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Front Pages

Athens Journal of Technology & Engineering

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The current issue is the fourth 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.

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A World Association of Academics and Researchers

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- Acceptance of Abstract: 4 Weeks after Submission
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- Submission of Paper: **27 May 2024**

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 Necessity of Developing Soft Skills in STEM Areas in Higher Education, with Special Focus on Engineering Training

By Ildikó Holik[*]*, István Dániel Sanda*[±] *& György Molnár*[°]

One of the challenges of higher education today is to prepare students for the demands of the labour market. A goal becoming ever more important is that, in addition to the so-called hard skills (knowledge obtained from textbooks), the development of soft skills (inter- and intrapersonal skills) also be emphasised. It is a particularly important question in the field of STEM (science, technology, engineering, mathematics), and especially in engineering education, which abilities and skills are essential for new graduates on the labour market. The aim of our questionnaire survey, conducted in 2022, was to map the specifics of soft skills among engineering students. A total of 208 engineering students filled in our online questionnaire. We examined the characteristics of soft skills based on a list of 39 items. The 5 soft skills considered most important were problem-solving, reliability, resilience, communication and independent work. Students regarded themselves as most characterized by reliability, problem solving, independent work, responsibility and cooperation. Our research results drew attention to the importance of developing soft skills, especially social skills.

Keywords: *STEM, soft skills, social skills development*

Introduction

Since there is an increasing demand on the labour market for employees to possess several soft skills (Deming 2017), one of the objectives of today's higher education is to emphasize the development of inter- and intra-disciplinary skills in addition to high-level professional knowledge (hard skills) (Holik and Sanda 2021).

In the field of STEM (science, technology, engineering, mathematics) (Boon 2019), and especially in engineering education, a particularly important question arises as to which abilities and skills are absolutely necessary on the labour market (Kersánszki and Nádai 2020, Molnár 2022, Molnár et al. 2022). Research results draw attention to the fact that newly graduated engineers must meet the requirements in many areas: in addition to professional knowledge, they are expected to be flexible, communicative, open, creative, able to adapt to changes aswell as cooperate with their colleagues (Kolmos 2006, Lappalainen 2009, Williamson et al. 2013).

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Our study discusses the need to develop soft skills in STEM fields, primarily in relation to engineering education. Based on the results of a questionnaire survey of 208 engineering students, it gives suggestions as to which soft skills are absolutely necessary to develop in higher education.

Literature Review

The definition of soft skills is diverse in the pedagogical literature. Among the various approaches and grouping options, only a few are presented below.

Soft skills are often defined in terms of "those skills, abilities, and personal attributes that can be used within the wide range of working environments that graduates operate in throughout their lives" (Fraser 2001, p. 1).

These intra- and interpersonal skills are used in everyday life: at work, at school, in our relationships, for example, when we communicate with each other, when we resolve conflicts, when we work in groups or when we solve different problems.

Soft skills are different from hard skills, i.e. measurable knowledge that can be acquired from textbooks at school. In higher education, soft and hard skills are equally important; they complement each other and their synergy makes the teaching-learning processes more efficient.

Chamorro-Premuzic et al. (2010) 15 identified a system of soft skills comprising 15 components: "self-management, communicational, interpersonal, team-working skills, the ability to work under pressure, imagination/creativity, critical thinking, willingness to learn, attention to detail, taking responsibility, planning and organising skills, insight, maturity, professionalism and emotional intelligence." (Chamorro-Premuzic et al. 2010, p. 223).

The result of a competency survey with the participation of OECD countries is a list containing a total of 23 competencies, organized into three groups, which are characteristic of employees who can ensure future competitiveness within an organization:

- *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 (OECD 2001).

The reports of the World Economic Forum draw attention to the fact that the skills required and preferred by the labour market are constantly changing. Based on the ranking of the 2020 report, the following skills will be the most important in the labour market in 2025 (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

Lippmann et al. (2015) highlight the following five skills which are expected by employers and which enhance the success of employees: (1) social skills; (2) communication; (3) higher-order thinking skills (including problem solving, critical thinking, decision-making); (4) self-control; (5) positive self-image.

In Silva's study (2009), it is formulated as a labour market expectation that students and employees should be independent thinkers, problem solvers and decision makers. Therefore, education must not only provide basic professional knowledge, but also important thinking and reasoning skills.

A further challenge posed by our modern, information-based society is for employees to be able "to find and analyse information, often coming from multiple sources, and use this information to make decisions and create new ideas" (Silva 2009, p. 631).

Robles (2012) asked company leaders to list the soft skills they expect from new employees. Those considered the most important were the following: "integrity, communication, courtesy, responsibility, interpersonal skills, professionalism, positive attitude, teamwork skills, flexibility, and work ethic" (Robles 2012, p. 453).

Soft skills can also play an important role on the labour market from an economic aspect. In his study, Balcar points out "that soft skills are statistically significant determinants of an individual's wage and contribute to closing the gender wage gap" (Balcar 2014, p. 3).

Studying the labour market situation in the United States between 1980 and 2012, Deming (2017) found that social skills are increasingly recognized. "Employment and wage growth were particularly strong for jobs requiring high levels of both math skill and social skills" (Deming 2017, p. 1593). His study emphasises that "high-paying jobs increasingly require social skills" (Deming 2017, p. 1595).

In engineering education, it is also an important question what abilities and skills are necessary on the labour market (Kolmos 2006, Markes 2006, Van der Molen et al. 2007, Conlon 2008, Lappalainen 2009, Williamson et al. 2013).

At the international level, it is a fundamental problem that engineering education primarily focuses on the development of professional competencies and technical skills, and does not adequately prepare students for the challenges of the labour market and the demands of the workplace (Schomburg 2007). The feedback received from employers highlights a number of shortcomings in terms of the preparation of young engineers. The lack of social, communicative and personal competences poses a serious problem (Schomburg 2007), and the appropriate development of interpersonal skills would be of paramount importance for the effectiveness of engineering work (Direito et al. 2012, Berglund and Heintz 2014).

Several studies emphasize that, as a result of technical changes, the "traditional ways" of engineering education must be reconsidered and competences that meet the expectations of the labour market must be developed (Direito et al. 2012).

Some literature sources also draw attention to the fact that personality traits play an important role as they are considered key factors in engineering work in terms of work capacity and job satisfaction. In their research, Williamson et al. (2013) concluded that the examined engineers differ from members of other occupations in that they have more internal motivation and are more persistent; however, they are less confident, less conscientious, less extroverted, not particularly emotionally stable and not as optimistic as their peers.

Other studies (Lappalainen 2009, Direito et al. 2012) also draw attention to the shortcomings of engineers, i.e., that they have problems with effective communication, cooperation with others, teamwork, project management and lifelong learning.

In their research among university students, Rasoal et al. (2012) found that engineering students had a significantly lower level of empathy than psychology and social work majors. The researchers also found differences among different groups of engineering students: applied physics students achieved worse results than IT engineering students. These research results also drew attention to the need to develop empathy.

In their study, Berglund and Heintz (2014) emphasize the importance of collaboration in engineering work. They highlight the fact that project-based learning implemented in a real workplace environment develops abilities and skills (such as teamwork, communication, problem solving and conflict management) that facilitate the students' future employment.

Schulz (2008) also draws attention to the importance of soft skills and emphasizes the opportunities of skills development. He stresses that personality development plays an important role in university education in addition to academic and technical knowledge. Therefore, he recommends the inclusion of the development of soft skills (e.g. management skills, communication skills, conflict management) in the curriculum.

He emphasizes the responsibility of university lecturers in this regard, and considers it important that they draw their students' attention to the relevance of developing soft skills and to the consequences of various deficiencies. He also recommends informal development opportunities to students, e.g. reading dedicated books, attending courses, and joining clubs or societies to broaden their

horizon, such as debating societies or scientific societies that offer presentations and discussions.

Seetha's study points out that "employers prefer to hire and promote those persons who are resourceful, ethical and self-directed with good soft skills" (Seetha 2013, p. 171).

Audibert and James are of a similar opinion: "soft skills such as leadership, communication, teambuilding and entrepreneurial interest have become critical for hiring and promoting employees to keep positions" (Audibert and James 2002, p. 72).

The development of soft skills is not supported by higher education institutions that are dominated by "traditional", i.e., frontal and knowledge-centred education, which works better in homogeneous groups, where the students' pace of work, way of thinking and knowledge level are almost the same. The drawbacks of the frontal work method are that it cannot take into account students' individual abilities and skills, it is not interactive, and therefore it is less suitable for the development of many skills.

In technical higher education, the psychological order of cognition plays a prominent role: sensing, perception, attention, memory, imagination and thinking. Often, however, due to the lack of time, human resources or tools, the greatest emphasis is placed on attention and memory, leaving no time or opportunity to deepen the course material with more complex cognitive operations, such as thinking, which would later be fundamentally important in engineering work.

There are a number of student-centred methods suitable for the development of soft skills, for example, problem-based, cooperative and collaborative methods, as well as gamification, using today's technical achievements. The application of cooperative learning techniques and courses aimed at developing social skills (Holik and Sanda 2020) have a positive effect on cooperation at work and personal relationships (Smith et al. 2005).

In a survey conducted among university students in 2021, two-thirds of respondents felt that the teaching method using gamification enhanced the examined soft skills (information processing, knowledge acquisition and learning skills, thinking, logical and problem-solving skills, communication and presentation skills, cooperation and conflict management skills) to a greater extent than the traditional method based on frontal work that had been used before (Módné Takács et al. 2022).

The development of soft skills has a strong influence on that of hard skills, too, because it is much easier to improve students' thinking skills if they are emotionally balanced and have healthy personalities.

Methodology

The aim of our online questionnaire survey conducted in 2022 was to map the characteristics of soft skills among engineering students at a Hungarian university. Our study was based on the following questions:

- How important do the responding university students regard hard and soft skills with respect to being successful in the world of work?
- Which soft skills do they consider the most important for their success at work?
- To what extent are students characterized by different non-professional skills?

Based on literature sources and our own educational experience, the following hypotheses were formulated:

1. Respondents would emphasize the labour market expectations for problem-solving, practical engineers.
2. The development of stress management and communication skills is highly necessary in higher education.
3. The questionnaire contained both open and closed questions. A 6-point Likert scale was used to examine soft skills.

Characteristics of the Research Sample

Our online questionnaire was primarily sent to university students studying in technical and economic fields within one institution. It was filled in by 208 students altogether, 24.8% of whom were female and 75.2% male (N=202).

Their average age is 27.62 years (N=197). The youngest respondent is 19 and the oldest is 56 years old. 1.5% are under 20 years, 68.5% are 20-29 years old, 19.8% are 30-39 years old, 8.1% are 40-49 years old, and 2% are 50-59 years old.

7.2% of respondents attend higher vocational education, 73.4% attend bachelor's education (BSc), 10.1% attend master's education (MSc), 1.9% attend doctoral education, 5.8% attend specialized further education and 1.5% indicated other training (e.g., BProf – Bachelor of Profession) (N=207).

24% are in IT, 23.1% in electrical engineering, 20.2% in mechanical and safety engineering, 10.6% in construction science, 9.1% in economics and 5.8% in light industry and environmental engineering. 5.8% of them are studying at a technical faculty and 1.5% are studying at a doctoral school (N=208).

57.7% of them participate in full-time, 36.1% in correspondence, 4.8% evening and 1.4% in distance education (N=208).

70.2% of them study in state-financed and 29.8% in self-funded training (N=208).

The respondents have significant work experience: 44.2% work full-time, 18.8% part-time, 13.4% work in other forms (student work, casual work, self-employed, trainee, within the framework of dual training). Only 23.6% do not work alongside their studies (N=208). 93.3% of non-working students are taking part in a BSc training (p=0.000 based on the Chi-square test on the data); 95.7% of them are in their twenties (p=0.000) and all of them are studying full-time (p=0.000).

Results

Based on a list of 39 items, we examined the characteristics of soft skills as to how important they are for workplace success and to what extent students are characterized by various non-professional skills. The list was compiled on the basis of job advertisements and literature sources (Holik 2019, Roberts et al. 2015). The respondents evaluated each soft skill on a 6-point scale.

The reliability of the measuring tool proved to be excellent (Cronbach's alpha values for the lists were 0.949 and 0.925, respectively).

Responding students regard problem-solving skills as the most important (mean: 5.53). This result confirmed our first hypothesis. Reliability (mean: 5.38), communication skills (mean: 5.28) and resilience, i.e., flexibility, ability to cope (mean: 5.28) are thought to be very important on the labour market. Generosity is believed to be the least necessary (mean: 3.11).

The importance of problem-solving skills on the labour market was also highlighted by a previous research conducted among IT engineering students (Holik 2019).

According to their own assessment, the respondents in this research are most characterized by honesty (mean: 5.50), reliability (mean: 5.38) and problem-solving skills (mean: 5.34). They are least characterised by self-assertion (mean: 3.75), again, according to their assessment of themselves. The surveyed university students also indicated a lack of self-confidence (mean: 4.06) and lack of leadership skills (mean: 4.20).

The biggest gap between the skills required in the world of work and the current skills of our surveyed students were in self-confidence, communication, stress tolerance, self-assertion and resilience. These are the areas in which development is the most necessary. This result verified our second hypothesis. A previous research conducted among engineering students also pointed to the necessity and possibilities of developing communication skills (Holik and Sanda 2020).

However, there are certain areas that the respondents believe to be much better at than is required on the labour market, for example, generosity, honesty and benevolence.

Table 1. *Means, Standard Deviations (SD) and Differences between the perceived Importance and Self-reported Proficiency Level of Competencies (N=208)*

	Importance		Own level		Difference	Wilcoxon test	
	Mean	SD	Mean	SD		Z score	sign.
Reliability	5.38	0.862	5.38	0.903	0	-0.494	0.621
Cooperation	5.11	0.966	5.13	1.055	-0.02	-0.172	0.863
Self-confidence	4.89	1.037	4.06	1.325	0.83	-7.052	0.000
Creativity	4.63	1.097	4.73	1.240	-0.1	-0.656	0.512
Self-assertion	4.06	1.312	3.75	1.472	0.31	-3.044	0.002
Character stability	4.30	1.208	4.73	1.336	-0.43	-4.063	0.000
Collegiality	4.38	1.182	5.02	1.582	-0.64	-3.473	0.001
Stress tolerance	5.16	0.994	4.52	1.332	0.64	-6.282	0.000
Curiosity	4.37	1.273	5.13	1.165	-0.76	-6.149	0.000
Cheerfulness	4.19	1.248	4.64	1.375	-0.45	-3.366	0.001
Orderliness	4.40	1.205	4.35	1.362	0.05	-1.132	0.258
Generosity	3.11	1.270	4.46	1.551	-1.35	-8.399	0.000
Moderation	3.62	1.271	4.33	1.512	-0.71	-4.853	0.000
Global awareness	3.96	1.561	4.73	1.650	-0.77	-4.805	0.000
Communication	5.28	0.873	4.49	1.511	0.79	-6.792	0.000
Persistence	3.96	1.322	4.74	1.876	-0.78	-3.196	0.001
Honesty	4.30	1.456	5.32	0.999	-1.02	-7.868	0.000
Resilience	5.28	0.908	4.99	1.208	0.29	-4.449	0.000
Positive thinking	4.38	1.286	4.50	1.324	-0.12	-0.211	0.833
Friendliness	4.36	1.192	5.10	1.043	-0.74	-6.664	0.000
Planning	4.62	1.149	4.62	1.245	0	-0.636	0.525
Integrity	4.36	1.466	5.50	0.994	-1.14	-7.966	0.000
Self-Consciousness	4.62	1.144	4.99	1.253	-0.37	-2.706	0.007
Imagination	4.20	1.305	4.75	1.280	-055	-4.279	0.000
Leadership	4.21	1.308	4.20	1.716	0.01	-1.188	0.235
Punctuality	5.00	1.050	4.81	1.277	0.19	-3.173	0.002
Benevolence	4.14	1.350	5.26	1.047	-1.12	-8.232	0.000
Self-respect	4.43	1.331	4.40	1.555	0.03	-1.271	0.204
Innovation	4.71	1.185	4.84	1.302	-0.13	-0.150	0.881
Dynamism	4.65	1.091	4.92	1.532	-0.27	-3.41	0.733
Responsibility	4.94	1.178	5.30	1.107	-0.36	-2.478	0.013
Authenticity	4.87	1.269	5.28	1.132	-0.41	-2.582	0.010
Self-control	4.77	1.164	4.85	1.233	-0.08	-0.510	0.610
Tolerance	4.58	1.221	4.79	1.267	-0.21	-0.984	0.325
Empathy	4.20	1.328	4.89	1.435	-069	-5.058	0.000
Self-knowledge	4.65	1.219	4.67	1.390	-0.02	-0.956	0.339
Openness	4.73	1.152	4.95	1.273	-0.22	-1.249	0.212
Problem-solving	5.53	0.776	5.34	1.080	0.19	-3.822	0.000
Independent work	5.26	1.030	5.31	1.101	-0.05	-0.877	0.380

Closer relationships between the data were examined using correlation analysis. The closest correlation of the soft skills characterising students is between empathy and tolerance (Spearmann correlation, r=0.622, p=0.000), positive thinking and cheerfulness (r=0.613, p=0.000) and benevolence and empathy (r=0.599, p=0.000).

Open-ended questions were used to reveal which soft skills the respondents owed their success to – according to their own judgment. The majority believe that they owe their success to their communication and problem-solving skills.

Table 2. *Soft Skills to which Respondents owe their Success (N=46)*

Which is the most important non-professional skill (soft skill) to which you owe your success?	**Frequency**
Communication	34
Problem solving	20
Co-operation	10
Creativity	6
Persistence	6
Teamwork	5
Diligence	5
Empathy	4
Openness	4
Kindness	3
Motivation	3

We also used an open question to examine which soft skills the students feel most lacking during their university studies. In the table below, we noted the soft skills that were mentioned by at least three respondents. Based on the data received, we found that most people feel a lack of communication during their university studies. It is important to pay attention to these areas in higher education, since students often drop out because they cannot manage their time, cannot cooperate and communicate with each other, and the flow of information is not adequate.

Table 3. *Soft Skills the Lack of which Students feel most during their University Studies (N=78)*

Which is the most important non-professional skill (soft skill) the lack of which you felt most during your university career?	**Frequency**
Communication	25
Creativity	7
Co-operation	5
Time management	5
Self-confidence	4
Empathy	4
Openness	3
Teamwork	3

The responding students could indicate which fields they would like to study during their university years. They could choose a maximum of three items from a list of 11 fields. They would most like to learn negotiation and reasoning techniques, time management, stress management and communication skills.

Table 4. *Fields that Students would like to Study (N=197) (Respondents could choose a Maximum of Three Options)*

What would you like to study at university?	Frequency
Negotiation and reasoning techniques	82
Time management	61
Stress management	58
Communication	53
Self-knowledge, self-assertion	49
Life path and career building	49
Conflict management	46
Leadership skills	46
Study skills	38
Labour market knowledge and job search techniques	25
Strategic and project management	25

By exploring the significant relationships with the background variables, we found that a higher proportion of female respondents would like to learn conflict management (34%) than males (19.7%) (Chi-square test, p=0.039). Likewise, more women (44%) wish to learn self-knowledge and self-assertion than men (18.4%) (p=0.000). On the other hand, men would rather learn leadership skills (27.2%); for women, this rate is only 12% (p=0.028).

Students who rated their communication skills low show a high willingness to take a communication course (p=0.001). The reality of this demand is proven by the fact that our K-MOOC (Carpathian Basin Online) course entitled "Communication in Social Relationships" was taken by 224 students in the fall semester of the 2022/2023 academic year.

Areas of Soft Skills Development

In the following, we provide some suggestions on the possibilities of developing students' soft skills within a university setting.

Negotiation and Reasoning Techniques

We consider it important that students learn different negotiation and reasoning techniques; become familiar with the characteristics of negotiation, its three dimensions (content, process, relationship), and its three-stage model (opening, discovery, closing); with different negotiation types (competitive, cooperative); negotiation styles (gentle, tough, principled) and strategies (competitive, problem-solving, compromise-seeking, avoidant, adaptive); with different negotiation problems; with factors influencing the negotiation, and with the role of verbal and non-verbal communication. Students will acquire the cooperative negotiation model; get to know the types of debate: quarrel, court trial, rational debate; the characteristics of effective reasoning, deductive and inductive arguments; the rules of rational debate, and the typical errors in argumentation. They will experience case studies, video analyses and role-play.

Time Management

The time factor is one of the biggest issues in the lives of university students. They must learn to manage their time. The university can help with this. It is important for students to learn techniques for the more efficient use of time and for the organization of their responsibilities; the elements, possibilities and hindering factors of effective time management; scheduling; establishing time balance during their studies, at work and in private life. Various training methods can contribute to this: problem solutions, situational exercises, knowledge-enhancing presentations, worksheets, topic elaborations, situational role-plays, tests, videos, etc.

Stress Management

Stress is increasingly present in the lives of university students as well. It is also possible to teach stress management procedures and develop stress tolerance within the university setting, thus reducing stress and creating a work-life balance. It is essential that students learn about potential stressors at work as well as in their private life; stress reactions and stress management habits; the effects of stress, along with effective procedures and methods for stress reduction (time management, procrastination management, lifestyle, coping strategies and relaxation techniques).

Communication

Both verbal and non-verbal communication must be emphasized in communication courses. Within verbal communication, prominent roles are played by lecturing, explanation and discussion, along with questioning techniques, debate and reasoning. Non-verbal communication includes body movement or kinesics, physical characteristics, contact behaviour, paralanguage (sounds accompanying speech), preparations, the environment, proxemics (spatial relations), chronemics (timing). It is important to examine the factors determining the effectiveness of communication, as well as the characteristics of communication in each communication arena.

Assertive communication is also increasingly important in terms of success at work. In the practical classes following the lectures, our students learn the eight communication steps of assertive behaviour. Furthermore, the course also includes visual communication and illustration, as well as changes in communication due to technical development.

Self-Knowledge, Self-Assertion

Defining and getting to know oneself is important, therefore self-identity, realistic self-evaluation, correct self-knowledge, self-identity, and self-attributions come to the fore during development. Objective self-awareness, the components of human emotions, and the interpretation of one's own and other people's

behaviour play a key role. It is essential that students learn the difference between extroversion and introversion, and that the accuracy of person perception, judgments of person perception, and the perception of personality traits come to the fore.

Stereotyping, the halo effect, covert personality theories, person perception and personality types, person prototypes, the formation of impressions and the creation of a "good impression" should also play an important role in the training. The search for the cause of the behaviour, attribution, attribution of responsibility, self-serving biases and the characteristics of personal relationships are also important. In the practical classes – in the framework of small group sessions – students analyse the variants of self-esteem, attraction, social influence, self-discovery, and conformity in situational situations.

Life Path and Career Building

Career building requires a great deal of self-knowledge. To this end, it is important that students be aware of their strengths and weaknesses (e.g., language skills, numeracy skills, negotiation skills, presentation skills, writing skills, creativity, leadership and organizational skills, problem-solving skills, conflict management skills, time management skills) as well as their personality traits (e.g., extrovert or introvert). In life and career planning, students must be aware of their own internal resources and external factors, their motivation and goals. It is important that students learn about the different career periods, the axioms of career philosophy, different career opportunities, and set realistic goals for themselves.

Conflict Management

Students' lives are accompanied by several conflicts. During their university studies, they can learn how to handle these situations. We consider it necessary for students to become familiar with the characteristics, types, and causes of conflicts, as well as methods of conflict management (using power, authority, leniency or the no-defeat method). They learn the techniques of conflict management (avoidance, independent decision, negotiation, mediation, involvement of an arbitrator, legal action), conflict resolution styles (competition, avoidance, problem solving, adaptation, compromise), constructive conflict management, and the possibilities of building better human and professional relationships. Analyses of case studies, trainings and role-plays in the framework of small group sessions can help understand the games behind the conflicts and arrive at satisfactory solutions.

Leadership Skills

Since some of our graduates will later acquire management positions, they must be prepared for this role during their university studies. In this area, leadership and leadership styles (autocratic, democratic, laissez faire) come to the fore. During the trainings, emphasis is placed on the leader's emotional stability,

belonging to the group(s) and interactions in the given group, the stages of group development, intergroup conflicts, and the concepts and phenomena of cooperation. Group decision and "group thinking", the issue of role conflict, polarization effects in the group, roles, compliance, prejudices, common stereotypes and the biased personality are key concepts during development.

Study Skills

Study skills enhance to the students' ability to complete their university studies more successfully and effectively. It is important that they get from mastering simple studying habits and techniques through trying efficient and effective studying methods to building a consciously designed studying strategy. Their university education can contribute to finding and applying the most effective, personalized learning methods and developing their own learning styles. From a methodological point of view, it is important to use mind maps, learn speed-reading techniques, raise the level of awareness through metacognition, develop self-motivation, self-regulated learning, learn cooperative learning techniques and explore learning difficulties. These techniques contribute to students' academic success by increasing the efficiency of exam preparations.

Labour Market Knowledge and Job-Searching Techniques

University education can prepare students for the challenges of the labour market. It is important for students to get to know the characteristics of the labour market, where practicality is expected in contrast to the theoretical predominance of university education. Furthermore, students must gain an insight into the different job opportunities and the challenges that arise there. Our courses can also help students learn to write a resume and cover letter, and prepare for a job interview by practicing a situation that is still unknown to them. The graphological analysis of handwritten resumes and motivation letters also provides personal lessons for the given student.

Strategic and Project Management

We believe it is important that university studies also focus on strategic and project management, as it is possible that graduates will work in projects on the labour market and later hold managerial positions. It is necessary for them to learn the concept and characteristics of projects, the actors involved in the project, the organizational forms of the project, the characteristics and efficiency factors of teamwork, the methodology of project analysis and project planning (problem analysis, definition of goals, SWOT analysis, Gannt diagram, cost planning, risk analysis), project management functions and areas, project cycle management, project management characteristics and documents.

Conclusions

In the labour market, there is an increasing demand for employees to have a number of soft skills in addition to hard skills. Therefore, in response to the needs of the labour market, one of the objectives of higher education is to prioritize the development of inter- and intra-disciplinary skills in addition to high-level theoretical and professional knowledge. In our paper, we study the STEM field, and within it the situation of engineering education, as to what abilities and skills are essential for engineering students or newly graduated engineers on the labour market. Based on the results of a questionnaire surveying 208 engineering students, we examined which soft skills are absolutely necessary to develop in higher education.

One of our research results is that the respondents emphasize the labour market expectations for problem-solving, practical engineers. From the data obtained, it is clear that the development of stress management and communication skills is particularly necessary in higher education.

Our research results draw attention to the importance of social skills and, in particular, of personality development. In engineering education, we promote the development of soft skills by courses that provide opportunities for cooperation, open and honest communication and the development of empathy in small groups, which contribute to the development of a positive self-image and realistic self-evaluation.

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A Data Streaming Architecture for Air Quality Monitoring in Smart Cities

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This paper aims to present a modeling approach for the seamless data streaming process from smart IoT systems to Apache Kafka, leveraging the MQTT protocol. The paper begins by discussing the concept of real-time data streaming, emphasizing the need to transfer data from IoT/edge devices and sensors to Apache Kafka in a timely manner. The second part consists of a literature overview that shows the analysis and systematization of different types of architectures in the broad sense of crowdsensing, followed by specific architectures regarding edge and cloud computing. The methodology section will propose an infrastructure and data streaming architecture for smart environment services, such as air quality monitoring. Lastly, a discussion about results and future development will be shown in the last two sections. The proposed integration approach offers several advantages, including efficient and scalable data streaming, real-time analytics, and enhanced data processing capabilities.

Keywords: *real-time data streaming, smart healthcare, Apache Kafka, data integration, stream processing*

Introduction

Efficient message distribution systems have gained significant attention in recent years, as they contribute to optimizing architectural frameworks. These optimizations became a necessity having in mind that the Internet of Things (IoT) paradigm, a leader in Industry 4.0, increased the number of devices connected to the Internet (Akbar et al. 2017, Froiz-Míguez et al. 2018, Khriji et al. 2022), creating a climate for the successful development of numerous services in the domain of smart cities (Cheng et al. 2018, Khriji et al. 2022, Samizadeh Nikoui et al. 2021). Moreover, nearly all services of smart cities are in demand for ultralow latency and fast response time, further proving the need for efficient message distribution systems.

Different architectures require different approaches in the modelling and development of message distribution systems:

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- (Hugo et al. 2020) propose the use of Apache Kafka as a centralized message distribution system to streamline the architecture of monolithic applications.
- (Fridelin Panduman et al. 2019) also propose the use of Apache Kafka server, alongside MQTT protocol, for SEMAR (Smart Environment Monitoring and Analytics in Real-time), a cloud computing platform based on microservice architecture.
- (Khriji et al. 2022) proposed AWS (Amazon Web Services) cloud-based architecture with AWS message broker - REDA (Real-time Event-Driven Architecture).

Smart city services are relying on infrastructures based on IoT, edge, and cloud computing technologies, whose interoperability requires an efficient message distribution system. This paper proposes a methodology that enables continuous monitoring and collection of air quality data in real-time, from sensors deployed at different locations in smart cities. The methodology introduces a two-layer architecture: Edge – air quality data collection, and Cloud – receiving and processing data in a stream.

This paper is organized as follows. Next section presents a review of relevant literature related to smart city IoT architectures and data processing. Then comes the methodology and design of the proposed data streaming architecture. While insights about the implementation and discussion about results are provided afterwards and finally the paper is concluded with a discussion of the applicability of the proposed architecture and future development.

Literature Review

Based on the rapid growth and complex requests of modern systems, for cloud and edge computing it is important to study different methods and architectures which have proven to be successful. This analysis will allow us to better understand best practices and address the challenges that bring us this dynamic field of computing.

Edge computing is a decentralized computing infrastructure that allows remote devices to process data closer to the edge of the network, near the source (Mitrović et al. 2023). Several analyses have been conducted on an edge computing platform that proves edge computing is a good solution for cooperation with cloud, network communication, and edge equipment (Chen et al. 2018, Martin Fernandez et al. 2018, Raza et al. 2019). This approach offers several advantages, including reduced latency, bandwidth optimization, enhanced privacy and security, offline operation (Hassan et al. 2019, Shi et al. 2016, Varghese et al. 2016). Also, one of the most important things in edge is data privacy, reduced attack surface, local threats, communication security, trustworthiness of edge devices. Some of these problems are addressed in the following papers (Ali et al. 2021, Markham and Payne 2001, Xiao et al. 2019).

Cloud-based Data Stream Processing is a type of data processing system that executes a set of continuous queries over a potentially unbounded data stream (Heinze et al. 2014). It constantly outputs new results and is designed to dynamically scale to hundreds of computing nodes and automatically cope with varying workloads. This streaming approach enables real-time or near-real-time data ingestion, allowing organizations to gain valuable insights, make data-driven decisions, and take timely actions based on the incoming data (De Souza et al. 2020, Sahni and Vidyarthi 2021). The main thing about cloud computing is that it allows users to quickly deploy their applications in an elastic setting through on-demand acquisition/release of resources at a low cost (Runsewe and Samaan 2021).

In recent years, there has been a growing interest in employing efficient message distribution systems to optimize architectural frameworks. The authors (Hugo et al. 2020) propose utilizing Apache Kafka as a centralized message distribution system to streamline the architecture for monolithic applications. The integration of MQTT and Apache Kafka is achieved through the development of a specialized Kafka Connect connector, enabling scalable and resilient data collection from MQTT sources and its transmission to Kafka server. This integration facilitates fast and reliable real-time data transfer between various applications, particularly for handling large data volumes. The platform called SEMAR (Smart Environment Monitoring and Analytical in Real-time) (Fridelin Panduman et al. 2019) presents a cloud computing platform based on microservice architecture. The system consists of a device that is placed in the car and sends data via MQTT protocol to the server on which Apache Kafka is installed. They found that the average delay in sending information is 0.09ms, which is enough for the system to be considered to work in real-time. REDA is a cloud-based event-driven architecture proposed for real-time data processing in wireless sensor networks and IoT devices (Khriji et al. 2022). This architecture offers flexibility, high availability, and distributed computing while achieving high throughput and minimizing latency. By utilizing open-source frameworks and components such as a sensing unit, gateway unit, lightweight messaging protocol, event-stream processing unit, and distributed document database, REDA presents a cost-effective solution for real-time data processing. Authors (Mitrović et al. 2023) presented an IoT based framework for air quality measurements, that is suitable for implementation into different smart environments.

The article of Javed et al. (2018) presents a fault-tolerant architecture for IoT applications, which combines cloud and edge computing. This architecture, named CEFIoT, allows flexible compute placement on edge or cloud without any changes in source code. Also, the article shows a case study of a security camera system to show fault tolerance possibility in architecture. Cao et al. (n.d.) explain edge computing as a computing paradigm that does a computation on the edge of a network. Proximity to users and the provision of better intelligent services are highlighted by better performance of data transfer and decreasing data latency. Edge computing aims to provide services at the edge of the network and meet the needs of the IT industry in high-speed connectivity, real-time processing, and data security. Also, one interesting topic is EMMA which serves as a middleware

solution that enhances the efficiency, reliability, and performance of MQTT-based communication in edge computing environments, enabling more effective and responsive IoT applications. The authors (Rausch et al. 2018) consider how edge computing can improve the performances of just cloud-based architectures. The opinion of Koziolek et al. (n.d.) is that MQTT Broker is a good choice for distributed IoT Edge Computing for a few reasons. First, MQTT brokers such as Eclipse Mosquitto, EMQX, HiveMQ i VerneMQ support the MQTT protocol which is lightweight, effective, and good for IoT communication. Therefore, these brokers provide support for clustering, enabling scalability and high system availability. As open-source code, they are customizable and available in different variants, providing opportunities to adapt to specific project requirements. These features make MQTT Brokers a popular choice for distributed IoT Edge Computing scenarios.

Sotskov et al. (2023) presented IRONEDGE architectural framework that can be used in different edge Stream Processing solutions. The first layer of this architecture is the Data Source layer which is used for processing and sending data. Data that is collected and processed in the Data Source layer is ready for publishing and called Data Reports. The second layer consists of a few services. The first one being Data Collection service which receives data from corresponding Data Sources sending it to the Stream processing service which is used to derive knowledge from the accumulated Data Reports, which creates a base for event creation. Data transfer is enabled by AMM (Asynchronous Messaging Middleware). Local data, events, and reports are stored in Local Storage for further analysis. Data stream processing can be divided into more phases: receiving data, mapping in a particular object, decomposition of data according to certain criteria, analysis of grouped data, and transferring to the cloud. As AMM (Sotskov et al. 2023) chose Apache Kafka because of easy connectivity with external systems. The authors have observed the performances of the system in two cases: with Kafka Connect (K0-WC) and without Kafka Connect (K1-NC). They concluded that for loss rates and latency, K1-NC offered lower event loss and lower processing latency compared to K0-WC. For actual throughput and log time, K1-NC showed an increase in throughput but never matched the input rate for the Data Reports, while K0-WC clearly showed low throughput resulting from high losses.

As it is shown in previous examples of architectures, to send data in constantly changing environments and at the same time in real-time, MQTT is particularly useful, while Apache Kafka is used to store large amounts of data or to integrate different applications or data centers. Because of their similarities, they can be considered a great couple. Both have topics and publish/subscribe patterns. There are several ways to connect MQTT and Kafka (*MQTT and Kafka. How to Combine Two Complementary… | by Techletters | Python Point | Medium* n.d.):

1. Sending messages from edge devices, using MQTT and Kafka broker. The problem arises in the fact that the device has to send data using two protocols, and it has to be sure that the data either arrive on both or does not arrive on either of them.

2. Creating an application that will represent a bridge between MQTT and Kafka.
3. Connecting to Kafka via MQTT proxy. It is used if there is a need to send messages that will for sure arrive on the other side.
4. Connection of MQTT broker and Kafka cluster via Kafka Connect – a good solution that uses connectors as an extension to connect.
5. Connection between MQTT broker and Kafka via MQTT broker extension - this extension enables the injection of messages from IoT devices into the Kafka cluster.

Most authors include mobile phones in their systems to gather data from mobile device sensors. In the research of Kraft et al. (2020), a mobile collective sensing system is proposed that enables the implementation of a noise level map for tinnitus patients. After the requirements analysis and design phase, the system is decomposed into bounded contexts to achieve a clear and shared definition of consistency between team members. Five bounded contexts were identified, including user identity, social aspects, measurement, incentives, and communication. This architecture uses a cloud-native approach, which enables efficient and scalable processing of concurrent noise measurement requests, using microservices and containerization technologies such as Docker and Kubernetes. In addition, the system uses in-stream processing and the Apache Kafka platform for real-time data processing and enabling decoupled processing of incoming geospatial data. To display polluted areas on the map, the authors decided to use geospatial data partitioning techniques. Hierarchical partitioning of geospatial data, such as the implementation of the Discrete Global Grid System (DGGS), allows data to be divided into different levels of detail. DGGS enables the representation of data in different partition sizes, which enables aggregation and visualization at different scales. The map has Hexagonal Hierarchical Spatial Index (H3) system. H3 systems allow precise positioning of geospatial data in appropriate partitions based on their coordinates. This technique facilitates analyzing and visualizing polluted parts on the map.

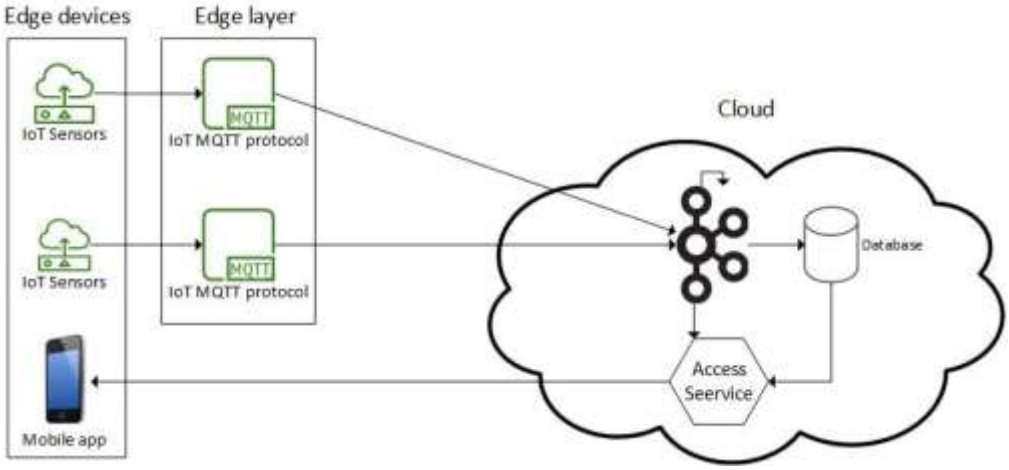
The development of the mobile crowdsensing system for monitoring noise pollution for decision-making purposes in smart cities by collecting, storing, and visualizing data on noise pollution in real time has been described in the article (Jezdović et al. 2021). These authors also point out the experiment results conducted in Belgrade, Serbia, and recommendations on how this system can be applied in other cities. The application presented in this paper is a mobile crowdsensing system for detecting noise in smart cities. The system contains a crowdsensing mobile application, cloud, and big data infrastructure. The mobile application enables noise recording using a microphone on mobile devices, recording the location of detected noise using a GPS device, performing spectral analysis on audio data, and storing transformed data and location data in a cloud database. The web application allows the view of polluted data on Google Maps. The type of the map is a heatmap on which is presented red, orange, and green areas for the high, medium, and low levels of noise respectively. In the last two

papers we can see that the authors have used two different approaches to represent their data on the map.

Methodology

This paper presents a methodology that enables continuous monitoring and collection of air quality data in real time, from sensors deployed at different locations in smart cities. With this architecture, data is transferred from Edge devices to Cloud servers, where it can be further analysed and used for decision-making and air quality management in smart cities. The methodology of this research includes the use of a two-layer architecture: Edge and Cloud. In the Edge layer, air quality data is collected from sensors connected to a Raspberry Pi (RPi) device. According to the Environmental Protection Agency, the data that needs to be measured in Belgrade are SO_2, PM_{10}, NO_2, CO, NO, $PM_{2.5}$ (*Агенција За Заштиту Животне Средине - Министарство Заштите Животне Средине* n.d.). Such data is sent via the MQTT protocol to the cloud (see Figure 1).

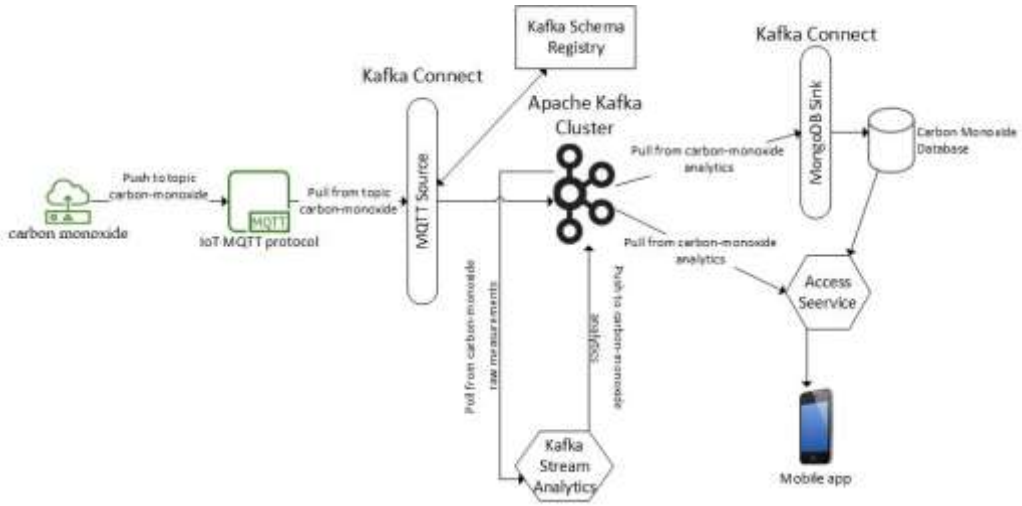
Figure 1. *Data Streaming Architecture for Air Quality Monitoring in Smart Cities*



To enable data transfer, the MQTT protocol is used and the Mosquitto MQTT broker, which is installed on the RPi device. Mosquito was chosen because it is the MQTT protocol which provides a lightweight method of carrying out messaging using a publish/subscribe model. This makes it suitable for IoT messaging such as with low power sensors or mobile devices such as phones, embedded computers or microcontrollers (*What Is Mosquitto MQTT?* n.d.). These tools allow sending data to Apache Kafka, which resides in the Cloud layer of the architecture. Apache Kafka is used as a central mechanism for receiving and processing data in a stream. Also, it is chosen as the tool because it is highly scalable for processing and streaming data in real time. Kafka enables data replication and data availability even in case of network failures or interruptions, which is important for continuous monitoring of air quality (Korab n.d.). Also, Kafka supports simultaneous sending and receiving of data, which enables real-time data analysis and processing. This is

a very important feature in smart cities because it provides quick detection and reaction to changes in air quality. The data coming to Kafka would be processed and saved in the database and sent in real time via the access series to end user applications.

Figure 1. *Data Streaming Architecture for Air Quality Monitoring in Smart Cities with Data Flow*



This paper proposes a detail architecture which is presented on Figure 2. The system is designed to connect to devices across the city. A Raspberry Pi device is set up to which a group of sensors for measurement is attached SO_2, PM_{10}, NO_2, CO, NO, CO_2, NH_3, $PM_{2.5}$. The image shows the flow of data from the carbon monoxide sensor. Data is prepared for sending by creating an object with all the necessary information and metadata (see Figure 3). From this point data will be sent to corresponding MQTT topic and from there streamed to the Apache Kafka. Specifically, carbon monoxide data will be sent to the topic named carbon-monoxide. Connection between MQTT and Apache Kafka using Kafka Connect was chosen. In order to connect MQTT with Kafka, there is a special Kafka connect that collects data and writes it to the Kafka topic (carbon-monoxide) – MQTT Source Connector. Before the data reaches the Kafka Cluster, it is necessary to check if data is valid. Kafka Schema Registry serves to validate the object that arrives to Kafka. If the structure of the objects does not match, that data will not be processed. When the data reaches the Kafka Cluster, i.e. on the carbon-monoxide topic, it is forwarded to Kafka Stream Analytics, where data analysis is performed, such as geographic analysis based on location, time analysis for tracking data history etc. The processed data is forwarded to the carbon-monoxide analytics topic. From this topic, data is collected by the Access Service and forwarded to all users for monitoring pollution in real time. The processed data is also stored in the database to monitor the history of air quality. The data is first pulled from the topic via a Kafka Connect called MongoDB Sink, which is used to write data to MongoDB.

Figure 2. *Example of Object Sent to Apache Kafka*


```
{
    "measurement": {
        "type": "carbon_monoxide",
        "value": 2.54
    },
    "device_info": {
        "manufacturer": "Raspberry Pi",
        "model": "RPi-4",
        "device_id": "uuid",
        "height": 10
    },
    "timestamp": "2023-06-09T10:15:00Z",
    "units": "ppm",
    "location": {
        "coordinates": [9.967101535538086, 48.384883089298114],
        "municipality": "Vožđovac"
    }
}
```


Results and Discussion

A prototype data streaming system was developed to display measurements of air quality, focusing on monitoring Sulfur Dioxide (SO_2), Particulate Matter (PM10, PM2.5), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO) and Nitric Oxide (NO), Ammonia (NH_3), carbon dioxide (CO_2) levels. The system was based on a Raspberry Pi microcomputer with various sensors connected, including the MQ-7, MQ-137, MQ-135, MQ-136, MQ-165, MG-811, WSP-1110, and SDS011. Moreover, instances where a sensor malfunctioned or produced default values that significantly deviated from previous measurements resulted in the exclusion of data from being sent to the cloud for processing.

To evaluate the quality of data, it was necessary to take into consideration that sensors might exhibit a certain degree of imprecision. To ensure reliable values, averaging calculations were performed using data from multiple sensors. This approach allowed for a more accurate assessment of data quality and minimized the impact of potential inaccuracies from individual sensors. The collected raw data was streamed via Apache Kafka. Every type of sensor has its topic in the MQTT broker which sends data to the Kafka topic for that specific measured value. Apache Kafka performed real-time analyses of collected data, stored them to the MongoDB and streamed live. NoSQL database has been chosen because large amounts of data are expected from IoT systems with numerous writing operations (Tudorica and Bucur 2011). By leveraging the power of Apache Kafka, the system facilitated efficient data transmission, allowing for real-time monitoring and analysis of air quality metrics. To derive meaningful insights, calculations were performed to determine the average pollution levels for each specific hour (see Figure 4) and specific periods of the day (see Figure 5). All measurements are shown on different

diagrams due to the sensors different output value ranges. These metrics provided valuable information for assessing air quality trends and identifying potential pollution patterns during different periods of the day in Belgrade.

Figure 3. *Line Chart Based on Average Values for Every Hour in the Day*

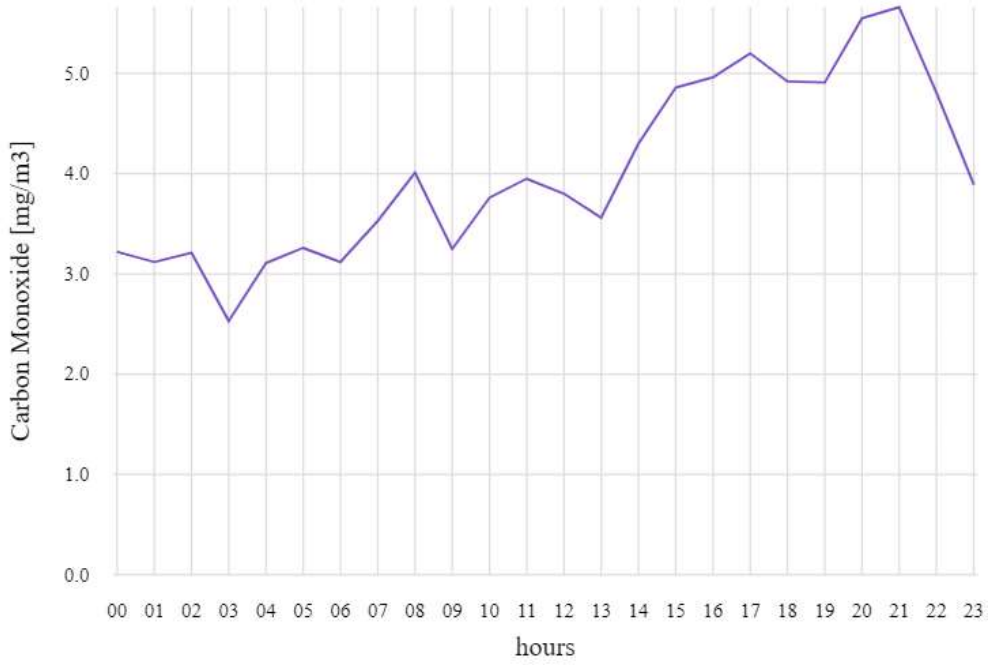


Figure 4. *Bar Chart Based on Average Values for Specific Times of the Day*

Conclusions

The main goal of this paper is to present the design and development of the robust architecture for crowdsensing systems in smart cities. This architecture provides the base for effective collection and analysis of data in real-time, opening new possibilities for measuring and monitoring level of pollution and other parameters in local environment. Even though the architecture shows easy processing and analyses of data, some shortcomings have also been identified. Setting optimal number of topics and replication factor of topics, and how many brokers is it needed. For now the replication number is set to three, because it is the golden rule (Ibryam n.d.), but with the further analysis and testing that can be changed because of a number of sensors that will be sending data to the Apache Kafka.

Implementation of the developed architecture has applicability in practice for creating crowdsensing systems in smart cities, especially for measuring air quality levels. This enables fast and efficient data collection from various sensors and devices, providing valuable information for management and monitoring of environmental quality. Future steps may include implementing the developed architecture on the Docker platform, scaling the system via Kubernetes, and displaying measurements via a map. This would enable better resource management and scaling, as well as greater flexibility and fault tolerance in the system environment. Through this work, it was observed that creating an efficient architecture for data streaming in crowdsensing systems is essential for successful real-time data collection and analysis. These results can serve as guidelines for other researchers dealing with similar problems in the field of smart cities and air quality meters. Future research will be focused on exploring the possibility of applying this architecture in wider contexts of smart cities, as well as optimizing the number of topics, replications, and brokers to achieve maximum efficiency and scalability. Also, research into the integration of this architecture with other relevant technologies and platforms opens the door for further improvement of crowdsensing systems in smart cities.

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Automatic Generating System of Information Security Policy

By Kiyoshi Nagata[*]

Information is indispensable in any organization, and its security must be properly guaranteed. At present, information security in an organization includes not only confidentiality but also integrity and availability, and means a balance between them. Establishing an information security policy is effective as a means for that purpose, but it is considered to be a high hurdle for organizations such as SMEs, which have neither personnel nor financial leeway, to tackle it. We thought that a system to help establish information security policies was necessary, so we proposed a framework and tried to implement it in application programs. At present, the creation process of the basic policy by presenting the template and the creation of the organizational profile are implemented. In this paper, we propose a method to reflect the characteristics obtained from the organization profile not only in the basic policy but also in the following countermeasure standards and implement it in the application program.

Keywords: *security policy, information asset, ontology, generation system, SMEs*

Introduction

According to the IMD Word Digital Competitiveness ranking 2022[1], the total rank of Japan is 29th amongst 63 counties, and 8th even amongst 14 Asia-Pacific counties. In the report, they say that the cybersecurity capabilities both at the company and governmental level have become very important factor, then the result reflects those factors facilitating the strengthening of capabilities to protect digital infrastructure from cyber-attacks. As one of subfactors for the ranking evaluation, "Cyber security" rank of Japan is 45th which dropped the overall evaluation value along with other indicators values.

Bartlett (2019) investigates Japanese cyber-security policy making process by adopting Campbell's four categorizations (Campbell 2014). According to his result, Japan's cybersecurity policy was swayed by the motives of each organization before 2010, and it was finally affirmed after 2011 where new set of provisions aiming explicitly at improving the cybersecurity of small-and medium-sized enterprises (SMEs) were implemented regarding information technology. Although more than 30% of 195 Japanese SMEs assumed information security risks as a risk that makes business continuity difficult, only 19.6% of SMEs cited awareness of cyber security as a reason for increasing IT investment over the next five years (2022 White Paper on Small and Medium Enterprises in Japan).

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[1]https://www.imd.org/centers/world-competitiveness-center/rankings/world-digital-competitiveness/.

From the ISTR (Internet Security Threat Report 2019[2], attacks on organizations with 250 or fewer employees are no less common than those on larger organizations, and it claims that "Employees of smaller organizations were likely to be hit by email threats-including spam, phishing, and email malware than those in large organization. They claim that "Smaller organizations can be held hostage when faced with cyberattacks since they have fewer IT security resources to avoid or respond to complex attacks".

Even if the government establishes a cybersecurity policy and provides financial assistance, it is difficult for SMEs to cope with the shortage of IT engineers with advanced knowledge. Moreover, it is true that the cause of cyber security breaches is not necessarily the lack of advanced IT technology. Together with MIC (Ministry of Internal Affairs and Communications) and NPSC (National Public Safety Commission), METI (Ministry of Economy, Trade and Industry) published a report title "Occurrence of unauthorized computer access and research and development of technology related to access control functions" (in Japanese)[3], in which the number of the identification code theft type unauthorized access that have been cleared from 2018 to 2022 was listed by method. These are top three means of stealing amongst 482 cases: "Taking advantage of the lax password setting and management of authorized users" (230), "committed by a former employee or an acquaintance who was in a position to know the identification code" (41), and "Leakage from authorized users or by social engineering" (38). These problems are not due to the lack of advanced IT technology, but due to the lack of information security awareness and recognition.

In order to cope with information security issues mentioned above, establishing information security policy is essential and principal mean. Ministry of Education of Japan (MEXT) issued a notice to encourage national universities to develop and publish security policies, and raised the importance to private universities. Then almost all the universities and colleges published information security policy statements on their website.

Although we could not find out any results of a fact-finding survey on the status of information security policy development in SMEs in Japan, the survey report titled "Cyber Security Breaches Survey 2019: Statistical Release"[4] conducted by the Department for Digital, Culture, Media and Sport in UK pointed out that only 32% of micro and small firms with less than 49 employees established the cybersecurity policy while 71% of medium firms and 74% of large firms did.

With the aim of establishing information security, especially in SMEs, we tried to construct a support system for information security policy developing (Nagata and Kigawa 2019). We proposed the framework and created prototype, however the system development as an actual application is still underway. In this paper, we propose a method of creating a basic policy document suitable for each organization by incorporating ontology.

[2]https://www.academia.edu/14479611/INTERNET_SECURITY_THREAT_REPORT.
[3]https://www.meti.go.jp/press/2020/03/20210304003/20210304003-1.pdf.
[4]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/813599/Cyber_Security_Breaches_Survey_2019_-_Main_Report.pdf.

The rest of paper organized as follows; our former works and some general issues on security management and policy are described along with the review of some papers on cybersecurity applying ontology in the next section. And the outline of our proposed system is explained as the methodology in the following section. The last section is on the discussion, and the conclusion and future works.

Literature Review

In this section, we will review some of papers or issues on the information security management including our former works, and on cybersecurity related ontology in the following two subsections.

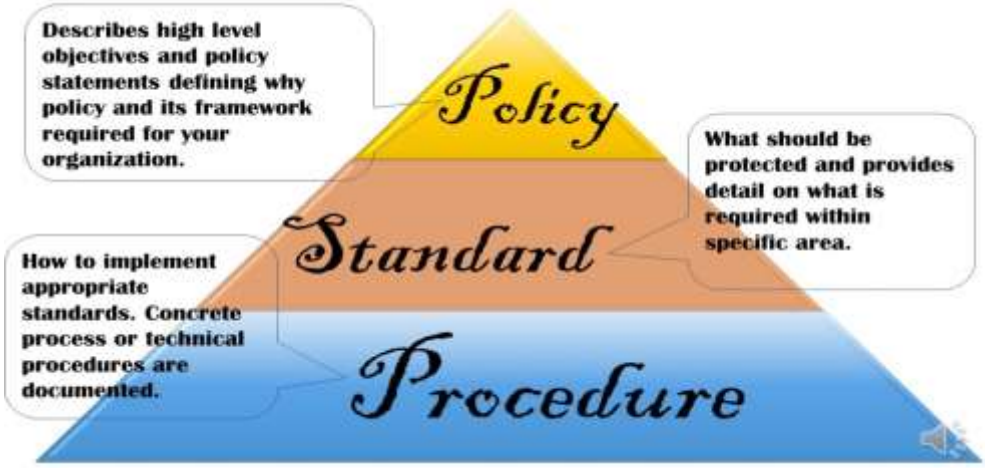
Former Works and Issues on the Information Security Management

One of well-known ISMS frameworks is ISO/IEC 27000 family[5] some of which are based on BS7799. In 3.1.24 of the latest version of ISO/IEC 27002: 2022 quoting the ISO/IEC 27000:2018, 3.53, the policy is determined as "intentions and direction of an organization, as formally expressed by its top management". Since ISO/IEC 27002 is the guideline for organizational information security standards and management by giving code of practice for information security controls, policy is handled as one of controls in parallel with some of others such as asset classification, personal security, physical and environmental security, etc.

However, the information security policy is sometimes considered as the comprehensive and integrated system for implementing ISMS where various types of controls and measures are incorporated. In an issue titled "Information security policy sample"[6] published in 2016 by Japan Network Security Association, five layers model is adopted. Zinatullin (2016) shows four layers model consisting of "Policy", "Standard", "Guideline", and "Procedure", where "(Basic) Policy" is defines as a document providing a high-level overview of how organizational processes should operate in a secure manner. He also described "Standard" as regulation for the approach to security in the designated scope by preventing them from implementing conflicting or redundant solutions, and "Procedure" as a set of basic steps aiding the implementation of policies and standards. Here we adopt much simpler model of three layers, with "Basic Policy", "Standard", and "Procedure" shown in Figure 1 with short descriptions.

[5]https://www.iso.org/standard/iso-iec-27000-family.
[6]https://www.jnsa.org/result/2016/policy/data/policy_gaiyou.pdf.

Figure 1. *Tree-Layer Model for Information Security Policy*



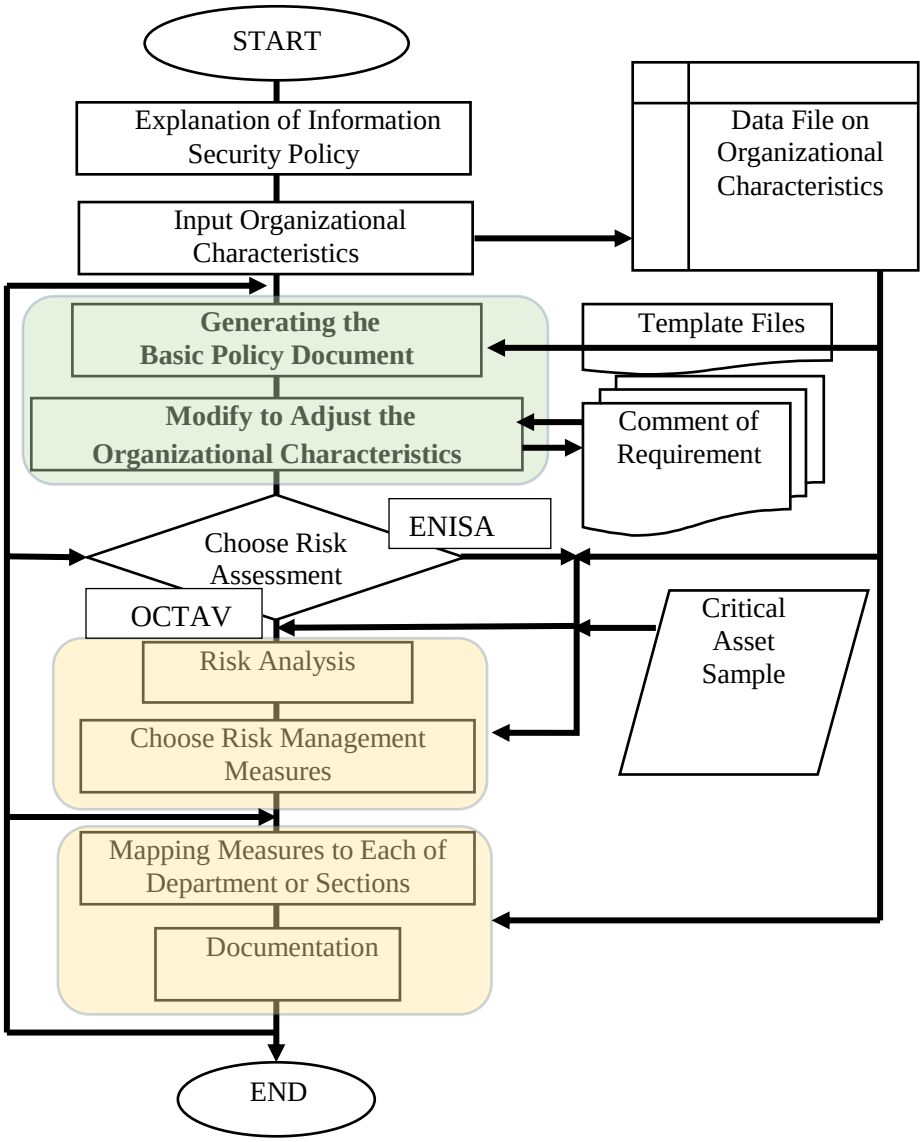
According to the model, we proposed to construct a supporting system for generating the security policy, and an initial program was created as a prototype (Nagata and Kigawa 2019). The flow of our proposed system is depicted in Figure 2.

- At first, the information security policy is explained to those who are responsible for the organization in several media such as text, audio, video, etc.
- Organizational characteristics are input, and they will be used in each stage.
- Basic policy is generated using template consisting of several items by referring organizational data file and displayed with some comment on requirement when adopting this expression or word.
- If going on standard stage, choose one of risk analysis methods from OCTAVE (Alberts et al. 2005) or ENISA. Although the analyzing process is somewhat different depending on the method, they output a set of mitigation controls. We have proposed some system for evaluation of risks and find out a set of proper mitigation controls (Nagata et al. 2009). To identify information related assets, we will prepare a list of possible ones (Nagata 2012).
- On procedure stage after information risk analysis, summarize and document the procedures for each department, and the document will be completed after hearing the opinions of each department.
- Over all security policy usually equipped with PDCA cycle. The arrows from down to up in the left part represent it.

In our previous works, we implemented the total framework and the generation and modification process, as shown in the first shaded parts in the figure 2, in a Java application program. Basic policy document is generated by presenting several candidate sentences that reflect the basic organization data and enumerate them, and then correcting them by policy creators. However, the

organizational data refection process is just replacement of some terms such as "company" instead of "school" or "university", "client" instead of "student", etc.

Figure 2. *Overall Flow (Former System)*



Source: Nagata et al. 2019.

Here we propose to incorporate ontology-based system for sample sentence creation process by which the organization's characteristics will be more reflective.

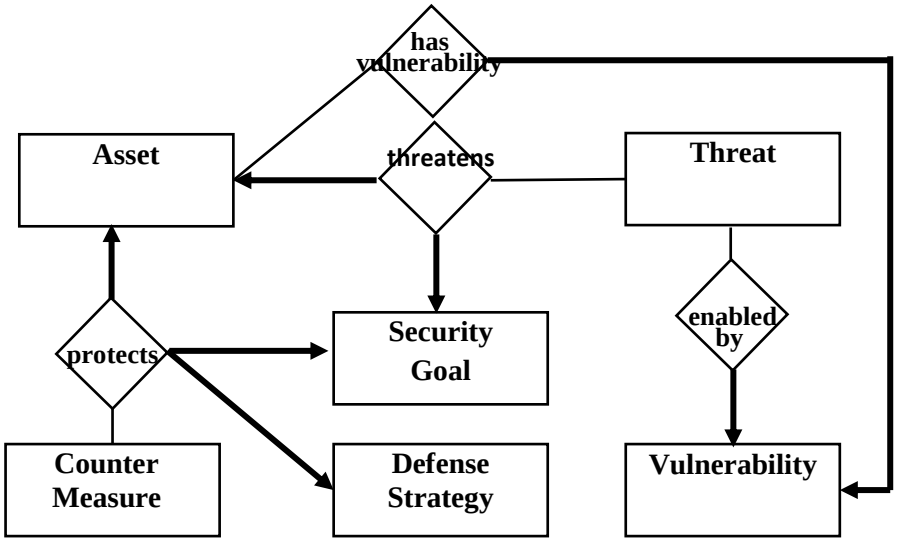
Review of Some Ontology-Based Information Security Management Systems

Gruber (1993) noted that "ontology is an explicit specification of a conceptualization. The term is borrowed from philosophy, where an ontology is a systematic account of existence. For knowledge-based systems, what "exists" is

exactly that which can be represented." He also claimed that sharing common understanding of the structure of information among people or software agents is one of the more common goals in developing ontologies. Noy and McGuiness (2001) published a guide for ontology development where an ontology is denoted as a formal explicit description of concepts in a domain of discourse, properties of each concept describing various features and attributes of the concept, and restrictions on slots.

Herzog et al. (2007) gave a security ontology built upon classical components of risk analysis, and their relations to each other. Figure 3 is a graphical description of overview of the security ontology that depicts only core concepts and core relations from the original one.

Figure 3. *Core Concepts and Core Relations of the Security Ontology Overview*



Source: Herzog et al. 2007.

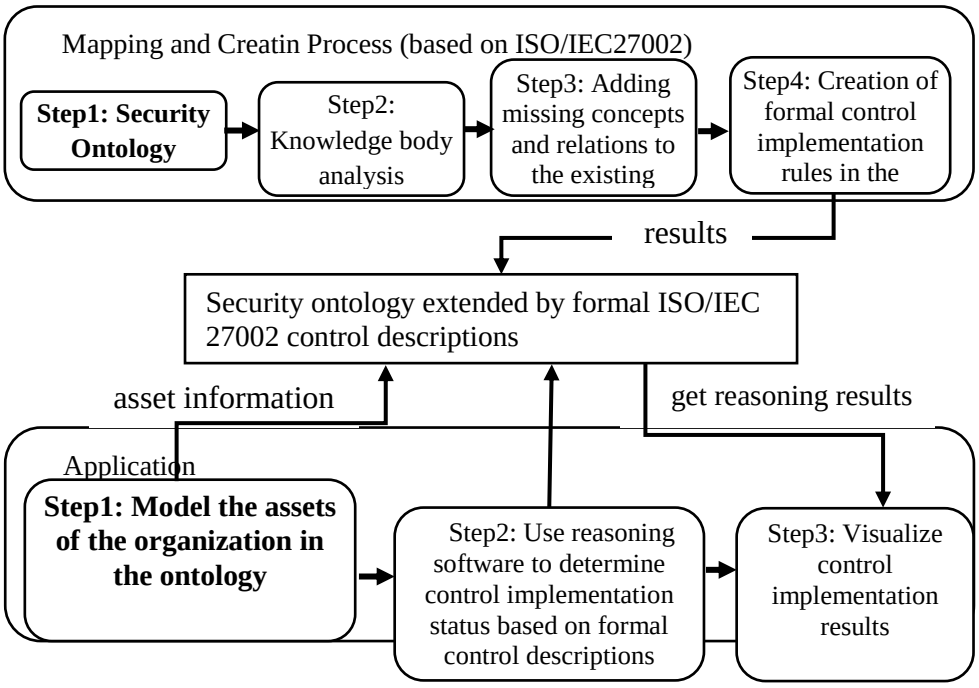
Since the organization's information assets play a central role in establishing an information security policy as an ISMS, creating a detailed information asset ontology becomes important. Zeb et al. (2015) proposed an ontology-supported asset information integrator system (AIIS) which can help industry experts to exchange the tangible capital assets information and transform the way they were exchanged at that time between the municipal and provincial governments in Canada. In the paper, they presented the ontology development methodology in ten steps as the hybrid version of former works.

Adesemowo et al. (2016) published a paper on IT assets ontology aiming to assist in determining inherent attribute of IT assets that can assist in the process of IT assets risk value assessment. They divide Assets into Personnel, Network, Services, Data, Hardware, Software, and Information. For ontology creation, "IT Asset" class is divided into "TangibleAsset" and "IntangibleAsset" classes according to which properties, "tangible" or "intangible", they have.

As application of ISMS policy implementation of policy ontology, Fenz et al. proposed an ontological mapping of ISO/IEC 27001 (Fenz et al. 2007) and ISO/

IEC 27002 (Fenz et al. 2015). Figure 4 is the overview of creating security ontology based on ISO/IEC 27002. We stress the first steps in each process with bold face letters, as these initial steps are related to our proposing system.

Figure 4. *Overview of Mapping ISO 27002 in the Ontological Structure and Applying the Results*



Source: Fenz et al. 2015.

Pereira and Santos (2012) represented the conceptual framework for information security ontology which is somehow different from that of Fenz et al. (2015). Although they have Asset, Threat, Vulnerability, and Control as common classes, relations between two of them are distinct. For instance, "Control, protect, Asset" in Pereira and Santos, whereas "Control (is) implemented (in) Asset" in Fenz et al. (2015). Thus, the configuration of the ontology will vary depending on the adopted criteria, organizational characteristics, purpose, way of thinking, and etc.

Almost all the policy-based ontologies aim to present mitigation measures for risks and threats and means to compensate for vulnerabilities. For that purpose, it is necessary to create a detailed ontology that matches the characteristics of the organization. Nicola (2009) proposed Unified Process for Ontology (UPON) for building a large-scale ontology in four workflows such as Requirements, Analysis, Design, Implementation, and Test by domain expert and knowledge expert. Their methods, UPON, may be helpful for creating a precise ontology.

KAoS by Uszok et al. (2004) is a pioneering policy management framework using semantically rich ontological representation and reasoning composed of three layers, "Human Interface Layer", "Policy Management Layer", "Policy Monitoring and Enforcement Layer". Basic form of KAoS policy is as follows:

[Actor] is [constrained] to perform [controlled action] (which ha [any attributes])

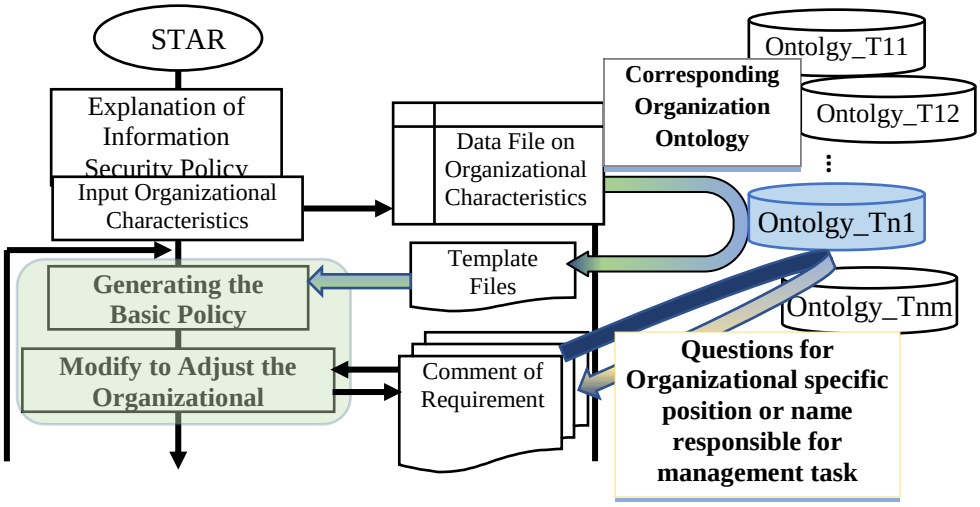
Implementing the enforcement system of OWL policies using the KAoS policy framework into multi-agent systems built on top of the JDK1.4 is also discussed (Tonti et al. 2004).

Proposing System

Although several methodologies mentioned in the previous section are useful and effective for organizational information security establishment, these are concerned with the creation of ontologies that reflect policies and the methodology of automatically configuring means to ensure information security using ontologies. Here we aim to automate the stage of creating basic policy statements in the upper part of the Figure 2.

Figure 5 depicts the newly proposed part of the system for creating general basic statement by applying organization related ontology. In the upper part, the system queries corresponding ontology by using input organizational essential data, then constructs set of candidate phrases of basic policy. Policy makers try to adjust or modify the represented policy with help of the ontology again in the lower part.

Figure 5. *Improved Version of the First Stage of our Former System*



In the above diagram, the organizational ontology also plays an important role, but what is needed here is for creating basic policies phrases, not the detailed ontology that is treated in many studies. For the process, ontologies for different types of organizations must be created in advance. We describe the method for the ontology creating.

Step 1. Gather the set of sample phrases of basic policy. Then classify them into each of typical items in our former implemented system, such as “Concept and

Purpose", "Scope of Application", "Definition of terms", "Composition/Positioning", "Management system", "Role/responsibility", and "Basic requirements".
Step 2. Analyze sample policy to get competency questions (CQ) for ontology. For example, if there is a sample phase reading "The CEO serves as chairman of the information protection committee and is responsible for information security within the organization", then CQs will be like as follows:
CQ1: "Is there a body for ensuring information security"
CQ2: "Who serves as chairman of the ISMS committee?"
CQ3: "Is the chairman ultimately responsible for ISMS?"
Step 3. Configure each of ontologies according to type of organization. These types of organization are pre-determined relatively broadly according to business conditions, such as universities, high schools, manufacturing industries, distribution industries, etc., as well as their scale and management style. Then create an ontology that will be common to each of these types.

In step 3, we can apply existing ontologies for general matters such as FOAF ontology for academic organizations (Kalem and Martiri 2011).

Conclusion & Future Works

We proposed automated basic information security policy statement generation system for embedding into existing Java application program. The key point is to apply ontology, and unlike existing research, we also propose a method of creating competency questions from sample sentences and configure an ontology which can respond to them.

We use Tree-Tagger for language structure analysis, in the CQ generation process, and then configure ontologies according to type of organization by using Protégé. In our renewal Java application, we will include a SPARQL (Simple Protocol and RDF Query Language) engine, e.g. ARQ, and adopt some readability indexes (DuBay 2004) for evaluating the representing sentences.

However, ontology configuration is a time-consuming and skill intensive process, and the validity assessment of the prepared statement will be necessary. About the readability index we did not explain, there is also the problem of which index to choose.

Although application programming by Java is still in the development stage, we think that the direction for proceeding to the countermeasure standard creation stage following this basic policy stage is indicated.

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Transformation of the Acoustic Amplifier into a Modular Structure

By Paweł Pieńczuk[*] & Jakub Wierciak[±]

The modular concept of device construction is most often based on the results of economic analyses. It allows lowering both manufacturing and design costs. It also improves their operating characteristics, in particular their repairability. It also happens that the modular structure of a consumer product is used to strengthen its market position. The authors of the article faced such a situation. The management of a company producing audiophile equipment decided to offer its potential customers an acoustic amplifier in which the user would be able to replace the preamplifiers himself, depending on the requirements related to the input signal. This type of modularity is known as "component swapping." Before commencing the development of the structure, detailed analyses of the benefits and potential risks related to the individual stages of the product's life cycle were carried out: design, production and operation. On this basis, the "Divaldi" company, the manufacturer of the equipment, developed assumptions regarding the designed amplifier. In particular, it was considered that the modular system would be built by modifying the existing, successful design of the INT-02 amplifier. The modification will enable easy replacement of the two preamplifier sections. Users will have a choice of classic preamplifiers: line and phono, as well as modules integrated with an analogue-to-digital converter and a module with a Bluetooth receiver. A low-volume production was assumed from previously manufactured and stored components: the base and typical preamplifier sections. As for the exploitation stage, the possibility of self-replacement of modules by the user has been adopted. Based on these assumptions, the concept of an amplifier with two identical pockets was proposed, enabling the simultaneous installation and use of two preamplifier sect ions. Detailed requirements for interfaces between the modules and the base unit were formulated: mechanical and electrical. A review of the available types of signal connectors led to the selection of the PCIe connector as the one that best meets the technical and economic criteria. From the mechanical side, it was proposed to use sliding guides, guaranteeing proper positioning of the modules in the pockets of the base. After selecting and approving the solutions, constructions of the mechanical components of the system were developed, creating a new standard: frame, module pockets and preamplifier module. The successful implementation of the amplifier's modularity became the basis for formulating proposals for further modifications of the design to meet the growing requirements of users who expect more and more possibilities to adapt the structure and interfaces of devices to their own needs.

Keywords: *modularity, acoustic amplifier, customization*

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Introduction

The Role of Modularity in the Construction of Devices and Other Products

The modular design of the devices is of great importance, e.g., for the economics of their production, ease of use or susceptibility to maintenance services. The most popular modular devices that we deal with in everyday life are e.g. personal computers, food processors, some gardening tools and machines, and motor vehicles to some extent. The modularity of products means such standardization that allows modification of their function or appearance by means of relatively easily replaceable units. As in the case of other standards, also when using modularity, many benefits are obtained in the organization of production, storage or service of products. Also, like any standardization, modularity is not without specific disadvantages, in particular, stopping the development of some product features for the duration of the "validity" of the adopted standard, i.e., most often for at least a few years.

It happens that the modular concept of the product is used to improve its market image, i.e., to increase its attractiveness compared to other competing products of the same type. An interesting example of such an approach may be the market of toys for children. Toys are not only supposed to give a child pleasure, but often also help them understand the world around them. A well-known example of combining a toy with the idea of modularity are LEGO bricks. These building blocks, being modules, have a standardized, simple mechanical interface and an ever-growing number of variations, dimensions and functions. Thanks to this, they allow children to create various compositions while teaching them shapes, recreating what they see and their own creativity. By adding new types of blocks to the offer, the number of possible implementations using this simple system is constantly growing, and blocks from a dozen or so years ago will still work with freshly designed modules (Figure 1). With this modular approach, LEGO has to some extent revolutionized the toy market.

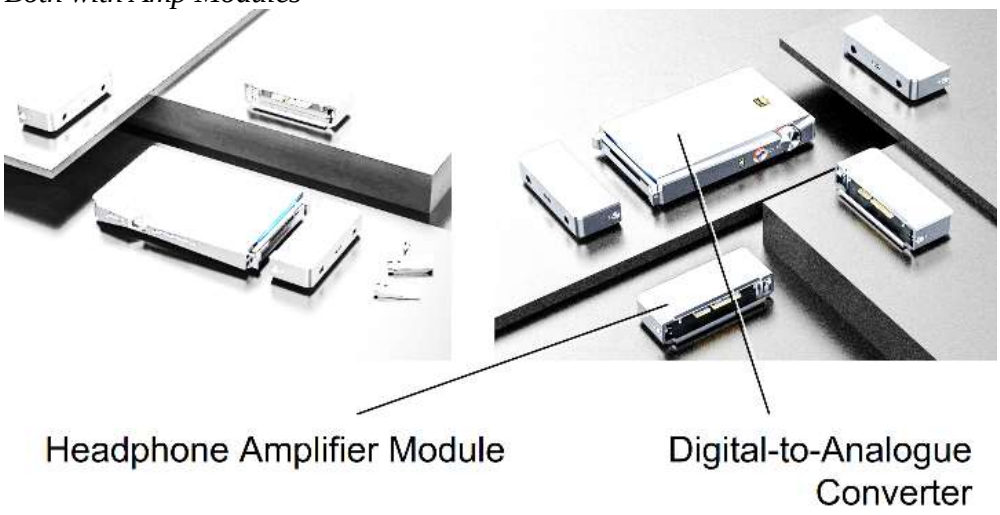
Figure 1. *Fragments of LEGO Ads: a) from 1981, b) from 2023*

Source: LEGO 1981, LEGO 2023.

Modularity in Audiophile Equipment

Manufacturers of audiophile equipment, as well as manufacturers of other expensive market products, try to beat competing companies by offering their customers solutions that are both aesthetically attractive and best suited to their needs in terms of functionality. Thus, they compete in the field of design, technical parameters and available functions. When it is difficult to offer new attractive features in the above-mentioned ranges, then you can consider changing the usable concept of the device, offering customers easy modification of its functions through the use of a modular structure. An example of such a solution is shown in Figure 2. These are two Fiio products - the X7 mk2 file player (Fiio 2016) and the Q5s analogue-to-digital converter (Fiio 2017).

Figure 2. *Fiio X7 Mark II Digital Audio Player (left) and Fi-io Q5s DAC (right). Both with Amp Modules*



Source: Fiio 2016, Fiio 2017.

DIVALDI, a Polish manufacturer of audiophile equipment, has also decided to follow this path. A typical set of devices used by listeners to play music and other sound forms is shown schematically in Figure 3. The dynamic development of this equipment is dictated, on the one hand, by the tendency to fill the space with sound, and on the other hand by the increasing number of sources, and at the same time the types of sound signal that must be transformed and then amplified to the level required by the loudspeakers. The preamplifier shown in the diagram, whose task is to adapt the signal parameters to the requirements of the power amplifier, can be a stand-alone device, can be built into the sound source, or can be a component of the main amplifier (Figure 4). The management of the company decided to offer users of audio systems a power amplifier equipped with replaceable preamplifier modules.

Figure 3. *Schematic Diagram of the Audio System*

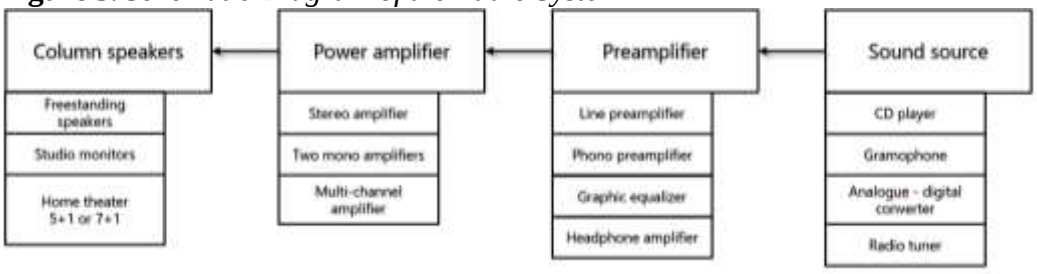
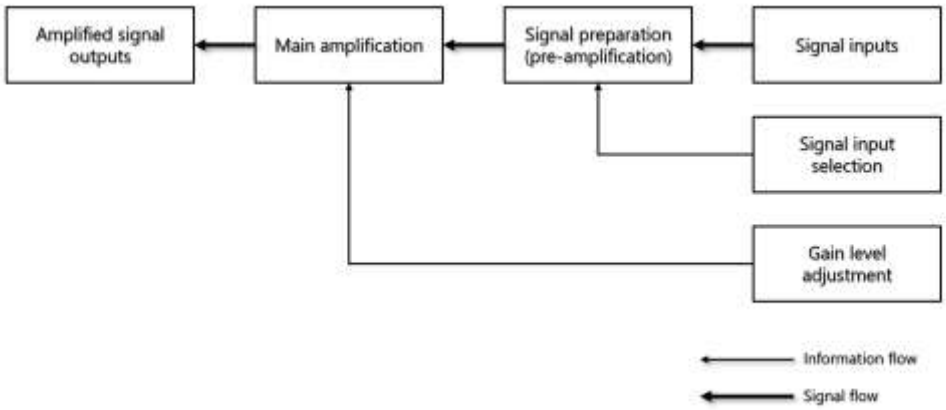


Figure 4. *Functional Block diagram of an Integrated Acoustic Amplifier*



Taking into account the favourable technical parameters as well as the visual attractiveness of the offered products, DIVALDI decided that the new, modular power amplifier should be built by modifying the existing, integrated amplifier INT-02 (Figure 5), which had already been positively received by the market.

Figure 5. *Integrated Amplifier INT-02 Accepted for Modernization - View from the Front Panel*

Objective and Scope of the Project

The aim of the work described in this article was to develop a construction of a modular acoustic amplifier that would meet the manufacturer's requirements, and in particular enable easy replacement of preamplifier modules by the user. At the same time, it was planned to offer the recipients classic preamplifier modules: line and phono, as well as modules additionally equipped with an analogue-to-digital

converter, a Bluetooth receiver, and even vacuum tubes. Each module will have appropriate connectors for signal inputs: pairs of RCA, XLR, USB or antenna connectors for modules with wireless communication. The power supply of the module will be provided by the amplifier, i.e., the basic module. It was allowed to offer more than one model of selected modules, to design a module "on request" according to detailed customer requirements, and to design new modules in the future. Such extensive development plans forced the need to provide a universal base for all preamplifier modules, in particular the adoption of such size restrictions that in the future will not become an obstacle to the implementation of new preamplifier design e.g., due to the dimensions of electronic components.

Work began with a review of literature sources on the construction of modular structures, hoping to obtain methodological guidelines to support the implementation of the project. The results of the review were used at the stage of formulating technical assumptions for the amplifier. The construction works were carried out based on the well-known methodology of designing mechatronic devices adapted to the needs of the project. The discussion on the obtained results concerns, above all, effective methods of proceeding in the design of modular systems.

Literature Review

Modular devices are characterized by quite unique standardization in a certain area of the product life cycle. Due to this cycle, we distinguish 3 stages of modularity: modularity in production, modularity in design and modularity in use (Baldwin and Clark 1994). The role of modularity in production is to optimize the number of parts used, e.g., by reducing the variety of fasteners in products or e.g. the base of materials used for the production of parts. Modularity in designing is aimed at creating a design structure capable of quickly introducing changes or corrections with as little impact on other parts of the device as possible. The creation of such a structure takes place through its decomposition at the conceptual stage and the creation of appropriate interfaces between the structures. Modularity in use allows modification, replacement or adjustment of auxiliary functions during its use by the customer. The selection of components is made by the user and he also decides about the possible expansion of the system and the purchase of additional modules, if any. The development of environmental sciences has also resulted in the development of an additional stage: modularity in product recall. The following issues are considered here: design for the environment (Li et al. 2008), design for disassembly, design for recycling (Campagnolo and Camuffo 2010). Each of the above-mentioned stages carries specific limitations adopted in the name of a certain goal resulting from economic, market, ideological or utility factors. These constraints have the benefit of streamlining the process, using predetermined structures and procedures that simplify the process or allow the project to be left open for expansion or evolution.

The modular structure of many devices is of great importance for the economics of their production, susceptibility to maintenance services, but also, as mentioned earlier, for the position of the product on the market. Currently, we can often

encounter modularity as an element that distinguishes a given structure from others offered. Typically this is accomplished by the assumption of modularity in use. If the end user is to choose a function from a palette available when he needs it, then the constructor is only supposed to provide an interface that allows combining modules in the configuration chosen by the user. This trend has developed in different stages of new product development: from marketing to design to technology (Fettermann and Echeveste 2014). Shifting the burden of adapting the device's functions to a specific user allows to simplify the conceptual design process due to the needs of the market. On the other hand, it makes it more difficult due to the greater workload of the research and development department and a wider scope of work on product design. Due to the difficulties in measuring the efficiency of the R&D department, it is also difficult to measure the competitiveness of such a solution (Clark and Fujimoto 1992). Of course, every company cares about the most efficient design process possible, and here modularity should be adjusted to the priorities in a given product family by making a profit and loss account that will show the sense and profitability of modularization in a given area (Clark and Fujimoto 1991a, Baldwin and Clark 2000).

Other stages of modularity are less obvious at first glance. Sometimes they reveal themselves in the common components used. Modularity in design can be recognized after the use of previously created modules in new products, which reduces the cost of their production, and at the same time shortens the process of constructing the product (Campagnolo and Camuffo 2010). Cost reduction is also achieved by reducing the variety of, for example, fasteners, which enhances the scale effect within the assumptions of large-series production. This has become commonplace in the automotive industry, where the most efficient ways to manage a product have been worked on for years (Clark and Fujimoto, 1991b).

Modularity has many aspects that need to be considered at the stage of creating design assumptions: from the principles of product design using the features of modularity (Baldwin and Clark 2000), through the goals of modularity, the effects of -carry modularity (Baldwin and Clark 1994), at what stage of product design it should be applied (Campagnolo and Camuffo 2010), to types of modularity, types of modules and stages modularity (Huang and Kusiak 1998, Kusiak and Huang 1996). These assumptions always start with the correct product decomposition (Huang and Kusiak 1998, Kusiak and Larson 1995). Each of these publications emphasizes a different aspect of modularity, and at the same time each of them defines the activities of the designer who was given the task of modularizing the structure. In industrial practice, the most common task is to transform an existing structure into a modular structure in order to obtain a specific, measurable benefit related to improving the efficiency of both the production process and the design process, as well as the relationship between them (Kuwashima and Fujimoto 2013, Awwad and Akroush 2016). Modularity is strongly associated with the product life cycle and sustainable development (Ma and Kremer 2015, Halstenberg et al. 2015), and also brings measurable benefits and costs associated with it (Campagnolo and Camuffo 2010). One of the distinguishing features that has been strongly emphasized in many studies is the

definition of the interface between modules, which, due to the limitations it builds, significantly affects further work (Ulrich 1992, Ulrich and Tung 1991).

In the case of the described project, it was assumed that the amplifier should allow the user to install and later use two selected preamplifiers. According to the publication (Kusiak and Huang 1996), this type of modularity of devices is called "interchangeability of modules" (Figure 6). Basically, we distinguish 3 types of cooperation between modules: interchangeability of modules is when auxiliary modules work with bases (basic modules) within one product family and each subsequent module works with existing bases; sharing modules - occurs when modules can go to other product families and modules from other families can create new families of modular products by creating a new set; bus modularity (Figure 7) - is used when a module with two or more interfaces can be matched to any number of basic modules. It allows the number and location of the basic components to be changed, whereas the previous methods only allow for the variability of the basic modules.

Figure 6. *Modularity of Component Exchange (left) and Representation of Modularity of Component Sharing (right): F_i – i-th Basic Module, M_i – i-th Auxiliary Module (Huang and Kusiak 1998)*

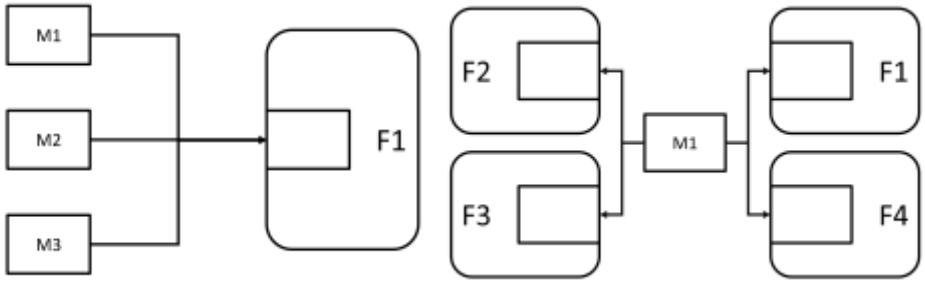
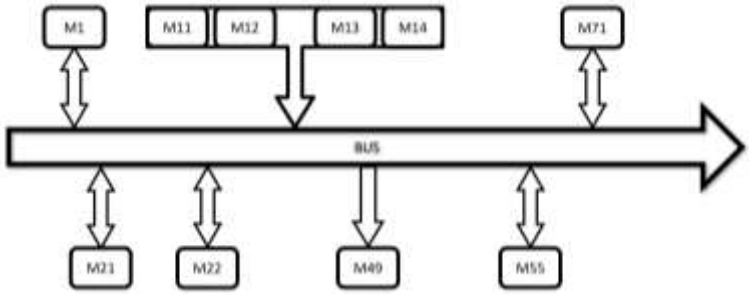


Figure 7. *Bus Modularity Representation (Huang and Kusiak 1998)*



Implementation Method and Course of the Project

The review of literature sources did not give contractors a full answer to the question about the algorithm for designing modular systems, but it provided valuable information systematizing the issues of building such systems. In this situation, the authors decided to use a well-known and proven in many projects algorithm for designing mechatronic devices (Mellal 2018), adapting it on an

ongoing basis to the specificity of the task undertaken. According to this algorithm, a typical design of a mechatronic device can be closed in a six-stage cycle, which has the following form:

1. Determining the user's needs - the result of which are e.g., system structure and list of interfaces.
2. System function analysis - leading to the identification of the necessary executive and measurement systems along with technical requirements.
3. Development of executive and measurement systems - ending with proposals of technical solutions for individual functional systems.
4. Development of subsystems of the device: mechanical, electronic and software - which results in technical documentation of the subsystems.
5. Supervision over the execution of the prototype - under which structural corrections are introduced.
6. Running the prototype - with possible improvements to the system.

The article presents the most important results of the work carried out in the first four stages of the cycle, preceding the execution and implementation phase.

Assumptions for the Product Life Cycle

Guided by publications on the life cycle of modular products (Campagnolo and Camuffo 2010), before developing the amplifier, an attempt was made to collect the assumptions made by the manufacturer for the new construction in relation to the individual stages of the product's life. The most important intentions formulated by representatives of DIVALDI are presented below.

Design Phase

The project was to be implemented as a modification of the existing design of the INT-02 integrated amplifier. The modification was to enable easy replacement of the preamplifier section by the user. During the design process, it was important to ensure the use of standard signal connectors to ensure easy availability of manufacturer's parts and documentation.

Production Phase

The company established a small-lot production of the amplifier. It was assumed that semi-finished products from which ready-made modules will be assembled will be stored in the warehouses. Production planning will take place according to the number of incoming orders. Ultimately, the most popular configurations should be available in stores on an ongoing basis, and the production of less popular modules will be organized according to needs and sales.

Testing Phase

The manufactured sub-assembly will be tested prior to assembly by measuring the ratings. If all parameters meet the strict standards set by the company, the subassembly goes to the finished product. The finished product is also checked

with measuring equipment to ensure the highest quality. When this test passes, the device is checked in a ready-made reference audio system, where a subjective assessment is made through listening by a designated, qualified employee of the company. This ensures that the product leaving the plant is of the highest quality.

Storage Phase

Due to the requirement to supply stores with the most popular configurations so that they are always on the shelf in stores, the warehouse will contain several pieces of each module and base.

Distribution Phase

Distribution will be carried out by the DIVALDI online store and stationary audio equipment stores around the world. In each store, the most popular modules and the amplifier base will be on the shelf. When buying a product, the customer purchases a base and selects the number of modules he needs. He knows the price of the base and each of the modules. In the store, in addition to the most popular modules, you can order less popular modules that will be delivered to the store for the customer. The user can also order a special module with specific parameters by directly contacting the company.

Use Phase

By replacing the module, the user adjusts the function of the device to his needs. This operation can only be performed when the device is turned off. After placing it in the device, the module is immediately ready for operation. The assembly of the module can be carried out by the user strictly according to the instruction manual. The assembly of the modules is to be possible only in one fixed position, and it must not require the use of additional tools.

Disposal and Servicing Phase

The service of the device will be carried out by DIVALDI. Under the warranty, the product will be picked up from the customer by a courier and delivered to the company, repaired there, and a new one will be sent back to the customer right away to shorten the user's waiting time for the module as much as possible. Repaired modules, free from defects, re-checked by quality control will be sent for resale.

Recycling Phase

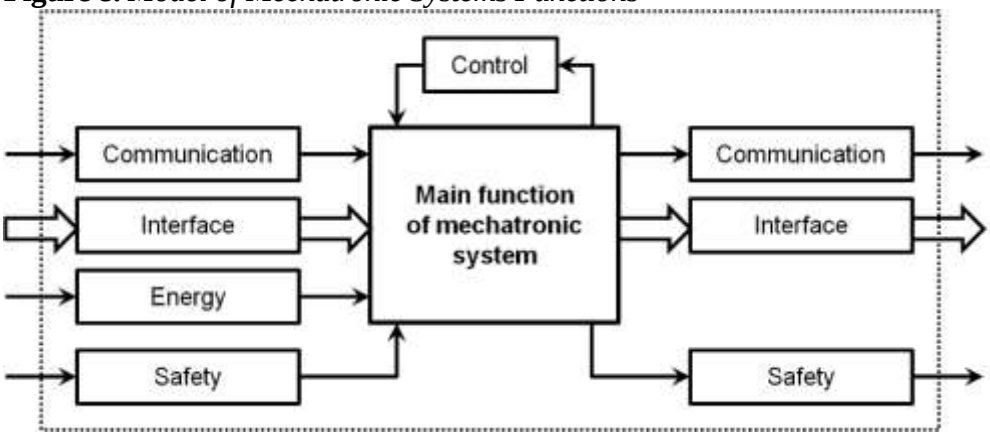
Damaged or worn modules returning to the plant will be inspected, then worn components will be replaced or their components used in new modules while maintaining the highest product quality. Any deviation from the nominal parameters disqualifies the product.

Work on the amplifier was carried out following the well-known and proven in earlier projects algorithm for designing mechatronic devices (Mellal 2018), which was continuously adapted to the specifics of the task undertaken.

Development of Technical and Operational Assumptions

According to Buur (1990), a convenient model of a mechatronic device that allows for the formulation of basic design assumptions is the function diagram shown in Figure 8.

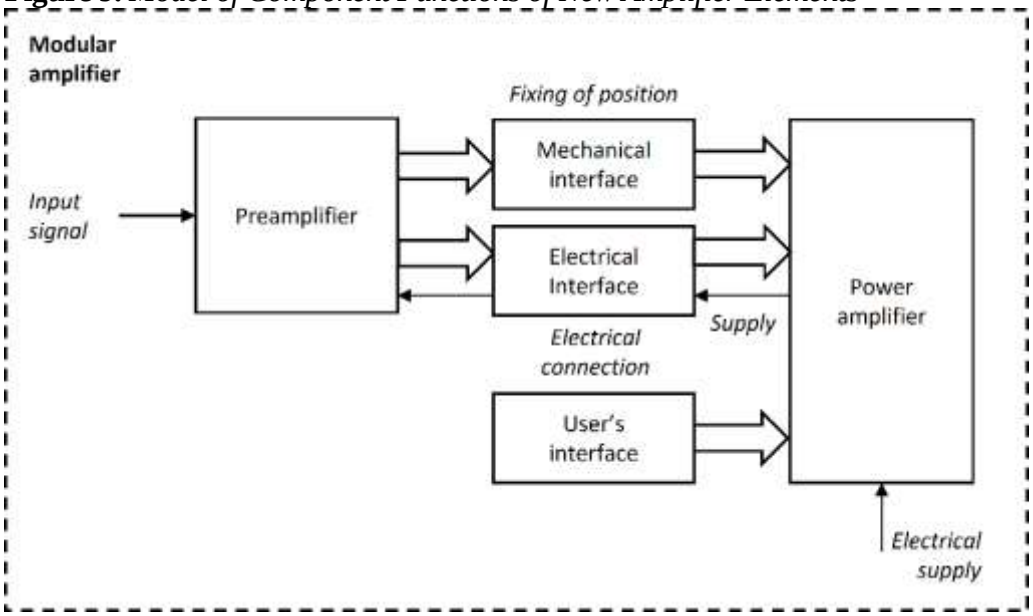
Figure 8. *Model of Mechatronic Systems Functions*



Source: Buur 1990.

Without limiting the application of the above diagram only to mechatronic devices, it can also be referred to in the analysed case. Then, the undertaken project concerns two electronic devices with strictly defined main functions: a preamplifier and a power amplifier, for which an interface with new characteristics is being developed (Figure 9).

Figure 9. *Model of Component Functions of New Amplifier Elements*



Mechanical Features

From the point of view of the implemented project, the individual components of the amplifier must fulfil specific mechanical functions, which are presented below.

Preamplifier

The mechanical functions of the preamplifier consist in its ability to be enclosed within certain dimensions of the electronic preamplifier circuits. In addition, it must be equipped with an input signal receiving system: contact or radio.

Power amplifier

From the operational side, it was assumed that the amplifier should allow the user to install and use two selected preamplifiers without the need to interfere with the mechanical structure of the basic module.

Mechanical interface

The mechanical interface is to guarantee the proper location of the preamplifiers in the basic module, including the implementation of electrical connections, and to protect them against accidental disconnection. The interface is also intended to allow the exchange of modules if the user deems it necessary.

Electrical interface

Its role is to ensure a reliable electrical connection between the leads of the electronic circuits of the preamplifier and the power amplifier, as well as a loss-free supply of the voltage supplying the preamplifier from the amplifier.

User interface

There is a potentiometer in the front panel, which is connected directly to the main amplifier and is used to adjust the sound level. There is also an input selector for the user to select the active pre-amplifier.

The functional requirements included the exclusion of the need to use tools when installing modules, as well as the approximate installation time not exceeding 5 minutes.

Operational strategy

As part of the project, it was assumed that the amplifier should allow the replacement of preamplifiers without any maintenance during the entire period of operation, while the permissible number of module replacement operations should not be less than 50.

Operating environment

The operating environment of the mechanical and electrical interfaces is the interior of the power amplifier, which had to be characterized, especially in terms of the temperatures inside it. This factor has a significant impact on the selection of functional components as well as on the mechanical design. The maximum temperature that can be expected inside the amplifier is 60°C.

System structure

This is where information is gathered concerning, on the one hand, the components that make up a given system, on the other hand, suggested or required technologies for their production, and finally their design form and ergonomics, which are particularly important in the case of market products. The management of DIVALDI has accepted the design concept according to which the preamplifiers will be in the form of drawers placed in the amplifier sockets by sliding them from the rear panel. The rear wall of the module contains signal connectors and, when inserted, forms an integral part of the amplifier's back plate.

The operational concept of the amplifier is illustrated in Figure 10.

Functional Analysis

As in the case of other projects, the algorithms for adapting the amplifier to the customer's needs implemented by the user himself were used to carry out a functional analysis of the constructed interface. The algorithms include: installing one preamplifier, installing two preamplifiers, and replacing the preamplifier. The algorithm for installing one preamplifier is shown in Table 1. In the case of a mechatronic device, the result of the functional analysis is a list of controlled executive systems and measurement systems necessary to perform its main function. When the considered device does not contain controlled mechanical systems, its functional analysis boils down to specifying the assemblies that will be used in performing manual activities. The assemblies identified in this way (Table 1) were included in the block diagram of the modified amplifier (Figure 11).

Figure 10. *Usable Structure of the Designed Amplifier*

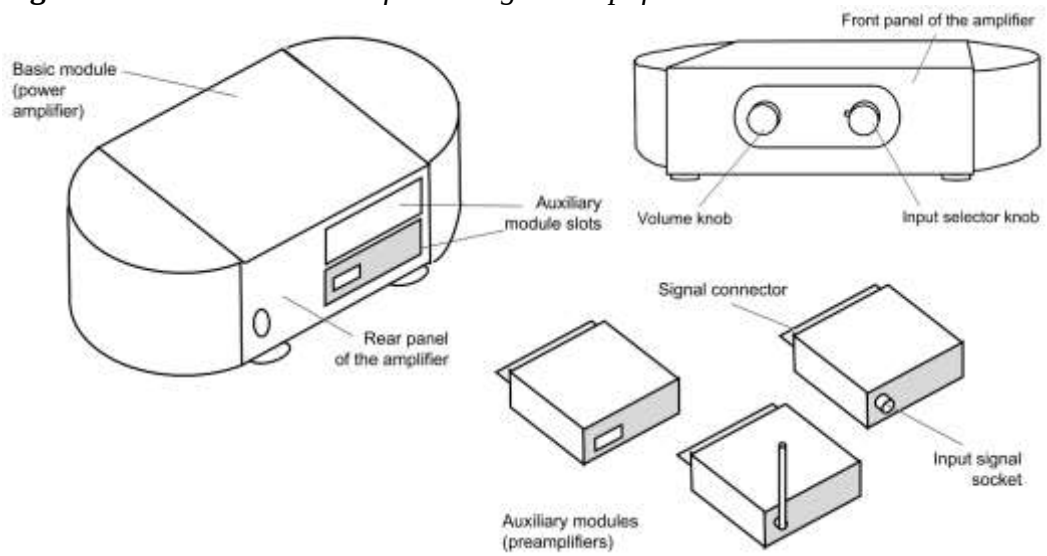
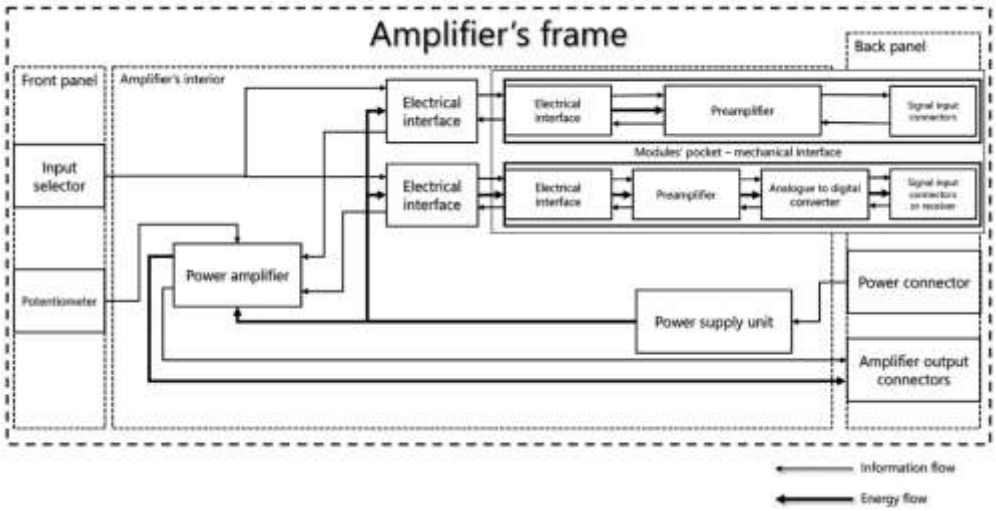


Table 1. *Single Preamplifier Installation Algorithm by the User*

No	Operation	Subassembly
1.	Disconnect the amplifier from the mains power supply.	1. Power switch/power cord
2.	Remove the selected preamplifier from the packaging and, if necessary, unlock the connector	
3.	Inserting the preamplifier into the amplifier's socket while connecting the signal contacts	3.1. Guide assembly 3.2. Contact assembly
4.	Mechanical fixing of the preamplifier module.	4. Module locking assembly
5.	Checking the correctness of assembly.	5. Module mounting indicator
6.	Unpacking the replacement module	
7.	Placing the replacement module in the second slot	7. Module positioning assembly
8.	Retaining the replacement module	8. Module locking assembly
9.	Installation correctness check	9. Module mounting indicator
10.	Mains power on	10. Power switch/power cord
11.	Source selection	11. Selector
12.	Volume setting	12. Rotary potentiometer

Based on the functional diagram, 3 main mechanical components can be distinguished, which also act as a housing and their electronic and signal components: front panel with signal input selector and potentiometer, rear panel with signal input connectors, column output connectors and power connector, the frame of the amplifier, consisting of a sheet metal construction and electronic components of the amplifier attached to it. The radiators together with the sheet metal body form a frame and partly function as a housing. The functional analysis stage was completed by formulating detailed technical requirements for each of the developed and modified assemblies.

Figure 11. *Functional Block Diagram of the INT-02 MODULAR AMPLIFIER*



Development of Functional Modules

Basic Module - Modification of the INT-02 Amplifier

Individual functional blocks were synthesized into modules and their assembly base. On this basis and using a multi-row model of the arrangement of objects inside the amplifier (Heragu and Kusiak 1991), a place for placing the amplifier modules was proposed as in Figure 12. Figure 13 shows the modified configuration of the rear panel of the amplifier.

Figure 12. *Suggested Location of Module Pockets in the Amplifier (top view)*

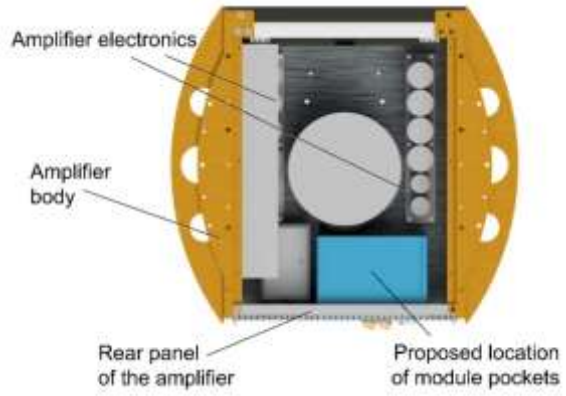
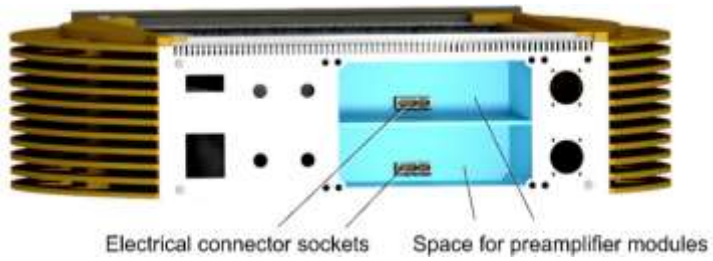


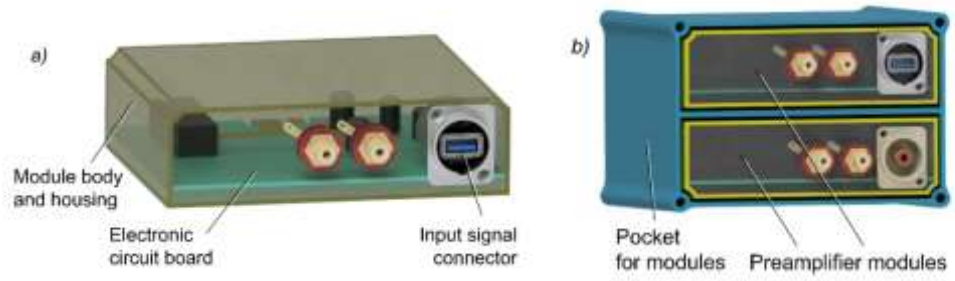
Figure 13. *View of the Rear Panel of the Amplifier before Inserting the Auxiliary Modules*



Auxiliary Modules – Preamplifiers

It was decided to implement the preamplifier modules in the form of cuboids (Figure 14a) strictly filling the space provided in the amplifier pocket (Figure 14b). The electronic circuits of the preamplifier must fit inside the module, and electrical connectors and guides must fit on its external surfaces.

Figure 14. *The Proposed Shape of Auxiliary Modules (a) and Their Location in the Amplifier Pocket (b)*



The adopted spatial configuration of the amplifier was consulted and approved by *DIVALDI*.

Electrical Connection

With the help of the connector, the signal prepared by the preamplifier is included for further amplification. This signal should be transmitted with as little interference as possible. Experts have suggested using connectors that typically carry high-frequency digital signals and have gigabit data rates. Following this path, it was decided to use an edge connector, often used in digital electronics devices, computers, measuring equipment, expansion cards or memories. These connectors carry signals with frequencies of the order of 1 GHz, and sometimes even more. Equally important are the transmitted power signals, and the power of these signals reaches up to 30 W of continuous load. Not every connector is able to accept so much power continuously. The design advantage is the fact that most of them implement one part of the connector in the form of contact pads directly on the board. Other implementations rely on a connector with such functionality, which we solder into the board. Thanks to this, we can make a connection by moving the socket and plug, which implements the assumption of guiding the connector to be inserted using a mechanical interface.

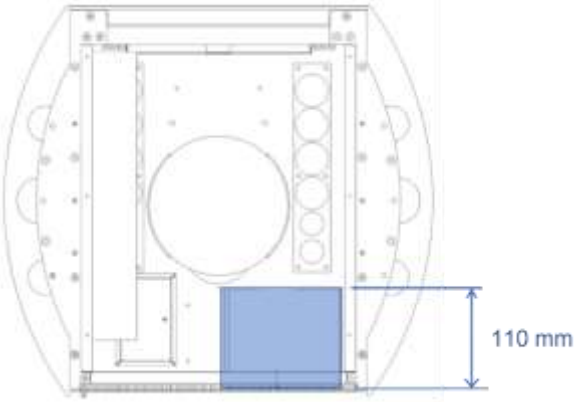
Guide

The mechanical interface has the task of positioning the module in the pocket, guiding it in the pocket when inserting, positioning it relative to the electrical interface, and fixing it in the pocket. A typical assembly that can perform these functions are guides. Trading guides consist of a trolley and a rail. Due to the small loads that occur between the module and the pocket when installing the preamplifier, it was decided to use a sliding guide.

Design of the Amplifier

On the basis of the previously conducted analysis, commercial parts were selected, and then a solid model of the module and the cooperating pocket was developed, which were oriented in the model of the acoustic amplifier supplied by the company. The project involved modification of the frame plate of the current amplifier design, creating space on the back plate (Figure 15) and developing the structure of the module pocket and the module itself.

Figure 15. *Determination of Pocket Depth*



Selection of Commercial Components

The required high quality, availability and multitude of types of edge connectors decided on the choice of edge connectors from the global manufacturer of Molex connectors. Due to the above requirements, the following types of edge connectors were taken into consideration for further comparative analysis: PCI Express, Sliver Card Connector, SATA, SAS SCSI, EdgeLock, Edge-Line, EdgeMate. Then, each of the connectors was analysed due to the parameters offered and the functionality it brings. The results of the analysis are presented in a summary table (Table 2), in which the most important features of each joint from the functional point of view were distinguished and assessed using a point scale.

Table 2. *Evaluation of Technical Properties of Joints with Scoring (Excerpt)*

c	Advantages	pts	Disadvantages	pts	cost	pts	Σ
PCI	- 8Gb/s data transmission - 36 signal lines - max 50VDC - the second connector is a board – Gold plated - Huge popularity	5	- Low resistance to the number of insertion and removal cycles: 50 - max 1.1A per line, so you have to run the power supply in parallel through several lines - assembly perpendicular to the receiving board	6	Minimum: 1 pc. 1 item: PLN 6.20	5	16
Silver Edge	- 32Gb/s data transmission - 140 signal lines - Higher durability: 200 cycles - mounting to the side of the board - gold plating of contacts - good fixing to the board	7	- low maximum voltage 29V; (on the border)	5	Parallel: Min.: 4,800pcs. 1 item PLN 23.28 Perpendicular: Min.: 16,800 pcs. 1 pc.: PLN 5.94	1	13
SATA	- 6Gb/s data transmission - High current 1.5 A per line, so we only divide the power supply into 2 lines, - max 30VDC perfectly fits the requirements, - high endurance of 500 cycles	3	- need to purchase both male and female connector	3	Minimum: 1 pc. 1 pair: PLN 8.44	4	10
SAS SCSI	- Data transmission 6Gb/s - max 30 VDC ideally suited to the requirements - high durability of 500 cycles - more lines (29) than SATA	4	- the need to purchase both male and female connectors, - max current 1.5 A per line, so we only divide the power supply into 2 lines,	4	Minimum: 2500 1 item: PLN 16.81	2	10
edgelock	- double crimp bracket with embossed contact pads as protection against slipping out - max current 3A - max 125VDC - the connector does not need a second plate, it has wires to be stretched to the devices	2	- the need to make a hole and fixing field in the plate - the need to develop a mechanism to open the safety catch - no possibility of attaching to the plate - no data on adaptation to very small high-frequency signals - the connector is more suitable for power transmission than audio signals	2	Min.: 1pc: 1 piece: PLN 2.93	6	10

On this basis, taking into account the economic advantages - greater popularity and over 12 times lower cost - it was decided to choose the PCIe connector. The author notes that the use of the Edge-Line ESP Power Plus connector is limited to the proprietary connector of one manufacturer, which in the future may cause problems with spare parts and the need for re-analysis in order to change the interface in new products.

On this basis, a set of features of each of the solutions is presented below. Three models of commercial guides were presented, the dimensions of which were initially qualified as possible for application between the pocket and the module. The results were compiled in a Table 3 on the basis of which the solution was selected.

Table 3. *List of Features of the Considered Commercial Guides*

Solutions	Advantages	Disadvantages	Cost
Igus drylin® N (low profile)	- Commercial solution - The *iglidur ® insert* is electrical insulator	- trolleys not adapted to multiple assembly and disassembly of the guide without special treatment of the guide - a fixed insert makes it difficult to remove the play	Trolley: PLN 11.05 Guide: PLN 88.90
Igus drylin ® T (miniature) Carriage: TW-04-07 Guide TS-04-07	- Commercial solution - The *iglidur ® insert* is electrical insulator	- trolleys not adapted to multiple assembly and disassembly of the guide without special treatment of the guide - a fixed insert makes it difficult to remove the play	Trolley: PLN 107.75 Guide: PLN 119.35/m
Pacific Bearing Mini Rail MR7	- Commercial solution - the ability to work at different temperatures - ceramic coating	- trolleys not adapted to multiple assembly and disassembly of the guide - no play clearance - the largest shopping trolley	Trolley: PLN 92.80 Guide: PLN 228.60/m
Sliding guide (plastic shell)	- can be built into the pocket and the module - huge compactness - a bearing shell with an electrical insulator - the bearing shell can be entirely made of plastic or it can be made of steel and covered with a plastic tape - the possibility of additionally designing clearance clearance	- own project - time devoted to the preparation of technical documentation - searching for the manufacturer of the part in the material of the cup	on order:

The considerations contained in the table above led to the conclusion that due to the similarities between the individual commercial guides, the choice is not made between four and two solutions - a commercial solution and the development of own construction. Both the carriages and the guides are of similar dimensions, so the constructor should choose them based on different properties. When choosing

commercial guides, the size of the trolley and the guide may be a problem. It will not allow for the maximum use of available space by limiting the possibilities of integrating solutions.

On this basis, it was decided to develop our own way of carrying the module in the pocket. Optimal use of the available space, which determines the maximum dimensions of the module's electronics system. In the future, this may be a threshold condition for creating new systems, so the designer's task is to provide as much space as possible, and it is also important, as in the case of the electrical interface, that the in-house design is resistant to the risk of being withdrawn from production by a third party.

Design Development

The pocket is located in the back part, on the right side. This caused the connectors in this place to be shifted to the left. The space for the previous solution of classic preamplifiers has been removed. The pocket is attached to the amplifier frame plate with rivets (Figure 16). Two printed circuit boards with fixed PCIe connector mounting holes were attached directly to the bay (Figure 17). The electrical leads of the connector are adapted to be threaded through the plate.

In the pocket, unlike the module, there is no need for a high-quality design form, as it will be hidden in the amplifier behind the back plate. The pocket will not be exposed to falls due to the user's inattention, so there is no need to provide it with increased stiffness and impact resistance. On this basis, it was decided to choose a sheet metal structure that would ensure the correct positioning of the module before connecting to the electrical interface at low manufacturing costs.

Figure 16. *Pocket for Modules Fixed Inside the Amplifier*

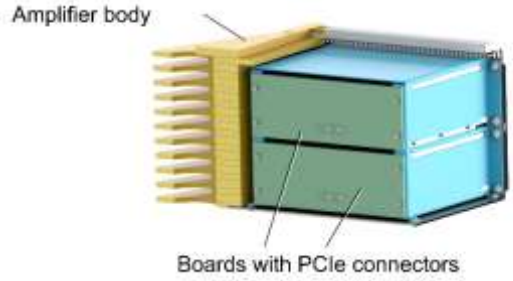
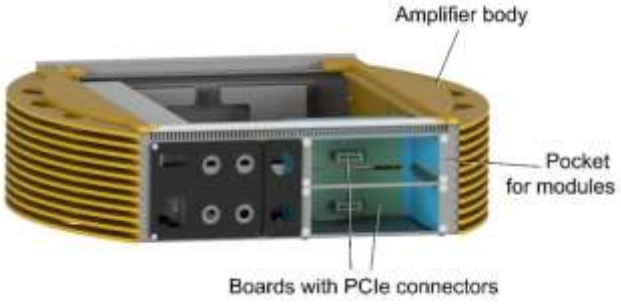


Figure 17. *Rear View of the Amplifier - Printed Circuit Boards (marked green) with PCIe Connectors Located on them are Visible in the Pocket*

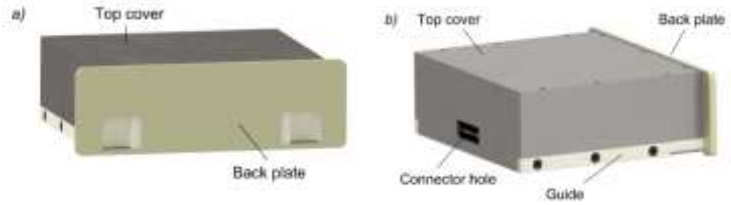


The pocket is a sheet metal structure attached to the frame with rivets. It is attached to the rear panel with conical rivets, thanks to which they do not protrude beyond the outline of the amplifier and do not constitute an obstacle to the installation of modules.

The body of the module will carry mainly loads from the mass of electronics and transport loads during the distribution process. Due to the loads mainly coming from the electronics system, which can be assumed to be in the order of hundreds of grams, it should be as light as possible. Then such a module will load its weight on the module pocket and the guide. Another requirement is the electromagnetic isolation of the module from the environment and the appropriate stiffness of the modules so that it works properly in the guide. The material of choice is either steel alloys or aluminium alloys in the 7075 family.

As part of the construction of the module body, a monolithic structure of a sheet metal, milled or cast body was considered. In order to implement a rigid structure, it was decided to make the body, which also serves as a housing, from milled duralumin elements. Input signal connectors are attached to the rear panel. The top cover eliminates the user's direct access to the electronic circuits (Figure 18). The modules were guided by elements made of sheet metal. The pocket has rectangular holes for latches that position and hold the module, preventing it from sliding out on its own.

Figure 18. *Mechanical Structure of the Preamplifier Module: a) Rear View, B) Front View*



Inside the module, closed with the top cover, there is a printed circuit board with the maximum possible overall dimensions. There is an edge connector on the board that is designed for a PCIe connector that slides through the hole. Mirror guides, made of Teflon, constitute a friction pair with a pocket made of steel sheet. The guides have latches that are deflected by the slats (Figure 19). An undercut was made in the leaves to allow them to be pulled back with the fingers of the hand (Figure 20).

Figure 19. *View of the Module after Removing the Back plate and Cover*

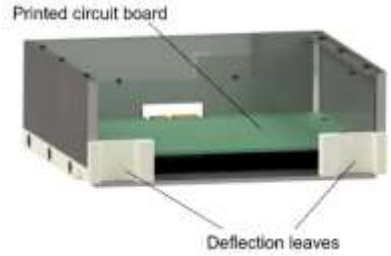


Figure 20. *Left Guide with a Latch*

Discussion

The described work is an important part of the design of the modular acoustic amplifier. As a result, documentation of the mechanical structure of the device was created, which ensures the possibility of easy installation and replacement of preamplifier modules. This documentation defines a kind of standard adopted by DIVALDI, which can be used in the subsequent years of production and development of the INT-02 amplifier.

The implementation of the construction study was preceded by a broad review of sources devoted to the design of modular systems. Thanks to this, it was possible to formulation by DIVALDI of the most important assumptions regarding the amplifier in the context of individual phases of the product's life. At the same time, it was noticed that an effective way of obtaining the necessary information from the contracting authority is to familiarize him with particular issues of modularity in a sequential manner. Thanks to this, it is easier for a company that has not carried out similar projects so far to make decisions regarding the further course of the project. At the same time, a review of publications showed the lack of an unambiguous algorithm for building modular structures (Gershenson et al. 2003). For this reason, after formulating the key assumptions, the authors decided to base further work on the methodology of designing mechatronic devices known to them, which guarantees the correct fulfilment of the adopted technical and operational assumptions. This methodology is a convenient tool for teams constructing technical structures including mechanics, electronics and software. Due to the adopted manual nature of the activities performed when operating the modular amplifier, this methodology was somewhat simplified, because there were no software components in the project, and electronic issues were reduced only to the use of a signal connector and the issue of signal shielding.

The issues of building modular systems are presented in the available literature by many specialists, however, often guided by different points of view. For this reason, it is difficult to combine these issues into a logical arrangement, allowing for the effective conduct of development projects. The authors had the opportunity to learn about these difficulties on the example of the described design of a modular amplifier. In this way, they gained some experience in combining the economic, management and engineering aspects of modularity, which is a strong impulse for them to undertake research on the principles of conducting such projects.

Conclusions

The analyses carried out during the project and the construction work performed are the basis for formulating conclusions regarding both the amplifier design itself and the methodology of proceeding in the construction of modular systems.

1. The design of the modular acoustic amplifier has set an internal standard covering the geometry and spatial configuration of the elements that make up the auxiliary modules. If approved by the Company's management, this standard will be in force for a longer period of time, probably for at least several years. During this time, the modules, both basic and auxiliary, will undergo natural developmental changes. For this reason, it is important that the adopted restrictions do not hamper this development. It seems that one of the ways to eliminate potential threats in this area should be to develop electronic structures of all currently planned preamplifiers to confirm that each of the developed boards will fit in the space provided for it in the auxiliary module and will be able to function properly in it.
2. Analysing the developed structure, it can be seen that it has the potential for expansion not only as part of further improvements of the interface pocket - preamplifier module, but also in the basic module itself. One of the possible directions of development of the design is the implementation of the front panel of the amplifier as another module, which, depending on the version, would extend the functionality of the entire amplifier or adapt the user interface to its needs, including stylistic needs.
3. Modular constructions, like other constructions, are created either as a result of the company's internal development work, or are commissioned to specialized design units. In both cases, decisions regarding the adopted standard are most often made by the company's management and are validation of the project. The specificity of modularity and the serious consequences that result from it indicate that those who decide on the scope and shape of the limitations introduced by modularity should have some knowledge of various aspects of modular constructions. On this basis, the authors suggest that projects of this kind should include some kind of training on modularity, or even workshops for the management of the companies concerned. Such action may increase the awareness of those responsible as to the consequences of their decisions.
4. The authors are convinced that the available knowledge on the construction of modular systems and their own experience in this field may be the beginning of work on an algorithm or a set of algorithms for project management of such systems. In the initial phase, it is planned to develop a detailed description of already implemented projects, including the one presented in this article. The target algorithm can then be created as a result of its further improvement. In these works, the technique of process modelling (Zakarian and Kusiak 2000) and their simulation using Petri nets (Kusiak and Yang 1993) or fuzzy graphs (Li et al. 2008) are expected to be used. This may also require modelling data from previously designed processes and determining the impact of the results of the analysis of such data on further actions (Kusiak et al. 1997). A clear, proven algorithm should not only increase the efficiency of the projects carried out, but

also reduce the risk of making significant mistakes, especially at the stage of formulating assumptions.

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