prediction of spread of virus and system execution for tracing of contact (WHO 2020). The major barriers are virus test delay, medicines or drugs and offering services to difficult zones. The main aim is early identification and detection of virus, contacts nursing, continuous checking, examination of medical and epidemiological reports from patients and development of drugs and procedures (Rahman et al. 2021). Several firms are guiding people to follow proper strategies to control the spread of this severe virus. These strategies namely: 1) to maintain social distance from one people to another people at least one metre; 2) to avoid social contacts namely touching, hugging or handshaking; 3) to stay at home if the individual has fever; 4) to avoid spitting, sneezing and coughing in the open air; 5) to wear mask to secure the respiratory system from virus through air and use gloves to handle the virus blowout; and 6) to sanitize and wash hands regularly and disinfect used items regularly (Uddin et al. 2020). Other preventive measures are also taken by government by putting lock down in countries, minimizing and/or closing migration within cities and among countries as well, quarantining foreign returned passengers, suspending offices, schools, restaurants, shopping malls etc. This deadly virus has made huge loss in economy among several countries. Though this disease is spreading quickly timing is an essential factor for controlling the disease as early as feasible. Hence from the beginning stage itself monitoring is needed for authorities to manage this pandemic situation (Dutta and Bandhopadhyay 2020). Government has stated to spend in COVID-19 vaccine enthusiastically and generously. Huge number of R&D activities is being planned pertaining to COVID-19 pandemic situation so deep learning and machine learning methods have been an essential option for the recognition of disease (Zhang et al. 2020). The technique of image processing has acquired huge familiarity in all healthcare sectors particularly in detection of cancer in smart cities. Hence these methods have been an essential option for combating COVID-19 virus as well (Khan et al. 2020). World Health Organization has framed a worldwide strategy to combat COVID-19 virus namely: 1) mobilization of human life to keep social distancing and hand hygiene; 2) monitoring periodic cases to hinder spread among community; 3) defeating spread of community by imposing similar limitations; 4) offering services of healthcare to lessen mortality; and 5) vaccine growth and therapeutics for big scale monitoring (Bhattacharya et al. 2020). Thus it can be inferred that among different results to fight COVID-19, Machine learning has been regarded as a great technology to offer smart solutions. Thus, in this research the usage of different computer vision algorithms (object detection, image classification, image processing, feature extraction, object tracking, instance segmentation, semantic segmentation, image reconstruction, and more) in machine learning models, to identify the social-distances among the people, through neural networking models to combat COVID-19 will be focused, where the social distancing, wearing face masks and hand-wash as hygiene will be the norms of filters (refer to Figure 1).

Figure 1. *Research Purpose*



Review of Literature

Machine Learning Models for Predicting Social Distancing

According to the study of Ahmed et al. (2020) a deep learning framework is proposed for tracking social distance using an overhead prospect. The deep learning framework uses the platform of YOLOv3 for recognition of object to recognize people in sequences of video. Hou et al. (2020) proposed a method for detection of social distancing using deep learning model to estimate the distance between people to resolve the effect of this COVID-19. The instrument for detection was evolved to warn people to keep safe distance with each other by estimating the feed of video. The results of the method are capable to determine the measures of social distancing between several people in a video. In the research of Rezaei and Azarmi (2020) a hybrid YOLOv4 based DNN and Computer Vision model is proposed for automated detection of people in the crowd in outdoor and indoor surroundings using similar security cameras of CCTV. The proposed deep neural network model integrates with an adapted technique of IPM (inverse perspective mapping) and algorithm of sort tracking leading to detection of robust people and monitoring social distance. Contrary to that Soures et al. (2020) proposed a new hybrid machine learning model named SIRNeT for predicting the spread of a virus that integrates with epidemiological frameworks. The model assists in learning non-pharmacological methods and interventions that reduce societal collateral loss and control methods for a prolonged period of time. The study of Ahmed et al. (2021) proposes a framework for social distance based on the architecture of deep learning as a step of precautionary that is used to monitor, maintain, reduce and handle the physical communication between people in top view surroundings at real time. This study used faster Recurrent Convolutional Neural Network for human detection in images. The results of the study indicate that the framework supervises social distance between people efficiently. Ansari and Singh (2021) proposed a structure that tracks people for supervising social distancing which is being trained. To achieve this objective of social distancing supervision an algorithm is evolved using the object detection method. Convolution Neural Network based detector of object is used to predict the existence of people. The study of Khamis and Samee (2021) uses artificial intelligence algorithm to maintain distance between people to reduce the virus exposure. Genetic Neural Network is used as a neural network algorithm in handling with varied characteristics. The genetic algorithm is better at developing the features choice leading to good outcomes. Kumar et al. (2021) presents a method for predicting social distancing using computer vision and deep learning between people to manage the spread of virus. This application is evolved to provide warnings to people for maintaining social distancing in crowded places. Mathurkar et al. (2021) proposed the YOLOv3 model which is a fully convolutional neural network algorithm to predict people in frames of video. The proposed system offers a systematic method for tracking violations of social distancing. The proposed model is advantageous rather than physical supervision which decreases the efforts of people needed and provides a wide enclosure of areas for the purpose of detection. Punn et al. (2021) proposed a deep learning structure for enhancing the activity of supervising social distancing using surveillance video. The proposed structure uses the YOLOv3 model for detecting objects to segregate humans from the background and uses deep sort method to track the recognized people with assigned Ids and the use of bounding boxes. Rahim et al. (2021) uses the YOLOv4 model for detecting objects in real-time and social distancing measuring method is established with a motionless Time of Flight camera. The proposed model denotes better performance with a 97.84% (Mean Average Precision) score and the acquired (Mean Absolute Error) between measured and actual values of social distance. Shukla et al. (2021) propose a system that is helpful in supervising public places like hospitals, malls, and ATMs for violations of social distancing. This study proposed a deep learning model which can be connected for coverage within some restricted distance. The model uses DL algorithms with library of open CV to evaluate the distance between people in the frame and a model of YOLO is trained on a dataset of COCO to recognize people in a fame, contrary to that Shalini et al. (2021) used YOLOv3 model for examining social distance among people using pedestrian's clusters during neighbourhood by obtaining the video feed. The proposed system was inserted into a pre-filmed video. By finding the space between two people a safe distance is handled which can be helpful to resolve the virus spread.

Table 1 shows the reviews of machine learning models for predicting social distancing.

Table 1. *Reviews of Machine Learning Models for Predicting Social Distancing*

S.No.	Author	Year	Model	Performance Evaluation	Findings	Drawback
1	Ahmed et al.	2020	Deep Learning YOLOv3	The model achieved 95% accuracy	Differentiates people who walks so closely and violates or breaches social distance	This study is limited to side and frontal view images of people
2	Hou et al.	2020	YOLOv3	--	Capable to predict the measures of social distancing between several people in a video	This study is Limited to only record the video of pedestrians walking on street
3	Rezaei and Azarmi	2020	YOLOv4 based DNN and Computer vision	The model achieved 99.8% detection accuracy	Track and detect dynamic and static people in public places to supervise the metrics of social distance in the era of COVID-19	This study is limited to MS-COCO and Google Open Image datasets
4	Soures et al.	2020	Hybrid Neural Network	--	Models the mobility role in handling the spread of virus	This study is limited to resource which is developing demand of pandemic rapidly compelling the choices of resource use
5	Ahmed et al.	2021	Faster RCNN	The Faster RCNN model achieved 96% accuracy	Monitors the social distancing between people effectively	This study is limited to top view dataset of human
6	Ansari and Singh	2021	Convolutiona l Neural	--	CNN based detectors of object denotes	This study is limited to the effect

			Network		promising results for supervising social distancing in public places	of Covid-19 with minimal damage to economic artifacts
7	Khamis and Samee	2021	Artificial Intelligence	--	Maintains distance among people to reduce virus exposure	This study is limited to artificial intelligence algorithm
8	Kumar et al.	2021	YOLOv3	--	Helps authorities to restructure the public places layout or take precautionary actions to resolve greater risk zones	This study is limited to people in real time
9	Mathurkar et al.	2021	YOLOv3 model	The model achieved 93.3% accuracy	Provides warning signals to handle social distance in this pandemic situation	This study focuses on regions where social distancing is not maintained and obtain SA for ROI in visual representation form through dashboard
10	Punn et al.	2021	Deep Learning and Deep sort method	The model achieved 78% detection accuracy	Monitors the social distance in real time	This study is limited to object detection models
11	Rahim et al.	2021	YOLOv4 model	The model achieved 97.84% detection accuracy	Provide an efficient social distancing monitoring solution in low light surroundings in COVID-19 situation	In this study the social distancing is supervised among people at fixed values of Cd
12	Shukla et al.	2021	Deep learning algorithm with YOLO model	--	Identify and estimate the distance between people in a frame	This study is limited to live images of CCTV cameras
13	Shalini et al.	2021	YOLOv3	--	Determine and find distance between people using pedestrian clusters by grabbing the video feed	This study is limited to deep learning and object detection model

The model developed by Hou et al. (2020) focused on examining the social distance between the pedestrians with YoloV3 model, where the model identified the distances fairly and needs further development for better accuracy. The study by Soures et al. (2020) developed a hybrid model named 'SIRNet' (epidemic + physical science + machine learning) to identify the social distances between people with Recurrent Neural Network (RNN) cells (Linear cells) + LSTM cells to identify the SEIR states (Suspected, Exposed, Infected and Recovered) of the individuals. Though the developed model is found effective, the model needs more sensitivity analysis towards refining the range-of-impact via various parameters. Ansari and Singh (2021) focused on convolutional neural networks based network with object detection algorithm to identify the human's social distancing during COVID-19. The results showed in public areas the model was efficient but the accuracy was not as expected and the model needs more training. The study concluded that using the Non-Maximum Suppression (NMS) algorithm in calculating the social distancing is feasible but however needs between people needs more training to overcome the overfitting problem.

Authors Khamis and Samee (2021) developed an artificial intelligence model with genetic neural network algorithm, to extract the features. The study concluded that the use of machine learning models to identify and classify the diseases during the COVID-19 aided the medical practitioners to affirm the diseases and control the spread by providing medication, that are faster than normal medical practice. Though the study concluded that the usage of machine learning models reduced the morbidity rate, the developed Genetic Neural Network model needs more training towards feature extraction to identify the diseases in individuals to attain higher accuracy (>90%). Study by Shukla et al. (2021) used the YOLO model with deep learning algorithm to identify the social distancing with parameters of violation like 6 feet between two people. The study concluded that, though the model was effective in identifying the distances, the drawback was the proposed system needs to be installed physically in the monitoring areas and it covers only the certain limited distance. Authors Kumar et al. (2021) developed a YOLOv3 algorithm based model to identify the distance among people in crowded areas. The developed model uses computer vision and concluded that computer vision is more accurate and efficient in identifying and estimating the distance between people than face detection and body temperatures. However, the study by Shalini et al. (2021) found that though machine learning models are effective and significance in object detection and tracking algorithms, the study concluded that, machine learning models with convolutional neural networks is also preferably better in classification algorithms. The deep learning with computer vision is identified to be more effective in the study but the developed model lacked in accuracy when the identification and classification of distances was applied in real-time. Thus through the rigorous reviews of the above studies, it is understandable that machine learning models are effective in social distancing estimation.

Machine Learning Models for Monitoring Usage of Face Mask

According to Almghraby and Elnady (2021) research a detector for face mask is proposed which supports healthcare for public people. This research uses MobileNetV2 architecture model which can manage both low and high processing loads of work. The main purpose of Basha et al. (2021) study develops a detector for face mask with Deep Learning, PyTorch and OpenCV models that helps to predict whether or not an individual wears face mask in public places during this COVID-19 situation. This study used a NN model named ResNet which is trained on dataset. Contrary to that Boulos (2021) establishes a NN system which can be trained to recognize facial characteristics of people while most of their faces are enclosed by face masks. The convolutional neural networks model is used in this study which has accomplished outstanding accuracy even the actual dataset is restricted. Boulila et al. (2021) is to utilize deep learning which shows outstanding outcomes in real life applications to assure effective real time detection of face mask. This study proposes MobileNetV2 to predict face mask in real time. Harshita et al. (2021) study proposes a method that uses the techniques of deep learning to supervise individual's activity assuring individual's safety in public areas. The major purpose of the study is to decide if an individual is wearing a mask and maintain social distancing as per guidelines and suggestions which are provided by governments and major scientists in this pandemic situation. The main purpose of Kulkarni and Suma (2021) study is to recognize whether an individual on video or image stream is to wear a face mask or not with the use of deep learning and computer vision. This study constructs a system for detection of face mask using many classifiers which is feasible on Convolutional Neural Network. Limbasiya and Raut (2021) proposed COVID-19 social distancing and face mask detector system which is a single stage detector comprising of ANN to combine greater level semantic data with numerous feature maps and a machine learning module to concentrate on finding social distancing and face mask simultaneously. The system can be used in any infrastructures which can be helpful to assure security and safety of people. According to the research of Mbunge et al. (2021) an extensive examination of AI models has been employed to predict face masks. This research showed that the models of deep learning accomplished 100 percent accuracy in predicting COVID-19 face masks. There is a requirement for sharing real-world face mask images of COVID-19 for modeling deep learning techniques. The study of Singh et al. (2021) proposed advanced detection methods for face masks using deep learning. Two state-of-art models of object detection namely FR-CNN and YOLOV3 is proposed to accomplish this model. This study compares both the model's performance with their inference time and rate of precision; however the study found that the usages of machine learning models vary according to the users where the impact of algorithms in computer vision impacts the model's performance and the efficiency. In the study of Taneja et al. (2021) a model is suggested and applied for detecting face that can find whether an individual is wearing mask or not accurately. MobileNetV2 is the architecture model used which is a lightweight convolutional neural networks that needs reduced power of computation and can be combined easily in mobile and computer vision systems. Similarly in the research of Tomas et al. (2021) an intelligent approach is proposed to detect when face masks are worn improperly in real time scenarios automatically. This study used Convolutional Neural Network with transfer learning to predict if the mask is used or not used but it also predicts mistakes that are not considered which may contribute to the spread of virus. The study of Teboulbi et al. (2021) presents an implementation of social distancing D and face mask detection framework as an embedded system for vision. This study offers a comparative research of varied face mask and face detection models of classification. The classification solution tracks people without or with masks in real time situation and assures social distancing by creating an alarm signal if there is damage in public places or scene.

Table 2 shows the reviews of machine learning models for monitoring usage of face mask.

Table 2. *Reviews of Machine Learning Models for Monitoring Usage of Face Mask*

S.No.	Author	Year	Model	Performance Evaluation	Findings	Drawback
1	Almghraby and Elnady	2021	Deep learning (MobileNet V2)	This study achieved 98% accuracy in validation	This model is efficient with resource when it comes to deployment which can be used for safety	This study has hardware barriers where the GPU takes huge amount of time and consumes huge amount of energy to train the model
2	Basha et al.	2021	ResNet	This study achieved 97% validation accuracy	Detects whether or not individuals wear face masks in public places which leads to their health and their contacts in this pandemic situation	This study is limited to CC camera footage at public areas
3	Boulos	2021	CNN	The model achieved 97.1% accuracy	Provides rapid and accurate results for face identification security systems	The actual dataset is limited in this study
4	Boulila et al.	2021	Deep learning	The proposed approach received 99% accuracy	Provides accurate face mask wearing detection and whether it is worn in real time or in a proper way	This study is limited to surveillance cameras in real world to verify if people are wearing masks and following norms properly
5	Harshita et al.	2021	Deep Learning CNN	This face mask wear condition achieved a healthy accuracy of 99.22%	Monitors individuals activity assuring individuals safety in public areas	This study is limited to public regions which is typical of supervision by closed circuit TV cameras
6	Kulkarni and Suma	2021	CNN	This study achieved 90% accuracy for training and 10% accuracy for testing the model	This model is successful in categorizing an individual in wearing a face mask or not and is capable to predict several people in a video frame	This study is carried out with limited set of data
7	Limbasiya and Raut	2021	Yolov3	The model used in this study achieved was between 85 % and 95%	The model is used to manage a secure surroundings and assures security of people by supervising public places automatically to avoid the spread of virus	This study uses only IP cameras and CCTV cameras to predict people without mask and violence of social distancing
8	Mbunge et al.	2021	Deep learning models	The study achieved 99.9% accuracy in finding COVID-19 face masks using Inceptionv3 CNN	This study detects face masks to assure adherence and compliance to covid-19 face masks	The datasets that are used to detect face masks are made artificial which do not indicate real world surroundings that influence the models precision accuracy when it is used in real world

9	Singh et al.	2021	R-CNN and YOLOV3	62% and 55% precision rates for YOLOv3 and FR-CNN, respectively	This study is used to supervise people wearing face masks in public places	This study comprises of people images of two types i.e., without and with face masks
10	Taneja et al.	2021	CNN	The model of face detector achieved greater accuracy of 99.8%	This study helps to recognize whether an individual is wearing a face mask or not properly and perform as a surveillance system as it performs for both real time videos and images	This study is limited to real time videos and images
11	Tomas et al.	2021	CNN	This study achieved 100% accuracy	This study have proposed an approach to predict when face masks are damaged in real time scenarios	The data sets on the status of wearing mask is usually small and it recognize only the existence of masks
12	Teboulbi et al.	2021	CNN	The system achieved an accuracy of 100%	Tracks people without or with masks in real time situation and assure social distancing by generating an alarm signal	This study is limited to CNN models

Machine Learning Models for Monitoring Hand Hygiene

The study of Yeung et al. (2016) developed a system which regularly checks on compliance of hand hygiene in hospital surroundings. This study proposes computer vision and an algorithm of machine learning using convolutional neural networks. This study handles with perception of depth and predicts if an individual is washing hands properly according to guidelines. The research of Ivanovs et al. (2020) et al proposed neural network which can be employed to build an application of mobile phone for real time feedback and automatic quality control for medical staffs. This research train the neural network on real world set of data with various movements of hand washing. Kim et al. (2020) proposed a wholly automated monitoring hand hygiene tool of hand rubbing action based on alcohol or video using spatio-temporal characteristics with three-dimensional convolutional neural networks. The convolutional neural network has increased the detection and identification of human actions. The main aim of Deshmukh et al. (2021) is to create a product which can be installed in different private and public places which predicts whether any people is following appropriate instructions of hand hygiene as mentioned by the World Health Organization. This study uses different models of convolutional neural networks to realize the appropriate method to acquire the best accuracy. The study of Lulla et al. (2021) presents a huge real world set of data with videos recording hand washing of medical staff as a part of their usual duties. This study explains how the information is used to train a machine learning classifier that accomplishes 75% accuracy of classification on test set of data.

Table 3 shows the reviews of machine learning models for monitoring hand hygiene.

Table 3. *Reviews of Machine Learning Models for monitoring hand hygiene*

S.No.	Author	Year	Model	Performance Evaluation	Findings	Drawback
1	Yeung et al.	2016	Convolutional Neural Networks	80.7% precision in identifying pose-based approaches in hand hygiene	It is essential to find the compliance of hand hygiene which is an essential factor of reducing the cost related with infections in hospital	It is not able to predict how the steps of hand hygiene is accurate or how long the individual is carrying out the task
2	Ivanovs et al.	2020	Neural Network	This study achieved greater than 64% accuracy in identifying varied movements of hand wash	Mobile phone application is constructed to enhance real time feedback and automatic quality control for medical staffs	This study train the neural network using 2000+ real world dataset
3	Kim et al.	2020	Convolutional Neural Network	This study achieved 76% accuracy	Monitors hand hygiene by reducing the infection outbreak in hospitals	This study experimented that from kinetics-400 transfer learning is advantageous whereas the stream of optical flow was not useful in dataset
4	Deshmukh et al.	2021	Convolutional Neural Network	This study achieved an accuracy of 77.24%	Proper hand wash is undertaken and people are motivated to manage hand hygiene accurately	This study is tested using 32471 annotated videos dataset for the need of categorizing the steps carried out by a user during washing hands
5	Lulla et al.	2021	MobileNetV2	This study achieved 75% classification accuracy	Enhances real world washing quality carried out by medical staff	This study is limited to 3185 episodes of hand washing which is annotated up-to 7 varied individuals

Challenges and Future Directions

Most of machine learning approaches depend on large-scale data for training like medical imaging, image sources and other medical applications. Due to the rapid increase of corona-virus, appropriate and valid datasets are not sufficient for accessing machine learning approaches (Mondal et al. 2021). Publicly accessible datasets adopted in various machine learning approaches are collected from sources of medical image like medical institutions and hospitals where it is difficult to pursue exclusion and inclusion criteria of COVID-19 like asymptomatic vs. symptomatic COVID-19 cases at which such images were considered. Due to large amounts of misleading reports and audio materials related to COVID-19 are recorded on different online sites. Processing of machine learning based algorithms will be slow when filtering erroneous information and audio (Pi 2021). It is complicated to work with incorrect and unclear data in descriptions of text. Huge amount of data from different sources might be false (Onyema et al. 2022). Therefore, extra information makes it difficult in exacting meaningful data.

The outbreak of COVID-19 virus has influenced the security and safety of people all around the globe. This virus has become a threat which spread all over the globe influencing millions of people's lives. The outbreak has a profound influence on people's wellbeing globally and the number of diseases associated deaths continues to develop worldwide. This pandemic situation requires immediate precautions and measures to avoid its worldwide impacts. Along with clinical treatment and methods the latest technology has assisted to manage deadly diseases earlier. From several years ago researchers, scientist, healthcare experts and doctors are using the latest computer techniques to resolve the criticality of disease (Sarker 2021). Technology is developing continuously with huge success particularly in the sector of deep learning and machine learning. Though the technology has been dwelling into daily lives of people with huge success particularly in deep learning and machine learning, a new paradigm Artificial Intelligence has become essential in healthcare sector (Silahtaroğlu and Yılmaztürk 2021). Artificial intelligence has assisted people in the critical battle against COVID-19 virus. Machine learning is one such way to offer essential solutions driven by data to support humanity to manage with COVID-19 virus. Machine learning has been used in assisting people to combat against COVID-19 virus. To manage COVID-19 the data driven solutions are promised to support humanity (Fink et al. 2020). A brief overview of Machine learning algorithms was discussed in this review for predicting social distancing, monitoring face mask and hand hygiene. Different unsupervised and supervised machine learning algorithms were discussed briefly and their uses in combating COVID-19 virus was also discussed with different datasets. The machine learning solutions performs well while finding the COVID-19 disease cases (Ibrahim and Abdulazeez 2021). The worldwide pandemic of COVID-19 virus has become the major security problem for several nations. The growth of accurate machine learning solutions for the outbreak of COVID-19 disease is important to offer insights into the consequences and spread of this deadly disease. Humans are facing the most difficult times presently. People are made to stay at home, cities are closed, the stock market is declining whereas nurses and doctors are busy in assisting patients affected with COVID-19 virus and police and soldiers are busy in guarding people to lock down at their homes safely to prevent them from this COVID-19 virus (Kalkman 2021). This review estimated the applicability of machine learning models for finding the outbreak of COVID-19 virus. World Health Organization and medical experts are providing essential guidelines to people to secure themselves from this deadly virus. A centralized set of global COVID-19 patient information will be advantageous for future machine learning and AI research to evolve diagnostic, therapeutic and predictive solutions against COVID-19 virus and relevant pandemic situation in future. This study could be further extended by collecting real time data and developing an advanced machine learning model using deep neural networks. The developed model could be trained using real time dataset and the performance of the model could be tested appropriate parameters in the future.

Machine learning approaches could be improvised for future for combating COVID-19 in these ways machine learning based approaches could be adopted for discovering viral components and protein composition using exact analysis of biomedical expertise like genetic sequences, viral trajectories and main protein structures. They are adopted for discovering vaccines and medications as well as simulating vaccine-receptor and drug-protein interactions, forecasting future vaccine and drug reactions for individuals with different symptoms related to COVID-19. By expanding knowledge graphs and social networks, machine learning approaches could identify and track the people characteristics near COVID-19 patients, efficiently predicts and tracks the likely spread of disease.

According to World Health Organization's report, post vaccinations and COVID-19 preventions in many countries, the death rates have been rapidly decreasing, which is fortunately a positive sign. However, in countries like Peru, China, Bulgaria, Georgia, Hungary, UK, Italy, and more the death rates of COVID-19 is still growing despite the measures and prevention techniques. Contrarily in countries like North Korea, Nigeria, Tanzania, Bhutan, Tajikistan, Macao, and more the death rates have packed down. This shows that, the countries that followed the preventive measures flattened the spreading of disease and decreased the morbidity rate and thus bought down their country's mortality rate. Usage of machine learning models to identify the preventive measures to classify the individuals is thus found to be efficient and effective than human intervention, when the target population is huge/unknown.

Conclusion

The current paper has reviewed in detail about several research works done by recent researchers on how machine learning as a technique could be applied for monitoring adherence of COVID-19 guidelines by the people. Different types of applications like social distance prediction, hand hygiene detection; mask prediction has been illustrated by the researchers of the past through machine learning techniques. Thus, it can be concluded that machine learning is suggested as an efficient tool to resolve the present pandemic situation and win against the battle of COVID-19 virus. If this opportunity is taken to gather data, integrate skills and pool knowledge several lives of people can be saved now and in future. From findings, it is concluded that for identifying the social distancing between people the machine learning L model with genetic neural network algorithm and AI algorithm is effective with higher accuracy of 99%. Similarly, the identification and classification of inputs (images/videos) to categorize with and without face masks the machine learning models convolutional neural network model with deep learning is found to be feasible, efficient, and reliable than other neural network models with minimum of 98% accuracy. Lastly, among the hand hygiene identification and classification machine learning models, the deep learning model was found effective with 100% accuracy. Thus, it is established through the analyses that deep learning and artificial intelligence models are far effective and accurate in identifying and classifying inputs, when combined with computer vision algorithms.

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