INTERNATIONAL SCIENTIFIC JOURNAL



SCIENCE . BUSINESS . SOCIETY

YEAR 10, ISSUE 1/2025

ISSN PRINT 2367-8380

ISSN WEB 2534-8485

PUBLISHERS:

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING "INDUSTRY 4.0"

108 RAKOVSKI STR., SOFIA 1000, BULGARIA

NATIONAL SOCIETY "INDUSTRIAL & NATIONAL SECURITY"

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ISSN: PRINT 2367-8380
ISSN WEB 2534-8485
YEAR X, ISSUE 1 / 2025

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Solution of a generalized system of differential equations of intercoupled energy and mass transfer at short-term phase contact

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Abstract: *Modern intensification of materials processing technology leads to an increase in the role of non-stationary interconnected exchange processes compared to stationary unconnected interconnected exchange processes compared to stationary unconnected. This fact is still insufficiently reflected in the field of solving energy and mass transfer problems (EMT) at small Fourier numbers (Fourier numbers $F_{0_K} \leq 0.1$) at short-term phase contact (SPC). In this article, a generalized mathematical model of interconnected non-stationary irregular energy and mass transfer mode at short-term contact across a boundary with selective permeability of phases is formalized. In vector-matrix form, a conjugate mixed boundary value problem is solved with excitation in each of the phases of flows of substances absent in the other phase. By analogy with heat exchange and mass exchange, matrices of potential assimilation of phases and a contact matrix are introduced, which allows obtaining a uniform solution for a number of special cases and especially simplified the entry for the vector of interphase flow densities. The mathematical notation of the solutions of the considered parabolic system of partial differential equations of the second order for intensive irreversible processes (Fourier numbers $F_{0_K} \leq 0.1$) are written in vector-matrix form and are close to the scalar Higbee theory for mass transfer.*

KEY WORDS: *SHORT-TERM CONTACT, MATHEMATICAL MODELING, SYSTEMS OF DIFFERENTIAL EQUATIONS, POTENTIALS, PHASES, MODES, VECTOR, MATRIX, HEAT AND MASS TRANSFER, COEFFICIENTS.*

1. Introduction

The processes of diffusion-filtration energy and mass transfer through capillary-porous colloidal and colloid-capillary-porous bodies are very complex and closely interconnected [1-4]. In many branches of industry (high-temperature heat exchangers, turbine blades, rocket nozzles, skins of high-speed aircraft, boiler installations, lining of heat and power generating plants, nuclear reactor systems with internal cooling, heat and power grids, etc.) high-intensity and high-temperature technological processes are nonlinear, non-stationary, non-uniform and asymmetric in nature, that is, at sufficiently high thermal, concentration and filtration gradients of potentials, the kinetic coefficients included in the conjugate system of differential equations depend on the parameters of the state of the transfer potentials, which in turn depends on the four-dimensional space of events of independent state parameters. [1-4, 10, 11].

2. Main Body

The generalized mathematical model (GM) of the interconnected non-stationary EMF with variable transfer coefficients and CCF conditions is formulated as a system of equations (SE) written in vector-matrix form [4,5]:

$$C_i\Pi_{i\tau} = (L_i\Pi_{ix})_x,\ \tau > 0, x \in ((-1)^i\infty, 0), i = 1,2 \qquad (1)$$

$$\Pi_i(x,0) = \Pi_i\left[(-1)^i\infty, \tau\right] = \Pi_{oi},\ \ \forall|x| > 0; \qquad (2)$$

$$K_\Gamma\Pi_i(0,\tau) = \Pi_{i+1}(0,\tau); \qquad (3)$$

$$L_i\Pi_{ix}(0,\tau) = L_i\Pi_{ix}(0,\tau), \qquad (4)$$

where Π_{it}, Π_{ix} are the local change in the vector of transfer potentials of dimension n_i, respectively, with respect to time τ and coordinate x in the i-th phase, x is the coordinate along the normal to the plane of contact with zero at the phase boundary, C_i, L_i are the matrices of capacitive and kinetic coefficients, respectively. Moreover, the elements of C_i are defined as the ratio of the stored amount of substance to the corresponding transfer potential and depend on the choice of units of measurement Π_i, just like the elements of L_i. The dimensions of the vectors Π_i are equal to n_i and, generally speaking, do not coincide, for example, in the case of coupled transfer in capillary-porous bodies (phase 2) in contact with a heating metal surface (phase 1), then $n_2 > n_1$[6,7]. Under the condition $\dim\Pi_i = \dim\Pi_2$ $(n_1 = n_2)$, the operations of narrowing the vector or matrix from $R_1 \cup R_2$to $R_1 \cap R_2$ and expanding by zeros in $R_1 \cup R_2$ are possible, K_Γ is the diagonal matrix of equilibrium constants $(n_1 \times n_2)$. In particular, if we are talking about multicomponent diffusion and heat propagation, then the diagonal K_Γ consists of Henry constants or coefficients of the linearized representation of the equilibrium compositions of the phases [8] and a unit corresponding to thermal equilibrium when determining the temperature of the phases in the same units of measurement.

The conjugation conditions (3) and (4) mean that in the absence of concentrated resistance at the phase interface x=0, the conditions of continuity of flows and transfer potentials apply. Using the self-similarity condition (2) and further omitting the phase index, the matrix equation (1) for the stated limit boundary value problem can be written in the form of a system of ordinary differential equations (SODE) of the form:

$$2tC(t)\Pi_t(t) + [L(t)\Pi_t(t)]_t = \bar{0}, \qquad (5)$$

where $t = x/2\sqrt{\tau}$ is the Boltzmann support, $\bar{0}$ is the zero vector. Further denoting the derivative $\Pi_t(t)$ by Z, we obtain an autonomous first-order SODE of dimension $\sum_{i=1}^{n} n_i$ with respect to Z(t)

$$L(t)Z_t + K(t)Z = \bar{0}, \qquad (6)$$

here $K(t) = 2tC(t) + L_t(t)$. In turn, SODE (6) can be represented as

$$Z_t = A(t)Z, \qquad (7)$$

where $A(t) = -[K(t)][L(t)]^{-1} = \|a_{ik}(t)\|$ is a continuous matrix function in some (finite or infinite) interval (a,b) of change of the real argument $t(i, k = \overline{1,n})$. The general solution of equation (7) has the form

$$Z = C_0M_{t_0}^t, \qquad (8)$$

where $Z(t_0) = Z_0 = E$ is the identity matrix; $M_{t_0}^t(A)$ is the matricant that determines the normalized solution (7), C_0 is an arbitrary constant matrix with determinant $|C_0| \neq 0$. The matricant and successive approximations Z_j can be found from the recurrence relations

$$M_{t_o}^t(A) = Z_j = Z_{j-1} + \left[\int_{t_0}^{t} A(t)\,dt\right]^j \quad j = \overline{1,n}. \qquad (9)$$

In the special case when A is a constant matrix

$$C_0 = Z_0 e^{-At_0}, \quad (10)$$

the general solution of equation (7) can be written as an integral matrix

$$Z = Z_0 \exp\left[A(t - t_{0)}\right], \quad (11)$$

where

$$e^{At} = \sum_{k=1}^{s} Z_k = \sum_{k=1}^{s} (X_{k1} + X_{k2} + \ \dots \ X_{km_k} t^{m_k - 1}) e^{\lambda_k t} \quad (12)$$

Here

$$\psi(\lambda) = (\lambda - \lambda_1)^{m_1} (\lambda - \lambda_1)^{m_2} \dots (\lambda - \lambda_s)^{m_s}$$

$$(\lambda_i \neq \lambda_k at \ \ i \neq k; i, k = \overline{1, s})$$

- the minimal polynomial of matrix *A*, and X_{kj} are linearly independent constant matrices that are polynomials in *A*, since in the right-hand side of formula (12) each term Z_k is a solution to equation (7), which is satisfied by the product $\varphi(A)e^{At}$ for any function *φ(λ)*, but $Z_k = f(A) = \varphi(A)e^{At}$, if $f(A) = \varphi(A)e^{At}$ and $\varphi(\lambda_k) = 1$, and the remaining m – 1 values of the function *φ(λ)* on the spectrum of matrix *A* are equal to zero [6]

Expressions (11), (12) make it possible to specify the structure of the desired solutions in the form of a linear combination of integral matrices. Then, as in [5-7], the solution to the CCF problem with constant transfer coefficients is represented as a linear combination of additional Gaussian probability integrals

$$Z(t) = Z_0 + terfc\left(v_j^{-1} t\right) C, \quad (13)$$

where $erfc\left(t/v_j\right)$ is the additional error integral function, v_j is the square root of the eigenvalue of the matrix *A*. In (13), the $erfc$ operation is applied to the diagonal elements of the matrix $v^{-1}t$ element-wise:

$$Z(t) = Z_0 + \sum_{i=1}^{n} c_i \, erfc(t/v_i) t_i, \quad (14)$$

where the j-th eigenvector t_j is the solution of the ES $At_j = v_j t_j$. It is easy to see that ES (5) with constant *C* and *L* and condition (2) is satisfied identically, and the vectors $C_1 \epsilon R_1$ and $C_2 \epsilon R_2$ of the constants of integration are determined from the boundary conditions (3) and (4). The generalized solution of the boundary value problem of the CCF with a functional dependence of the transfer coefficients on the potentials (the parameters of the state of the system) is reduced by two quadratures to the solution of the following system of nonlinear integral equations:

$$\Pi(t) = C_0 \int_{t_0}^{t} \exp\left\{-\int_{t_0}^{t} [L_t(t) + 2tC(t)] \, L^{-1}(t) dt\right\} dt. \quad (15)$$

3. Conclusions

A generalized mathematical model of the interconnected non-stationary irregular energy and mass transfer mode during short-term contact across the boundary with selective permeability of phases is formalized.

A conjugate mixed boundary value problem is solved in vector-matrix form when excitation of flows of substances absent in the other phase is carried out in each of the phases.

By analogy with heat and mass exchange, matrices of potential assimilation of phases and a contact matrix are introduced, which allows obtaining a uniform solution for a number of special cases and especially simplified the entry for the density vector of interphase flows.

The mathematical entry of solutions of the considered parabolic system of partial differential equations of the second order for intensive irreversible processes (Fourier criterion Fok ≤0.1) is written in vector-matrix form and is close to the scalar Higbee theory for mass transfer.

A set of thermophysical, chemical and thermodynamic characteristics together with mathematical modeling allows to reveal the regularities of external and internal heat and mass transfer in the most complete way, to find scientifically based ways of intensification and modular design of similar processes and devices of chemical engineering, biotechnology, industrial power engineering, mechanical engineering and construction industry (heating, cooling and condensation, rectification, evaporation, vacuum and convective drying, drying by pressure reduction, oscillating and combined drying method, drying of thermo- and xerolabile products by pulse pressure and vacuum release, absorption and adsorption, extraction, liquid distillation, crystallization, etc.).

The obtained results serve the development of the general theory of mathematical modeling, are useful in setting up experimental studies on non-stationary heat and mass transfer in the analysis and calculation of exchange processes of chemical engineering, biotechnology and bioengineering, industrial power engineering and design.

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Comparison of IMRT techniques for head and neck cancer treatments based on two different mathematical algorithms
Anisotropic analytical algorithm and convolution/superposition

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Abstract *Intensity Modulated Radiation Therapy (IMRT) is considered a crucial treatment for Head and Neck cancers for several key reasons related to the complexity of the tumor locations, the proximity to critical structure (organ at risk), and the need for precise dose delivery – distribution. Head and Neck cancer involve areas with highly heterogeneous tissues, which can present significant challenges for traditional radiation therapy techniques. IMRT addresses these challenges by offering highly conformal and precise radiation delivery that targets the tumor while minimizing damage to surrounding healthy tissue. In the context of IMRT, the mathematical algorithms, AAA (Anisotropic Analytical Algorithm) and Convolution/Superposition part of Monte Carlo Algorithm, are used in different aspects of treatment planning and dose calculation. Both algorithms are designs to compute the dose distribution in the body from radiation beams used IMRT, but they do so in distinct ways, and each has specific, use cases depending on the treatment and patient anatomy. Both algorithms, in IMRT are ultimately concerned with how radiation interacts with matter, specifically hoe energy deposition occurs in tissue as the radiation passes through them. The AAA and C/S algorithm consider tissues heterogeneity, but they model these interactions differently, which affects how they calculate the dose distribution. In our department of radiotherapy, of Amerikan Hospital Tirana we have installed and use both algorithms, in different treatment planning system which are developed by Varian and Elekta production company.*
KEYWORDS: *IMRT, AAA, CONVOLUTION/SUPERPOSITION, DOSE DISTRIBUTION*

Introduction

In the context of Intensity-Modulated Radiation Therapy (IMRT) the AAA algorithm and Convolution / Superposition algorithm are used in different aspects of treatment planning and dose calculation. Both algorithms are designed to compute the dose distribution in the human body from radiation beams used in IMRT, but they do so in distinct ways, and each of them has specific use cases depending on the treatment objectives and patient anatomy.

In radiation therapy, algorithms are often classified as Type A or Type B based on the complexity of their dose calculation and their approach to handling tissue heterogeneity. These classifications are more commonly used in the context of radiation transport and dose calculation methods, particularly in relation to their physical modeling and precision.

Type A algorithms are generally considered analytical methods or approximations that calculate dose distributions using simplified models of radiation transport and tissue interactions.

AAA is based on an analytical pencil beam model that uses simplified physics assumptions to approximate the radiation dose. While it includes a correction for tissue heterogeneity (anisotropic scattering), it does not simulate the detailed physics of radiation interactions.

Therefore, AAA is classified as a Type A algorithm because it is an approximate method with simplified mathematical models to estimate the dose distribution.

Type B algorithms are more advanced and physically detailed, often using superposition or convolution techniques to calculate the dose distribution. These algorithms are capable of modeling the physical interactions of radiation with tissues more accurately, especially in heterogeneous areas (e.g., around bone, air, and soft tissue interfaces).

Superposition calculates the dose distribution by adding up the contributions from each individual beam and modeling the radiation transport with more physical accuracy, especially in complex tissues.

The AAA (Anisotropic Analytical Algorithm) and Convolution/Superposition Algorithm are both techniques used in the context of solving problems, particularly in fields like signal processing, system modeling, and numerical methods. In the context of Intensity-Modulated Radiation Therapy (IMRT), the AAA (Anisotropic Analytical Algorithm) and C/S (Convolution/Superposition) Algorithm are used in different aspects of treatment planning and dose calculation. Both algorithms are designed to compute the dose distribution in the body from the radiation beams used in IMRT, but they do so in distinct ways, and each has specific use cases depending on the treatment objectives and patient anatomy.

In the treatment of head and neck cancer using Intensity-Modulated Radiation Therapy (IMRT), both, the AAA (Anisotropic Analytical Algorithm) and Superposition Algorithm are used, but the preference depends on the specific needs of the treatment and the clinical environment.

Methodology

Both algorithms are crucial in IMRT for ensuring that the radiation dose is delivered effectively to the tumor while minimizing exposure to surrounding healthy tissue. The choice of algorithm depends on the specific requirements of the treatment plan, including computational speed, accuracy, and the complexity of the anatomy involved.

The AAA (Anisotropic Analytical Algorithm) and the C/S (Convolution/Superposition) Algorithm in IMRT are ultimately concerned with how radiation interacts with matter, specifically how energy deposition occurs in tissues as the radiation passes through them. Both algorithms take into account tissue heterogeneity (variations in tissue density and composition), but they model these interactions differently, which affects how they calculate the dose distribution. In radiation therapy, the goal is to calculate how much energy is deposited by the radiation beams in different parts of the tissue, which in turn affects the biological effectiveness of the treatment. The energy deposition is influenced by several factors, including:

- The type and energy of the radiation (e.g., photons, protons, etc.).
- The atomic composition and density of the tissues the radiation passes through (heterogeneous tissues like lung, bone, muscle, etc.).
- The geometry of the tumor and surrounding organs.

Both the AAA and C/S algorithms take into account energy deposition in different ways, based on how the radiation interacts with matter, especially with tissue heterogeneity.

The AAA algorithm uses a pencil beam model for dose calculation, where it simulates how each individual beam interacts with tissues. It then accounts for heterogeneities (like air, bone, muscle) by adjusting the dose deposition based on tissue density.

In terms of energy deposition, AAA calculates how the dose from each beam contributes to the overall energy deposition at each point in the treatment volume, factoring in the material properties (like electron density) of tissues the radiation passes through. [1,7,8]

AAA uses a heterogeneity correction to model how radiation interacts differently with tissues of varying density (e.g., bone, lung, and soft tissue). For example, bone will absorb more energy per unit mass than soft tissue because of its higher electron density.

The energy distribution coming from a single arbitrary β ray (pixel) due to photons in a sufficiently large homogeneous region is calculated by the formula:

$$E_{ph,\beta}(\tilde{X},\tilde{Y},\tilde{Z}) = \Phi_\beta \times I_\beta(z,\rho) \times K_\beta(X,Y,Z)$$

The photon flux Φ_β is assumed to be uniform over the small intersections of the β beams.

The energy deposition function $I_\beta(z,\rho)$ shows the area integral of the energy deposited over the surface of the pencil bundle sphere at depth z:

$$I_\beta(z) = \iint h_\beta(t,v,z)\,dtdv$$

where h_β is a poly-energetic kernel of pencil beam derived by Monte Carlo simulations.

The electron density of tissues is a critical factor in calculating dose accurately, as it affects how much energy is deposited by the photons or particles in each voxel (small unit of 3D space).

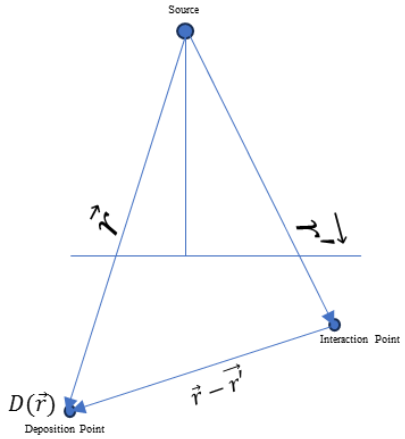


Figure 1. *Mathematical representation convolving a dose kernel*

The C/S algorithm is based on convolving a dose kernel (a mathematical representation of how radiation energy spreads through tissue) with the tissue's density distribution. It essentially sums the individual contributions of each beam or radiation segment to the total dose, which involves considering how the energy spreads and deposits in the tissue figure 1.

Dose at point $\vec{r}$ is the summation of the TERMA point $T(r')$ times the value of the energy deposition kernel $H(\vec{r}-\vec{r'})$ originating at point r' and evaluated at point r.

$$D(\vec{r}) = \int T(\vec{r'})H(\vec{r}-\vec{r'})d^3r' \text{ (FFT Convolution)}$$

$$D(\vec{r}) = \int T(\vec{r'})\frac{\rho(\vec{r'})}{\bar{\rho}}K_p(\bar{\rho}\left|\vec{r}-\vec{r'}\right|,\vec{r}-\vec{r'})d^3r' \text{ (Superposition)}$$

Where ρ (r') is the density at the interaction point site and $\vec{\rho}$ is the average density along the straight-line path between the interaction site and dose deposition site.

In beamless IMRT, the radiation delivery system can create customized beamlets or intensity-modulated beams without the traditional mechanism of moving the MLC in real-time. It can instead rely on static or pre-calculated beam shapes that do not require continuous changes in the beam shape during delivery. [2, 3, 7, 9]

The C/S algorithm uses a convolution method to model energy deposition, where the dose kernel (which represents the energy deposition per unit dose) is convolved with the tissue composition (including electron density).

It also takes into account the heterogeneity of tissues, but with a focus on how different tissues attenuate (reduce) or scatter radiation, which affects how energy is deposited in the volume of interest. (Barret A., Dobbs J., Morris S., Roques T., (2009))

The superposition part comes in by adding up the contributions from all radiation beams, each of which may interact differently with the tissue fig.2.

- Electron Density is central to both algorithms because it influences how radiation is absorbed by tissues. In the AAA algorithm, the correction for heterogeneities is directly related to electron density, which is used to adjust dose calculations for tissues with different compositions.
- Tissue Composition and Density: Both algorithms model how radiation interacts with tissues that have different densities and atomic compositions. For example, bone (dense, high electron density) absorbs more radiation, while lung tissue (low density) attenuates radiation more rapidly. This affects the energy deposition in those tissues.
- Radiation Beam Interactions: Both algorithms factor in the way radiation beams interact with matter. This includes photoelectric effects and Compton scattering (for photon beams), which contribute to energy deposition and the overall dose distribution.

In both cases, the goal is to accurately predict how radiation interacts with matter and to ensure that the right amount of dose is delivered to the tumor while minimizing damage to surrounding healthy tissue.

Results and Conclusion

In the context of Intensity-Modulated Radiation Therapy (IMRT), the choice of delivery technique—beamless for the C/S (Convolution/Superposition) algorithm and sliding window for the AAA —is primarily driven by the characteristics of the algorithms, the way they calculate dose distributions, and how they interact with the radiation delivery systems.[4,6,7,9]

The C/S (Convolution/Superposition) algorithm is typically used in beamless IMRT systems for several reasons related to how it models radiation delivery and dose distribution.

The C/S algorithm doesn't directly rely on the dynamics of the multileaf collimator (MLC) or sliding window technique during treatment delivery. Instead, it primarily focuses on the shape and intensity of the radiation beam delivered to each point in the tumor and surrounding tissue, based on the dose kernel and tissue composition.

In beamless delivery, the radiation source remains stationary in space (it may be positioned at a fixed set of angles), and the radiation intensity is modulated across the entire target volume, but without needing to adjust beam shapes continuously during treatment delivery. This is well suited for the C/S method, where convolution of the dose kernel with the target volume's heterogeneity can be performed efficiently without needing to dynamically change the beam aperture.

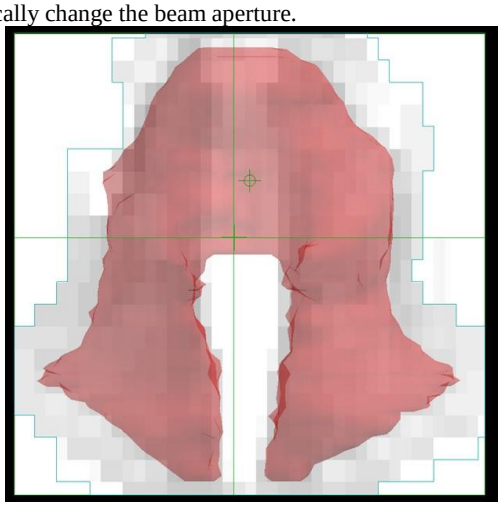


Figure 2. *Interaction of IMRT beamless in base of body density created by S/C algorithm*

The beamless IMRT technique can sometimes use predefined dose distributions or static beams, allowing the dose calculation (via the C/S algorithm) to be efficiently implemented with less real-time complexity.
Beamless delivery often takes advantage of advanced treatment planning, where complex modulations are pre-planned, and the system uses efficient delivery techniques that do not require real-time beam adjustments (like sliding windows).
The AAA in contrast, is usually associated with sliding window IMRT. The AAA algorithm typically uses a dynamic multi-leaf collimator (MLC) to modulate the radiation intensity. During delivery, the MLC continuously changes shape as the radiation beam is delivered, creating a more gradual modulation of intensity across the tumor volume.
In the sliding window technique, the MLC moves continuously during treatment delivery, creating dynamic beam shapes (or beam apertures) as the radiation is delivered. This is particularly well-suited for the AAA algorithm, which calculates dose distributions based on these dynamic changes in beam shape figure 2.
Since in our department both systems are independent and function separately, this allows us to assess which of the algorithms will give us the best dose distribution based on the patient's geometric complexity.
It is also worth noting that the use of the electron density phantom has been of great help, based on which we have been able to create calibration curves for each of the algorithms based on the data coming from its scanning for different energies.

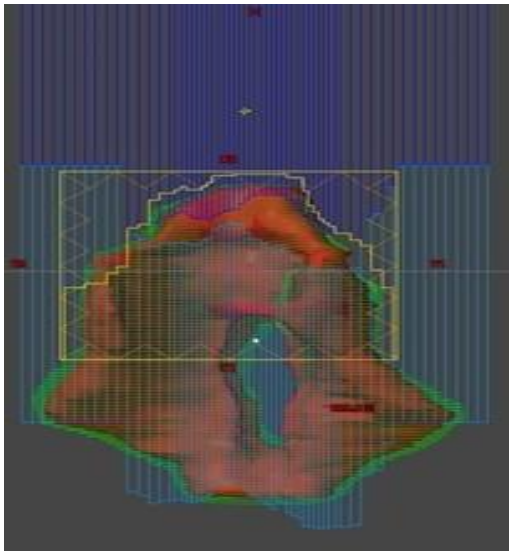


Figure 3. *IMRT sliding window techniques created by AAA algorithm*

The AAA algorithm requires precise control over the intensity modulation throughout the treatment. The sliding window technique allows for fine-tuning of the dose distribution by continuously adjusting the beam shape and intensity during treatment. This ensures that the dose distribution is accurately calculated and delivered as per the treatment plan.
Since AAA uses a pencil beam model, it benefits from the continuous modulation that a sliding window provides, enabling dynamic adjustment of the intensity profile across the beam's path as it delivers radiation.
Sliding window IMRT is generally more time-efficient for delivering highly modulated intensity profiles, especially for complex IMRT plans where the dose distribution varies significantly across the target volume.
The AAA algorithm works well in this context because it can calculate the overall dose distribution with high precision using the continuously varying intensity profile provided by the sliding window.
The C/S algorithm is often associated with beamless IMRT because it can calculate the dose distribution efficiently with fixed or pre-calculated beam shapes, without requiring real-time adjustments to the MLC during delivery.
The AAA algorithm is typically used in sliding window IMRT because it benefits from continuous dynamic changes in the beam aperture and intensity, which are required to implement the complex, highly modulated dose distributions that the algorithm calculates. The sliding window provides the dynamic control necessary for the AAA algorithm to deliver a precise and accurate dose fig 4.
In Head and Neck (H&N) cancer treatment, the dose distribution figure 5. is crucial because the target volume (tumor) is located close to critical structures such as the spinal cord, parotid glands, eyes, and other organs at risk (OARs). Achieving a high-dose concentration to the tumor while minimizing dose to the surrounding healthy tissues is essential for effective treatment.

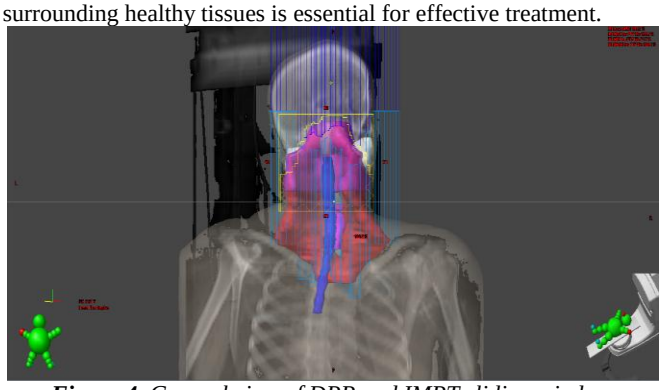


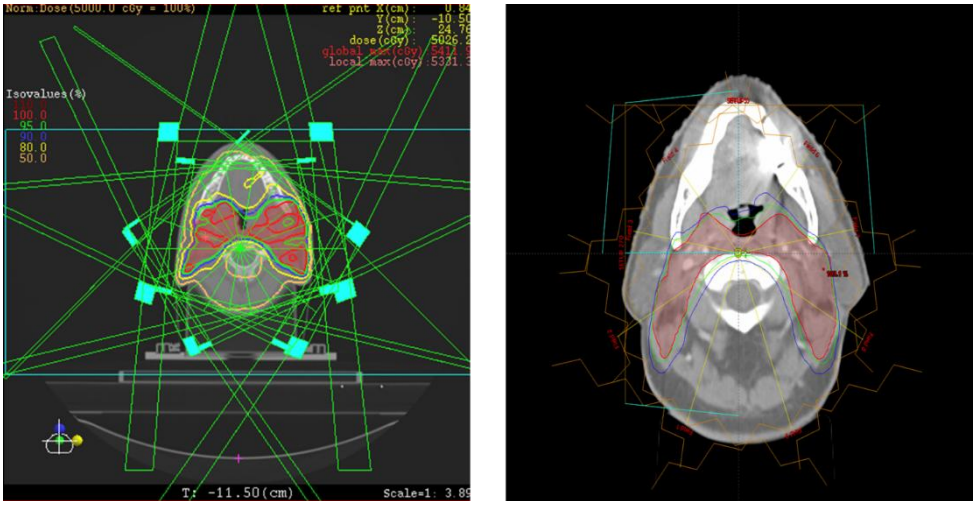
Figure 4. *General view of DRR and IMRT sliding window technique*

The dose distribution in IMRT (Intensity-Modulated Radiation Therapy) is influenced by the delivery technique and dose calculation algorithm used. The two algorithms you mentioned — C/S (Convolution/Superposition) and AAA (All-at-Once) — both calculate the dose distribution differently, and this can lead to variations in the treatment outcomes, especially for complex anatomical regions like the head and neck.
The C/S (Convolution/Superposition) algorithm is known for its precise handling of complex tissue heterogeneity. In the context of Head and Neck cancer treatment, this translates to a detailed modeling of how radiation interacts with various tissues in the treatment area, such as bone, soft tissue, muscle, and air-filled spaces (like the oral cavity or sinuses).

Conclusion

The **C/S algorithm** is often associated with **beamless IMRT** because it can calculate the dose distribution efficiently with fixed or pre-calculated beam shapes, without requiring real-time adjustments to the MLC during delivery.
The **AAA algorithm** is typically used in **sliding window IMRT** because it benefits from continuous dynamic changes in the beam aperture and intensity, which are required to implement the complex, highly modulated dose distributions that the algorithm calculates. The sliding window provides the dynamic control necessary for the AAA algorithm to deliver a precise and accurate dose.
C/S Algorithm provides a **precise dose distribution** for **Head and Neck cancers** by modeling the complex interactions of radiation with heterogeneous tissues. It works well with **beamless IMRT**, delivering predefined intensity-modulated beams to the tumor while sparing critical organs. However, it may have limitations when fine-tuning the dose delivery in real-time.
AAA Algorithm with **sliding window IMRT** allows for **dynamic intensity modulation** and is particularly effective in **sculpting the dose** around tumors in **Head and Neck** cases. It enables **high precision** in dose delivery, minimizing exposure to critical structures while maximizing tumor coverage.
In both cases, **accurate dose distribution** is key to successfully treating **Head and Neck cancer**, and both algorithms are designed to ensure that **high-dose radiation is delivered to the tumor** while

minimizing dose to surrounding healthy tissue. The choice between the two often depends on the specific treatment goals, tumor location, and the ability to deliver precise radiation based on the available technology.



a) b)

Figure 5. *Dose distribution according a) C/S algorithm and b) AAA algorithm*

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Building eco-friendly houses with construction coatings, bricks and panels based on sedimentary rocks

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Abstract: *In the development of new composite structural elements based on sedimentary rocks (clays) as inorganic binders and foam composite materials, their physical characteristics are presented for the construction of recipe compositions and the determination of their complex new properties. The role of the components of the compositions, together with organic reinforcing fiber materials such as straw, rice husks and others, basic parameters of the technological regime and other factors for ensuring adequate workability of the prepared composite compositions for obtaining building coatings and elements - bricks and panels for building ecological houses - is considered. The determination of the necessary technological characteristics of the composite mixtures ensures their effectiveness.*

KEYWORDS: *SEDIMENTARY ROCKS (CLAYS), PLASTICITY, DENSITY, VISCOSITY*

1. Introduction

In recent years, luxury homes made from sedimentary rock-based materials have begun to be built in Europe, the US and Australia, with more than 10,000 in Australia alone. Obviously, this is not about some fashion extravagance, because a similar trend can be observed in the construction of public buildings such as schools, hospitals, shops, tourist sites, museums, churches, etc. More and more universities, academic institutions and construction companies have become involved in the development of new compositions and technologies for the production of such materials.

There is a growing trend to consider natural materials used in construction as the materials of the future, mainly because of their energy and performance efficiency and the proven betterment of quality of life that they bring. It should be noted that buildings constructed using bricks, panels and mortars based on unfired sedimentary rocks absorb and release airborne moisture faster and to a greater extent than those using other materials (e.g. 30 times more than baked bricks). This is a characteristic that brings about a balance in the indoor climate. Unbaked products based on this kind of building material are able to conserve heat, isolate noise and save energy [1, 2]

The topical significance of the proposed material lies in the discovery of the fundamental interactions between the elements in the sedimentary rock-based recipe compositions which can contribute to the creation of a non-combustible and non-flammable thermal and acoustic insulating eco-composite building material. It can be obtained in two varieties:

(a) as coarse and fine eco-friendly coatings, by adding organic and inorganic modifiers (hemp stalk fibres, pieces of different lengths of wheat, rye, oats, or barley, rice husk, marl, glass and other fibres and waddings) to the basic raw materials;

(b) as heat-treated building elements for construction and renovation, where the material is enriched by adding suitable modifiers (heat-treated rice husk, expanded clay, expanded perlite, vermiculite, foam glass granules, etc.) to the basic raw material.

In order to ensure adequate energy efficiency, modern construction makes wide use of external thermal insulation systems for various types of buildings [3].

The research objectives of the present paper are of exceptional importance for the development and the future use of an innovative multifunctional eco-friendly composite building material based on plastic sedimentary rocks and possessing thermal and acoustic insulating properties.

A further possibility of applying different fractions of foam glass granules is their introduction, together with organic fibres, as lightweight additive materials.

Bulgaria offers the necessary conditions for the implementation in the construction industry of products and materials based on sedimentary rocks.

The increasing production capacities in various industries and the intensive utilization of the resulting products in various economic sectors and in everyday life are accompanied by the generation of significant quantities of waste materials of different origins [4-6]. The existing quantities of waste products such as waste glass, straw and rice husks represent a significant environmental problem with an alarming prognosis for its growth in the long term. Effective and safe waste management requires the existence of established landfills and an organized system of collection and transportation using specialized transport equipment [12-14]. A partial but very good solution to the problem is the development and implementation of production technologies through which a number of waste products can be recycled waste-free and then be used as primary raw materials in the production of a wide range of products.

Due to their high durability, significant chemical resistance and specific thermophysical and mechanical properties, glassy waste materials are considered as a fully usable raw material [7]. There are already industrial production methods implemented for the utilization of vitreous waste raw materials and the production of thermal insulating foam glass materials, mainly from differently sized granules [8-10].

A team from IMSETHC-BAS has been working on improving the foam glass production technology and developing innovative equipment for obtaining foam glass granules based on patents and utility models. At the same time, the team organizes the use of organic and inorganic fibres to strengthen the resulting mixtures.

The individual technological stages of the production cycle have been optimised. The laying of the coatings has been related to determining the time required to give them the necessary strength. Adequate regimes for the processing of the building elements - bricks and panels – have been developed, tailored to the specificity of the waste raw materials used and with a focus mainly on the use of a specific drying mode that can make the elements as strong as necessary.

A further possibility for creating the composite material recipes lies in employing different compositions of the base material - sedimentary clays and different fractions of foam glass granules introduced as lightweight additive materials, as well as in the use of differently sized fibres.

Innovative composite building elements have been developed using granulated foam glass and inorganic binders, with clays as the main component. Owing to their characteristics, the prepared composites represent a potential alternative to a number of traditional and standard thermal insulation building products. An experimental industrial line has been developed for the production of granules, panels and other elements with potential application in construction [11-14].

What deserves particular attention is the type and size of the fibres used. When the reinforcing material for the obtained clay products is straw, it must be cut to a certain size, the longitudinal pieces being mainly up to 5 mm long for coatings and up to 10 mm long for products such as bricks and panels. Another fibre material

is rice husks, treated in the same way as straw but without the need of cutting.

To further modify the material, a variety of research data with a broad thematic scope were analyzed. At the same time, the experimental results obtained in additional laboratory studies are a prerequisite for further expanding the technological possibilities for the preparation of new composite products based on sedimentary rocks.

The aim of the present work is to determine the technological characteristics of composite mixtures applicable for the preparation of different modifications of experimental specimens for coatings and separately for reinforced and unreinforced bricks and panels. The research carried out takes into account the existing experience in the field of composite materials [15-19] and the laboratory analytical methods presented in the specialized literature [20,21].

2. *Description of experimental thermal insulation composites based on sedimentary rocks*

1.1. Creation of thermal insulation compounds for coatings

Table 1 presents the experimental recipe compositions (series A.1 - A.4) developed on the basis of a dry mix consisting of clay, sand, foam glass granules up to 2 - 3 mm in diameter (Fig. 1.), fibre - rice husks (Fig. 2.), modifying additives (perlite and zeolite) and water at a water to dry mix ratio (B/CS) of 30% to 100% for coatings and 25% to 100% for articles, respectively.

The composition of the mixtures is in units of weight.



***Fig. 1**. Foam glass granules*



***Fig. 2**. Rice husks*

The availability of an optimal amount of water needed to obtain a mixture of normal density (viscosity) is one of the most important indicators of the obtained working mixture. This density should be neither low nor high, but just right to allow good adhesion to the work surface for application by hand or with a shotcrete machine. The drying temperature is very important. Drying at freezing temperatures is not permitted.

Compositions A.1	**Compositions A.2**
Composition A.1.1 Dry mixture (DM) = clay (C) : sand (S) : granules (G) : fibre (F) + water (W) C/S/G/F = 25+25+25+25	**Composition A.2.1** Dry mixture = clay (C) : sand (S) : granules (G) : zeolite (Z) : fibres (F) + water (W) C/S/G/Z/F = 35+25+25+10+5
Composition A.1.2 Dry mixture = clay (C) : sand (S) : granules (G) : fibre (F) + water (W) C/S/G/F = 45+25+30+5	**Composition A.2.2** Dry mixture = clay (C) : sand (S) : granules (G) : zeolite (Z) : fibres (F) + water (W) C/S/G/Z/F = 30+25+20+20+5
Composition A.1.3 Dry mixture = clay (C) : sand (S) : granules (G) : fibre (F) + water (W) C/S/G/F = 35+35+30+0	**Composition A.2.3** Dry mixture = clay (C) : sand (S) : granules (G) : zeolite (Z) : fibres (F) + water (W) C/S/G/Z/F = 35+20+20+25+0
Composition A.1.4 Dry mixture = clay (C) : sand (S) : granules (G) : fibre (F) + water (W) C/S/G/F = 35+30+35+0	**Composition A.2.4** Dry mixture = clay (C) : sand (S) : granules (G) : zeolite (Z) : fibres (F) + water (W) C/S/G/Z/F = 35+20+20+25+0
Compositions A.3	**Compositions A.4**
Composition A.3.1 Dry mixture = clay (C) : sand (S) : granules (G) : perlite : fibre (F) + water (W) C/S/G/P/F = 35+25+20+10+10	**Composition A.4.1** Dry mix = clay : sand : granules : perlite : zeolite, fibre + water C/S/G/P/Z/F = 40+20+20+10+5+5
Composition A.3.2 Dry mixture = clay (C) : sand (S) : granules (G) : perlite : fibre (F) + water (W) C/S/G/P/F = 30+15+35+5+5	**Composition A.4.2** Dry mix = clay : sand : granules : perlite : zeolite, fibre + water C/S/G/P/Z/F = 35+25+25+05+5+0
Composition A.3.3 Dry mixture = clay (C) : sand (S) : granules (G) : perlite : fibre (F) + water (W) C/S/G/P/F = 35+35+20+10+0	**Composition A.4.3** Dry mix = clay : sand : granules : perlite : zeolite, fibre + water C/S/G/P/Z/F = 35+15+25,10+10+5
Composition A.3.4 Dry mixture = clay (C) : sand (S) : granules (G) : perlite : fibre (F) + water (W) C/S/G/P/F = 30+20+25+20+05	**Composition A.4.4** Dry mix = clay : sand : granules : perlite : zeolite, fibre + water C/S/G/P/Z/F = 40+20+10+10+20+0

***Table 1.** Experimental compositions in weight %*

1.2. Data for determining the parameters of the composite mixture

1.2.1. For coatings

The choice of clay for coatings depends on its composition, homogeneity, particle size, moisture content and some other physical parameters.

The clay deposit is selected according to its composition in order to achieve the desired strength of the coating. Clays with more iron oxide content (red clays) and others with more aluminium oxide content (grey clays) can be used. After drying, the clay is ground to a particle size of 0.5 – 1.0 mm and the ingredients are dosed and homogenised. The studies were carried out with plastic sedimentary rock (clay) from the region of the town of Troyan. Solid mineral and biological inclusions such as quartz, belemnites, etc. were removed from the clay. Sands of different particle sizes – from 1.0 to 4.0 mm – were used.

Typically, coatings are not baked but dried at the natural ambient temperature. They are usually made up to 5.0 mm thick, therefore the size of the foam glass granules is small – up to 2.0 or maximum 3.0 mm and so are the sand ones.

The greater the excess water in the resulting mixture, the greater the drying distortion will be. Moreover, there is a danger of delamination of the mixture, which severely degrades its properties. Thus, any water layers that may have formed can freeze in winter working conditions and will cause the coatings to crack and crumble. It is therefore not recommended to work in winter conditions.

1.2.2. For bricks and panels

The materials used to make products such as bricks and panels do not differ from those for coatings except in the size of the components involved.

Depending on the type and size of the product, it can be reinforced using different materials, mainly steel grids for panels with larger dimensions, as well as modifications of the recipes with water glass modulus 1.4 (Si_2O_2/Na_2O) and sodium silicochloride (Na_2SiF_6).

The times for drying and removal of the formwork of the obtained elements are determined experimentally according to the thickness of the products.

The quantity of fibres and their size is also determined experimentally.

The quality of the articles - mainly their strength - depends on the time and pressure during the filling the formwork.

The determination of the normal density, i.e. the viscosity, is carried out using a vicat apparatus.

1.2.3. For coatings

Once the dough (mixture) is ready, it must retain its plasticity for some time before it can be used and processed. The drying time is determined on the same sample as the one previously used to establish the normal density.

1.2.4. Preliminary drying and final drying

These are parameters of the coating compositions and articles which depend on the condition of their gel masses. The evaporation of water from the gel masses causes surface and deep drying of the articles.

To prevent cracking of the articles, it is particularly important to observe the amount of water prescribed in the recipes, as well as the drying time and speed, all of which must be adjusted according to the composition.

A study of the physical and mechanical properties of compositions used for the preparation of thermal insulation coatings and articles

The water in the compositions is intended to be up to 30 or 25 % over the total weight. The viscosity of the coatings varies from 100 to 120 mN.s/m2 depending on the formulation of the dry mix. The viscosity of the articles was not measured as the material for them is not flowable but plastic.

The preliminary drying time of the articles is within 24 h before placing them in a drying oven for final drying.

Table 2. Physical and mechanical properties

Compo-sition type	Characteristic		
Viscosity, cP, [mn.s/m2]	Compressive strength, [kg/cm2]	Thermal conductivity coefficient, λ, [W.m-1.K-1]	Drying time, h
For coatings			
120	140	0.1-0.15	6
120	140	0.1-0.15	6
100	120	0.1-0.15	5.5
100	120	0.1-0.15	5.5
For articles			
-	150	0.15-0.17	12
-	150	0.15-0.17	12
-	135	0.15-0.17	12
-	135	0.15-0.17	12

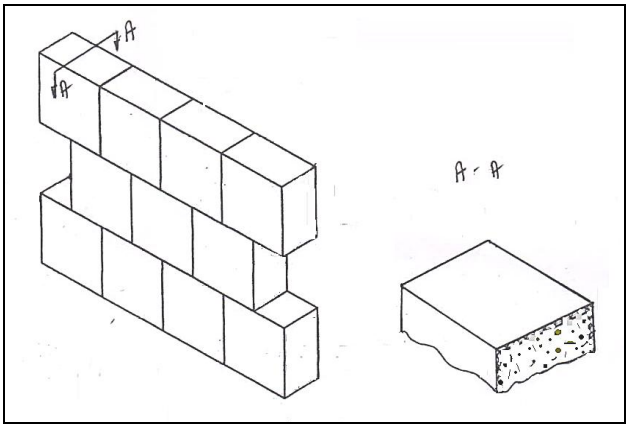


Fig. 3. *Diagram of brickwork for walls*

Figure 3 presents a diagram of brick masonry, according to composition A.1. – clay, sand, foam glass granules, rice husks.

2. Conclusions

With the increase of heat and sound insulation additives, the viscosity of the coatings decreases from 120 to 100 cP.

With the increase of heat and sound insulation additives (foam glass granules, perlite, zeolite, etc.), the drying time of the coatings decreases from 6 to 5.5 h, and for the obtained products it is 12 h.

With the increase of additives in the brick and panel composite, the compressive strength decreases from 150 to 135 kg/cm^2.

As a result of the present and forthcoming studies, it will be possible to correlate the obtained dynamic characteristics concerning the thermal and acoustic insulation of the modified sedimentary rocks, as well as the relationship with the static characteristics – the strength of the specimens of the different recipe compositions, the drying time of the mixtures, the viscosity of the coatings, etc., i.e. a decrease in some characteristics at the expense of an increase in others and vice versa. It will be possible to create mathematical models with which to optimise the compositions for different specific purposes.

Acknowledgments

The authors express their gratitude to the Bulgarian National Innovation Fund and the Bulgarian Small and Medium Enterprises Promotion Agency (BSMEPA) for funding the scientific and applied project - Contract № 13 IF-02-21/12.12.2022.

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Digital entrepreneurship education: essential topics

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Abstract: *The paper presents a methodology focused on digital entrepreneurship education for bachelor students in economic specialties. The conceptual framework is to present on the one hand a useful model for students who plan to create their own business, and on the other – to focus on the collaboration between academic lecturers and business representatives to combine efforts in teaching that provides practical-applied results and stimulates entrepreneurship initiatives. In this regard, the paper aims to give a foundation for future entrepreneurs to apply key instruments for business digitalization. Based on this educational unit, it is possible for the students to implement a specific technic that will increase their digital competitiveness. The application of the listed tasks in the process of business idea development can be beneficial for students to create start-ups that overcome threats from the external environment and the continuous confrontation with new crisis situations.*
KEYWORDS: *DIGITAL ENTREPRENEURSHIP, EDUCATION, TEACHING MODULE*

1. Introduction

Entrepreneurship in the 21st century is not only for business representatives but also can be applied at Higher Education Institutions. Academic entrepreneurship is a well-established concept in the developed countries but is yet to come in the focus for developing economies. Some researchers state that universities should try to become Entrepreneurial Universities in the long run with the willingness to break with educational traditions and to create something new in the future of Entrepreneurial Education [1] [2]. This paper is part of a project "Academic Entrepreneurship Roadmap", funded by Erasmus+ Programme, Action type KA220-HED - Cooperation partnerships in higher education, 2023. It aims to thoroughly examine the benefits of digital entrepreneurship education from a variety of angles, with a focus on students, faculty, and business professionals.

The topic's significance is pertinent to the Bulgarian economy because of the rapid advancement of technology, the growing importance of strategic events, and the new labor realities that have put many organizations in a difficult position where they must compete for managers with the right kind of entrepreneurial skills.

The purpose of this paper is to present a methodology focused on digital entrepreneurship education for bachelor students in economic specialties. This pilot teaching program has been approbated in the course *Entrepreneurship Practicum* for Business management students, fourth year of education. The teaching module includes lectures and seminars including practical exercises. The conceptual framework is to present on the one hand a useful model for students who plan to create their own business, and on the other – to focus on the collaboration between academic lecturers and business representatives to combine efforts in teaching that provides practical-applied results and stimulates entrepreneurship initiatives.

The object of the study is an academic discipline, and its curricula focused on digital entrepreneurship.

The focus is to explore innovative digital instruments and programs applied by managers and crucial for successful business development.

The research thesis is that increasing students' digital competencies in business management is a competitive advantage in the digital era. Finding specific dependencies between the traditional entrepreneurship education and accompanying new digital skills incorporating the best teaching practices is the basis of the suggested teaching program.

The paper is organized as follows: after the introduction, the preliminary considerations about the tasks and teaching modules in the field of digital entrepreneurship are presented in the second part. The latter paves the way for the third section, which focuses on specifics in the Industry 4.0 and Industry 5.0 related to the suggested discipline. The fourth part presents digital tools for business management. The paper concludes with the potential wider impact of the approbation of academic discipline and recommendations for future research in the field of digital entrepreneurship education**.**

2. Entrepreneurship Practicum as Academic Discipline

2.1. Tasks and Educational Modules

Entrepreneurship as an academic discipline is a multifaceted phenomenon that lies in specific knowledge gained by different economic disciplines. Mazzarol [3] suggests that the discipline of entrepreneurship is "rather changeable" and remains closely linked to the more mature domains of economics and management. Higher education institutions should not only be knowledge depositories and transmitters, but sources of solutions to many practical problems. Morris [4] focuses on the attention that *Entrepreneurship* as a field of academic enquiry was virtually ignored until the early 1970s. Nowadays, it has grown substantially since then to feature substantive curricula filled with rigorous courses that have been refined over the years, incorporating the best teaching practices. Much research based on empirical evidence [5], focus the attention that entrepreneurship offerings come in various shapes and forms, and results from several multinational surveys are interpreted in terms of syllabi and pedagogies utilized.

The task of the course presented is to implement the experience and good practices in business-scientific collaboration. Its aim is practical-applied and includes:

1) Establishing students' abilities to identify and formulate the problems that every organization is faced with

and looking for possible and acceptable solutions to these problems, such as transformation of theoretical knowledge into practical skills.

2) To give a foundation for managers to use the economic theory for construction of company strategy and for the achievement of company goals.

3) To assist the application of the concept for innovation and competitiveness for achievement of the designated company goals in the conditions of dynamic market environment.

A strong foundation in business, finance, marketing, and even psychology, typically cultivated through comprehensive higher education, creates the basics of entrepreneurship. Every academic field, from marketing and computer science to business administration and finance, has special abilities and information that can support entrepreneurs to succeed. The problems addressed in the *Entrepreneurship* academic discipline will support students and future entrepreneurs and managers:

1/ To reveal the connection and the dependencies between economic subjects and to assimilate the principles on economic thinking.

2/ To recognize the main economic problems that stand in front of every entrepreneur or manager.

3/ To report on the influence of economic problems on future activity and can search for the most acceptable practical solutions.

4/ To reveal the regularities in the environment in which every entrepreneur or manager functions, and the resulting behavioral changes.

5/ To argue their own position at the examination on the different problems and to show this practically in analyses and forecasts.

6/ To develop and implement start-up projects.

By refining these skills, individuals can enhance their ability to identify opportunities, innovate, and navigate the challenges of starting and growing a business.

2.2. Innovation of the Teaching Program

Based on the above stated, it is innovative to elaborate the teaching program by a team of lecturers and business representatives with recognized competencies in the field on entrepreneurship, management of business organizations, competitiveness, digitalization, etc. Team teaching is founded on excellent communication and collaboration between the lecturers who have worked together in different scientific projects, scientific research, having many joint publications and activities.

Today's products and solutions are so complex that interdisciplinary teams are indispensable. The innovative thing in this case is that the teamwork skills will be demonstrated in front of the students. Networking, mentorship, and continuous learning are also vital for entrepreneurs to stay abreast of market trends and best practices. This synchronization will upgrade traditional teaching practices, will create a feeling for community and collectivity at solving management problems. The curricula strive to encompass current topics that are considered in context of entrepreneurial activity upgrading the knowledge, competences and skills of students, including in the field of digitalization in the era of Industry 4.0.

Successful graduates training by this educational discipline will know (i) the essence of entrepreneurship, including entrepreneurial analyses, strategies, models, etc.; (ii) the conceptual models in developing entrepreneurial culture; (iii) the essence of business methods and techniques for company strategies construction, product competitiveness, competitive positioning. It is expected the students to apply methodical schemes to create business plans, to approve theoretical knowledge by the discipline in a newly established organization, to solve problems related to environmental analysis, to motivate them to start their own business startups, to incorporate toolset for business management and competitiveness.

3. Conventional Entrepreneurship - Mandatory Basis for the Digital

3.1. Characteristics of the Successful Entrepreneur

Entrepreneurs are not just wealth creators, but also innovators and problem solvers. The specific efforts grounded in this course are to force students to think outside the box and challenging conventional wisdom that can sometimes yield the most innovative ideas, as it often involves taking risks and exploring uncharted territory. Many papers focus on the skills and personality of successful entrepreneurs [6]. The targeting skills that are expected to be gained by students can be summarized as follows:

-Communication and influencing people: Managing and leading employees, sales skills, building partnerships, exchanging information with stakeholders, public speaking.

-Discovering opportunities: Solving real problems for significantly less money and time than competitors.

-Discipline and resilience to failure: Overcoming mental states and emotions and consistent work efforts. Failures are the daily life of a successful entrepreneur, which he can take with a smile, while others cannot.

-Work as a manifestation of personality: Work should not seem like a burden, but an opportunity to make dreams come true every day.

-Learning from the previous day: Dynamic learning according to circumstances, environment and people, not just from textbooks, books, articles and reports.

3.2. Industry 4.0 – Focus on Efficiency and Self-Reliance Processes

In the context of Industry 4.0, digital entrepreneurship education should focus on the students' capacity to apply the research findings and the so-called operational validity. Refocusing attention on conducting research that has an impact and recalibrating the field of entrepreneurship as an academic endeavor are necessary. Living in the era of Industry 4.0, entrepreneurship is the engine of innovation, productivity growth, and the creation of jobs and wealth. This relates to the topic of gaining applied knowledge rather than theoretical. Some of the issues that are to be observed in this teaching program are focused on the new reality and trends:

- Automation: Intensive implementation of automated production processes.

- Internet on Things (IoT): Connectivity on devices and systems for exchange on real-time data time.

- Artificial Intelligence and Machine Learning: Applying AI for analysis and optimization on processes and ML for self-study on the algorithms.

- Cloudy Computing and BIG Data: Storage and Processing on data in the cloud for better accessibility, Big Data - management on big volumes data for taking on informed solutions.

3.3. Industry 5.0 - focus on Human-Algorithm Collaboration and Improving Working and Living Conditions in the new Digital Reality

Industry 5.0 is poised to transform production, increase efficiency, and reshape customer experiences using AI, robotics, and big data. This phase, which builds on Industry 4.0, promotes greater human-machine collaboration, increasing the agility, innovation, and sustainability of businesses. On the one hand, the scientists argue about the exact period of enhancing Industry 4.0 to Industry 5.0, while others state that it has already started. Industry 5.0 complements and extends the features of Industry 4.0 while aligning them with the new demands. Furthermore, it applies to all sectors and organizations, not just those in the industry. For this reason, it is crucial for students to begin learning about this idea and adjust their business plan to accommodate the new revolution as soon as possible. Based on this, it is fundamental to apply this knowledge in the entrepreneurship curricula. The new reality necessitates to focus on:

- Human-centricity: Placing humans at the center of the technological process.

- Human-machine collaboration: Harmonious interaction between humans, algorithms, and robots.

- Personalization: Production, marketing and service oriented towards individual needs and preferences.

- Ethics and Sustainability - AI/People/Ecology: Introduction of an ethical code of conduct for the use of AI, socially aware AI systems with minimal harmful impact on the environment.

3. 4. GEN AI – Application and Selection on Tools

The notion of Industry 5.0 is a relatively contemporary term employed by the European Union on multiple occasions, reflecting its significance as a pivotal force in the economic and social transformations currently underway, transcending mere efficiency and productivity as primary goals. Some of the tools that are part of digital entrepreneurship education include the following:

Gen AI generates content for elaborating creative works such as articles, essays, images or music. It is broadly applied in marketing, business, and education. The students gain knowledge of how to create business plans using this tool but moreover how to check the validity and analyze the suggestions generated by the program.

Every tool has advantages and challenges. To summarize some of them it is necessary to mark the next advantages: (1) it saves time and effort; (2) Offers creativity and innovation in various industries. (3) Allows customization and scaling on the processes. On the other hand, the expected challenges are: (1) Ethical issues related to disinformation and copyright; (2) Limited accuracy at complex or specialized tasks; (3) Potential for biases, carried over the training data. The students should develop a more transformative view of growth that is focused on human progress and well-being based on deep analyzing and theoretical knowledge.

The curricula present a platform choice:

- Textual Models: ChatGPT, Gemini, Bard, meet on questions and write texts.

- Models for images: DALL·E and MidJourney, which create visually content by text descriptions.

- Coded assistants: GitHub Copilot, which helps programmers.

- Models for music and sound: Jukebox, creating musical compositions.

- Creation on video: RunwayML, which generates video, based on text or other data.

- Chat with specific content: Notebool LM with option for assignment on questions to content.

4. Digital Tools for Business Management

The consolidation of new enabling technologies, such as AI, machine learning, and predictive analytics, has expanded the traditional entrepreneurship education. Through digital devices, it empowers students and promotes a human-centered approach to technology. They benefit from technology but asking what we can do with new technology is not enough; we also need to use technology to modify production processes to meet the needs of employees. In this regard, the educational program presents different opportunities and their practical implementation:

- In the field of digital marketing tools - Social Media Marketing (SMM), Advertising campaigns on Google and Meta platforms (PPC), Search engine optimization (SEO), Email marketing

- In the field of digital business elaboration - Websites and Content management systems CMS (Wordpress, Joomla, Wix). The website creation is part of an overall marketing strategy. The course focuses attention on what is important for customer satisfaction, i.e. the home page structure and business priorities, the visuality - professional photos, 360° and video, functionalities. Furthermore, the importance of mobile design: mobile-first design, think about what it means for a user to log in via phone, tell stories with images, not text. Some of the Advantages of CMS include:

- Quick start and easy to use: CMS like WordPress or Joomla offer ready-made templates and plugins that allow for quick site creation without the need for deep technical knowledge.

- Affordable: Content management systems are cheaper to implement and maintain compared to sites built from scratch.

- Scalability and flexibility: Easily add new functionalities through plugins and modules, without the need for programming.

- Support and updates: Regular updates and extensive support for communities make CMS maintenance easier.

On the other hand, some of the disadvantages of CMS include:

- Limited customization: CMS often have limitations in design and functionality, especially for specific or unique requirements.

- Security issues: Popular CMSs are often subject to hacker attacks, especially if plugins and templates are not updated.

- Dependence on plugins and themes: Excessive use of plugins can lead to conflicts, slower site performance, and maintenance difficulties.

- Slower loading speed: Compared to custom sites, CMS sites are often slower because they use generic solutions rather than those optimized for specific needs.

The digital entrepreneurship module as part of the *Entrepreneurship* curricula includes practical experience on the next types of CMS:

- WordPress: With a 62.7% market share in the CMS industry, WordPress is a dominant platform known for its flexibility, extensive library of plugins, and themes, making it suitable for both blogs and complex websites.

- Shopify: With a market share of 6.4%, Shopify is a specialized e-commerce platform offering an easy-to-use environment for creating and managing online stores, with built-in payment and marketing tools.

- Wix: Holding 3.9% of the market, Wix is a cloud-based platform that allows users to create HTML5 websites using drag and drop tools, without the need for programming.

- Squarespace: With a market share of 3%, Squarespace offers an integrated platform for building websites, blogs, and online stores, with a focus on design and user experience.

- Joomla: With a 2.4% market share, Joomla is an open-source CMS known for its flexibility and extensibility, suitable for creating a variety of websites and online applications.

5. Conclusion

For the future industry to maintain its position as a long-term driver of prosperity, it must be able to swiftly adjust to shifting conditions for key value chains [7]. Digital technologies will play a special role. However, it's important to note that the goal of the Fifth Industrial Revolution is to leverage the creativity of human experts in collaboration with efficient, intelligent, and precise machines to achieve resource-efficient manufacturing solutions preferred by users [8].

According to Nahavandi [9], as a direct impact of Industry 5.0, many startups will create a new ecosystem to provide personalized robotic solutions, both in terms of hardware and software, worldwide. Based on the statement of Al-Emran and Al-Sharafi [10], education is considered a fundamental necessity and a cornerstone for the progress of any country. It is constantly evolving in response to changes in culture and business, producing the knowledgeable and skilled individuals that businesses need to thrive.

The current paper presented good practices in digital entrepreneurship education. Future research in the field is important to increase the potential research agendas and give solutions for overcoming the digital challenges and promote the successful adoption of digital entrepreneurship in education.

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AKNOWLEDGMENT

This paper is part of a project namely "Academic Entrepreneurship Roadmap", funded by Erasmus+ Programme, Action type KA220-HED - Cooperation partnerships in higher education, 2023.

Improving Ecological end Economical Results of Marine Transport by Using Different Additives on Fuel

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Abstract*: The usage of alternative fuels that reduce the emission of harmful components, but do not eliminate **th**eir presence (especially nitrogen oxides) will be analyzed in the article. researchers prove that operation process of diesel on standard fuel is characterized by the formation of nitrogen oxides during the combustion of a heterogeneous mixture of diesel fuel and air in those local zones, in which the composition of the mixture is close to the stoichiometric mixture. According to this, an actual problem today is to develop the method of perfect combustion process for diesels, when during the diesel operation the local values of air excess coefficient αi and temperature Ti will not be in the range in which nitrogen oxides and soot are formed. So, converting a diesel engine into gaseous fuel ensures a reduction of toxicity and smokiness in exhaust gases and from this point of view, the values of the air excess coefficient will be considered in accordance with the mode of diesel operation and possibility of using various types of impurities to improve fuel properties and, as a result of their consumption, to improve both, ecological and efficient indicators.*

Keywords: alternative fuels, homogeneous operation mixture, combustion chamber, diesel engine, gaseous fuel

1. Introduction

Production and application of modern scales of the internal combustion engines increase their influence on the living conditioner of environment earth, living creatures. Amount of emission of the internal combustion engines is such, that it can change the concentration of the chemical substances included the air. Also, water and ground are under influence, they become dangerous first of all for human being and other biological creatures.

Commandment about the ecological characteristics of the internal combustion engines. Should be understood as a part of the industrial ecology, which takes in consideration the influence of the technique on the engine local or being in operation engines global influence. Application of alternative fuel, of course reduces the emission of dangerous components, but does not fully exclude their exclude their existence. (especially nitrogen oxides) Professors: T. Lieuwen, V. Xang, R. Yetter, A. Boehman (USA) O. Le Corre (France), S. Sazhin (England) R. Kavtaradze (Georgia) and the investigations of others.

Analysis of mentioned directions show, that the reduce of nitrogen oxides and swarm concentrations are so called "conflict of goals", which is shown as [NOx] reduction causes the increase of the swarm concentration. Due to it scientists studying the engines and the manufactures reduction of one of them based on increasement of the other. Solving the problem is difficult due to the fuel that the reduction of maximum temperature of the engine cycle s [NOx] which increases the fuel cost.

2. Submission

In the classical process of the operation of the diesel nitrogen oxides are produced while burning diesel fuel oil and heterogenic air mixture in those local areas, where the mixture is near stochiometric mixture, temperature Tis more than 1800 k. Swarm is produced in that local zones, in which due to excessive rate of air a is less than 0.6-0.7. Due to not uniform mixture. According to above mentioned facts actual problem for today concerning the internal combustion process of the diesel is necessary to carry out such methods during which the rates of excessive air αi and temperature Ti local meanings won't be in such range in which nitrogen oxides and swarm won't be produced. According to numerous research in case of use such special adding's will be reached new, alternative fuel oils or in case of using such adding's for process of homogeneous operating mixtures will be used in creation of working mixture. Compressed and liquefied "natural gas" or other types of supplements on main fuel oil [1].

The analysis of the experimental research showed that the saturation of the fuel before channel with gas reduces the concentration of liquified phase in the central part of the swarm, mixes it with oxidization and increases the latitudinal pass of the dropping suspension. This fact forms the mixture and improves the process of combustion, though existence of gas in the oil acts negatively on scavenging of fuel and destroys the regularly of delivery of fuel. Except this, to plus the gas adding's into the fuel requires the modernization of fuel delivery equipment and diesel engine. It's necessary to have a compressor, according to it, it is excepted, that appropriate economically. That's why it is appropriate to add supplement to oil fuel to the cylinder and carry out outer mixture [2].

According to stricter international and environmental protection the use of LPG may be the best variant for many ships. The high cost of marine fuel and worthening of ecological parameters gave place to new technologies on economical and ecologically clean fuel, such as natural liquified gas. Natural liquified gas is a potential exchanger of the parameters of the marine environment protection in the aspect of reliable and economical view. In comparison with the petroleum liquified fuel natural liquified gas became an important fuel which has the important influence on global energy. Due to its characteristics, it is considered as one of the alternative fuels, which has future. Application of the LPG showed that it decreased the emission of toxic Sulphur oxide. Also, it reduces CO2 and nitrogen (NOx) emission, which is actual from 2015 ECA regulation adoption and entering into force. Due to the small existence of the carbon dioxide can be reduced to 25-30%.

When working on non-traditional diesel fuel, there are several difficulties related to fuel supply to the cylinders the process of mixture formation, the principle of ignition in the combustion chamber and the peculiarities of the combustion processes by the required properties. It must be also taken into consideration the qualitative adjustment of the load carried out in the diesel engine, where the air excess coefficient α depending on the load changes in a wide range α = 5 and more, with low engine power and idle modes, and α = 1.35–1.45 at full engine load. The range of permissible change of α depends significantly on the properties of the fuel used. Therefore, converting a diesel engine to a gaseous fuel provides a reduction in toxicity and smokiness in exhaust gases, as well as lowers fuel costs. It should be noted that the transport diesel engines will run on natural compressed and liquid natural fuel. When using compressed natural gas, fuel costs increase significantly compared to liquid natural gas.

Concentration of diesel engines takes place with gas diesel and with the sparkles of the gas oust fuel, which is more easy. It has the ability during necessity work on process of standard diesel. In gaseous diesel. In gaseous diesel operation is used regulation of the qualitive load which prevents the production of the enriched mixture, which is connected to CnHm mixture production in emissions and worsening of economy of fuel [3].

While using gaseous diesel cycle the power indicator is increased up to 15-20% in comparison of the standard diesel. In order to keep the power indicator while the using the process of gaseous diesel is necessary to regulate working mixture quality as during any kind of load choose that meaning of α which provides the compensation of power. It may be reached from the condition if we allow the heat coming out from the standard combustion process of the heat will be equal to the same process of the amount of the heat which we have after the operation of the diesel operating on gaseous diesel fuel. It will take place in equation:

(1) $Q_{di}=Q_{gi}$ and $H_{di}=H_{gi}$,

For standard diesel engine (1>1.35) working mixture combustion heat:

(2) $H_{di} = H_{ud}/(1 + a_{di} l_{do})$,

But for gaseous diesel engine (1>1.35)

(3) $H_{gi} = H_{ug}/(1 + \alpha_{gi} l_{go}) + H_{ud}/(1 + a'_{di}\, l_{do})$,

Where:

- H_{di} and H_{gi} are the amount of heat released due to complete combustion of the working mixture of standard diesel and gas-diesel loads, respectively.
- H_{ud} and H_{ug} are respectively the lowest heating capacity of diesel and gas fuel.
- α_{di} and α_{gi} value of air excess coefficient according to diesel and gas-diesel engine load.
- l_{do} and l_{go}, respectively, the amount of air theoretically required for the complete combustion of diesel and gas fuels.
- α_{gi} and a'_{di} of air excess coefficient caused by the amount of gas and explosive fuel in gas diesel.

It is important to consider the impact of both dosage and injection advance angle on gas diesel engine performance.

To evaluate the influence of explosive fuel dosage, let us introduce the concept of dynamism factor, which shows the amount of explosive fuel in the working mixture for each mode, and it is expressed as below formula:

(4) $K=G_{di}/G_{gi}$,

where G_{di} - is the amount of explosive fuel, G_{di} - the amount of gaseous fuel.

It's also important to determine the equivalent coefficient

(5) $$\alpha_{eqv} = \frac{L}{m_g l_g + m_d l_d + m_i l_i}$$

Where:

m_g -amount of gaseous fuel.

l_g - the amount of air required for complete combustion of gas fuel.

m_d - amount of liquid fuel.

l_d - the amount of air necessary for complete combustion of liquid fuel.

m_i - amount of ethanol.

l_i - the amount of air necessary for complete combustion of ethanol fuel.

L - the amount of air entering the cylinder.

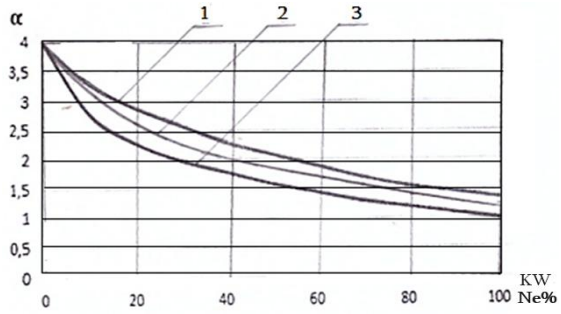


Figure 1. Dependence of air excess coefficient on engine load:

1 - traditional fuel only; 2 - basic traditional diesel fuel +(15-20)% compressed liquid gas +(10-15)% ethanol; 3- main fuel liquid gas-ethanol + explosive diesel fuel (10-15)%.

According to the classification of fuels used in marine transport, the fuel used in marine transport (in a large cargo ship) must have the following basic properties:

1. high combustion temperature'
2. minimum content of moisture, sulfur, carbon and other impurities'
3. Long burning process'
4. Relatively low cost'
5. Stability of characteristics during long-term storage.

In a standard diesel engine, a large amount of heat is wasted in the vaporization of the injected fuel during the intermixing process, compared to the small amount required in a gas-diesel cycle engine. It is also important to note that the pressure reduction at the end of compression in a gas-diesel cycle engine is caused by a decrease in the density of the fuel mixture, since the volume of the fuel mixture consisting of natural gas and air is greater than in the case of liquid fuel, on the other hand, the heat spent on the gas-air mixture formation decreases, which can lead to heat compensation.

The efficiency of the engine can also be estimated by the coefficients:

(6) $$\theta = \frac{T_{\max}}{T_{\min}} = \frac{T_Z}{T_a} = \frac{T_Z}{T_b}\frac{T_b}{T_a} = \theta'\theta'' \text{ and}$$

$$\pi = \frac{P_{\max}}{P_{\min}} = \frac{P_z}{P_b}\frac{P_b}{P_a} = \pi'\pi''$$

In this case, the value of and the coefficients are important. the more important these coefficients are, the more perfect the engine is.

The combustion process can be carried out in the case of liquid gas-ethanol with a gas-diesel cycle, (hybrid combustion, liquid gas-ethanol + diesel fuel), which can improve the engine's environmental and efficiency indicators compared to gas-LNG fuel consumption.

As the fuel mixture is more stable, its density is high and the combustion rate increases significantly, distributed almost evenly in the entire volume of the combustion chamber, where the methanol fuel mixture is arranged layer by layer in the volume, thereby ensuring a stable hybrid combustion process. Implementing such a process improves the efficient operation of gas-diesel cycle engines.

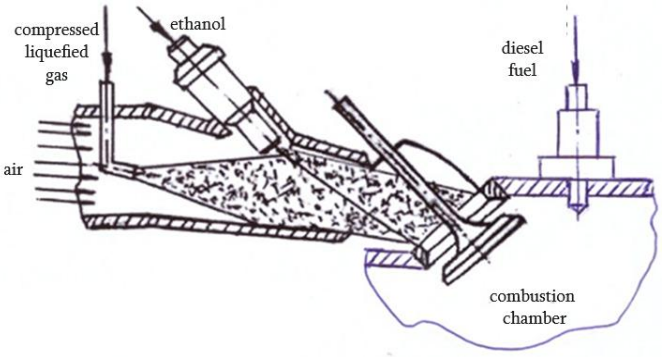


Figure 2. Scheme of the operating mixture of compressed gas-ethanol or liquid gas-ethanol

Fig.2 shows how to carry out the mixing process in the case of using gaseous and ethanol or methanol fuels. The injection of ethanol and liquefied gas fuel into the inlet manifold occurs almost simultaneously and the process of external mixing is carried out until the end of the compression process. Then the diesel fuel is injected with a certain advance and the hybrid combustion process occurs, as it is carried out in the Otto cycle (at V=const.). Therefore, in the case of the hybrid combustion process, the pressure value is higher than in the case of using compressed natural gas fuel, it should also be noted that the fuel mixture of liquid natural gas and ethanol allows for an increase in the degree of compression by 3-5 units and a full compensation of the effective indicators.

From an extensive literature review, we can say that it is planned to convert the ship's diesel to liquefied petroleum gas (LPG). In this case, if the operating mixture consisting of liquefied gas and ethanol, hydrogen, or methanol fuel is prepared, as discussed above, i.e. a gas-diesel cycle with external premixing occurs, where it is important to select an explosive fuel that would have a low auto-ignition temperature, which reduces the auto-ignition delay period, improves the internal pre-mixing process and the cycle carried out in the engine approaches the Otto cycle, that increases the environmental and efficiency indicators of diesel, compared to the engine running on both standard fuel and compressed natural gas fuel, where diesel fuel is used as an explosive fuel.

When using methanol (ethanol) as a gas fuel additive, it should be noted that the volumetric and mass energy intensity of methanol (heat of combustion = 22.7 mJ/kg) is 40-50% less than gasoline, but at the same time alcohol-air and diesel fuel - The heat release of air mixtures during their combustion in the engine differs because the high value of the heat of vaporization of methanol (ethanol) improves the filling of the engine cylinders and increases its density, which leads to an increase in the completeness of the combustion of the alcohol-air mixture. As a result, engine power output increases by 7-9%, and torque by 10-15%. so for example Racing car engines running on methanol have a compression ratio greater than 15:1, while in conventional ICE engines, the reduction ratio is correspondingly less than 11,5:1.

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Factors Affecting the Hotel Revenue Management System

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Summary. *The article reviews and evaluates the factors affecting the revenue management system in hotel facilities. Based on the statistical data of the State Statistical Committee of the Republic of Azerbaijan for 2005-2023, it is determined here that at the current stage of the digital economy in the globalized world economic system, the service sector is one of the fastest growing sectors compared to other sectors of the economy and responds faster to the socio-economic processes taking place globally. The article reviewed the one-time capacity, room stock, revenue from the sale of rooms and total revenue of hotel facilities of the Republic of Azerbaijan for 2006-2023, and calculated the RevPaR indicator, which expresses the efficiency of their services, for these years. The study also conducted a correlation and regression analysis between the RevPAR indicator and revenue from the sale of rooms of hotel facilities in the Republic of Azerbaijan, and determined the extent to which an increase in revenue from the sale of rooms increases the RevPAR indicator of hotel facilities.*
KEYWORDS*: EFFICIENCY, HOTEL, REGRESSION, CORRELATION, REVPAR INDICATOR, PANDEMIC, REVENUE, ELASTICITY COEFFICIENT.*

Introduction

At the current stage of the digital economy, the service sector, as one of the fastest growing sectors of the economy, accounts for 75% of the gross domestic product (GDP) in developed countries and an average of 50% in developing countries [8]. One of the largest areas of the service sector is the hotel business. Currently, the hotel business accounts for 6% of the world's GDP and 5% of total tax revenues [7, 8]. The study suggests that, depending on the level of development and location of hotels, the number of direct jobs for every 10 tourists staying in hotels is approximately 3, and for indirect services, it is 2 [7, 8].

It is worthy to note that the performance of hotel facilities largely depends on improving the efficiency of services. Improving the efficiency of hotel services in hotel facilities as a leading area of the service sector has a key role to play in generating revenue from hotel services by improving the level of service provided to guests. The current state of the hotel services market at the current stage of the development of the digital economy is characterized by a high level of competition, a variety of types of services provided, and an increase in the level of service [1, 2]. Along with improving the level of hotel services, studying the issues that need to be addressed by the enterprise in order to find out what people need in the hotel business and what they should be offered in the current conditions, as well as their optimal implementation, can have a significant impact on increasing revenue from hotel services. This requires marketing research in order to improve the level of hotel service. Marketing itself determines how a product or service will be sold, what price will be set, and what channels and tools will be used for promotion [3]. At the same time, this ensures monitoring of results and improvement of market offer. Revenue management is among the tools aimed at determining the optimal pricing policy to optimize the revenue of a hospitality industry facility based on determining the dynamics of demand [4]. The formation of an effective pricing mechanism must meet the interests of both the seller and the buyer.

Main body. Revenue management is a set of interrelated actions and decision-making technologies that allow forming prices for individual types of products, as well as pricing policy in a global sense, based on the use of demand forecasting methods for the services provided. The criterion for assessing the effectiveness of revenue management is closely related to the constant achievement of facility profitability [3], which leads to an increase in the profitability of hotel services. Note that optimal management of hotel income and expenses leads to an increase in the level of profitability, which expresses the efficiency of hotel services. The main place in the revenue management system of hotel facilities is the formation of Revenue Per Available Room (RevPAR) in the hotel, which is characterized by the rate of room occupancy. Room occupancy rate is determined by the ratio of revenue from the sale of rooms to the number of available rooms based on the RevPAR indicator. The Figure below shows the occupancy rate of hotel facilities in the Republic of Azerbaijan.

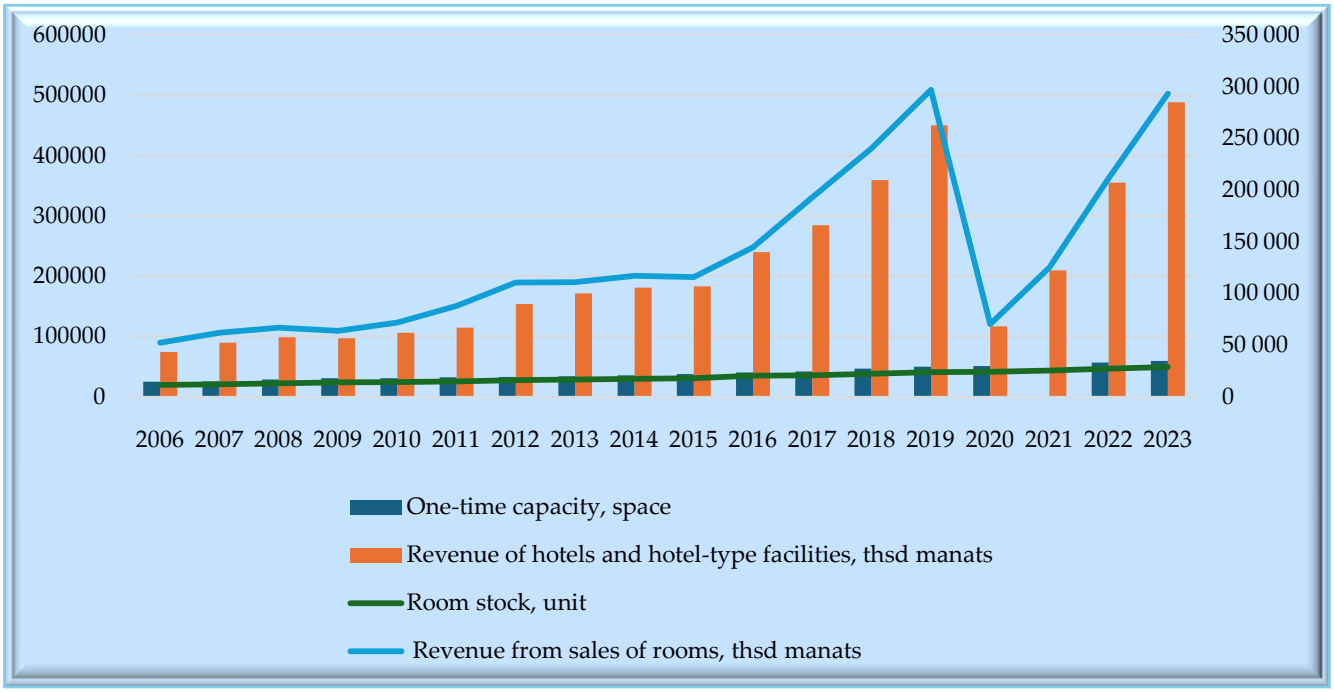


Figure 1. *One-time capacity, room stock and revenue of hotel facilities in the Republic of Azerbaijan in 2005-2023. Source (6)*

As can be seen, since 2005, the one-time capacity and room stock in Azerbaijan's hotels have continued to grow, and in 2023, the one-time capacity increased by 2.5 times compared to 2005, reaching 28,688. Accordingly, revenue from room sales and total revenue grew before the COVID-19 pandemic. In 2020, compared to 2019, revenue from room sales decreased by 76.4% and amounted to 70,273.9 thousand manats, and total revenue in 2020 compared to 2019 decreased by 3.8 times – from 450,188.5 thousand manats to 116,798 thousand manats. In the periods after 2020, it developed with increasing dynamics, and total revenue for 2023 amounted to 488,826 thousand manats, which is 8.6% more than in 2019.

If we calculate room occupancy rate (RevPAR), which is the ratio of revenue from room sales to the number of available rooms, based on the indicators presented in Figure 1 above, we get the result presented in the Figure below.

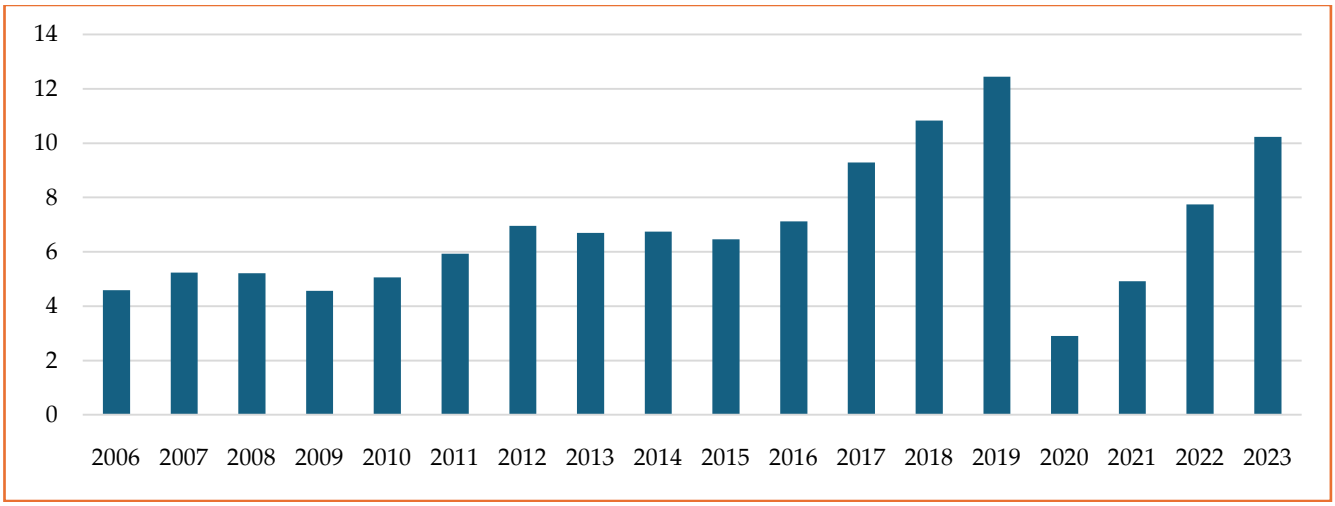


Figure 2. *RevPAR indicator for hotel facilities in the Republic of Azerbaijan in 2006-2023. Source (6)*

According to the graph, the RevPAR indicator of hotel facilities in the Republic of Azerbaijan in 2006-2023 is observed with volatility. In 2009, 2015 and 2020, the RevPAR indicator tended to decrease. The main reasons for such a decrease in these years were the global financial crisis that occurred globally in 2009, as well as the depreciation of the national currency against the US dollar due to a sharp decline in world oil prices in 2015, and the consequences of the COVID-19 pandemic in 2020. Note that there is a very high correlation between RevPAR and revenue from room sales. This is more clearly seen in the Figure below.

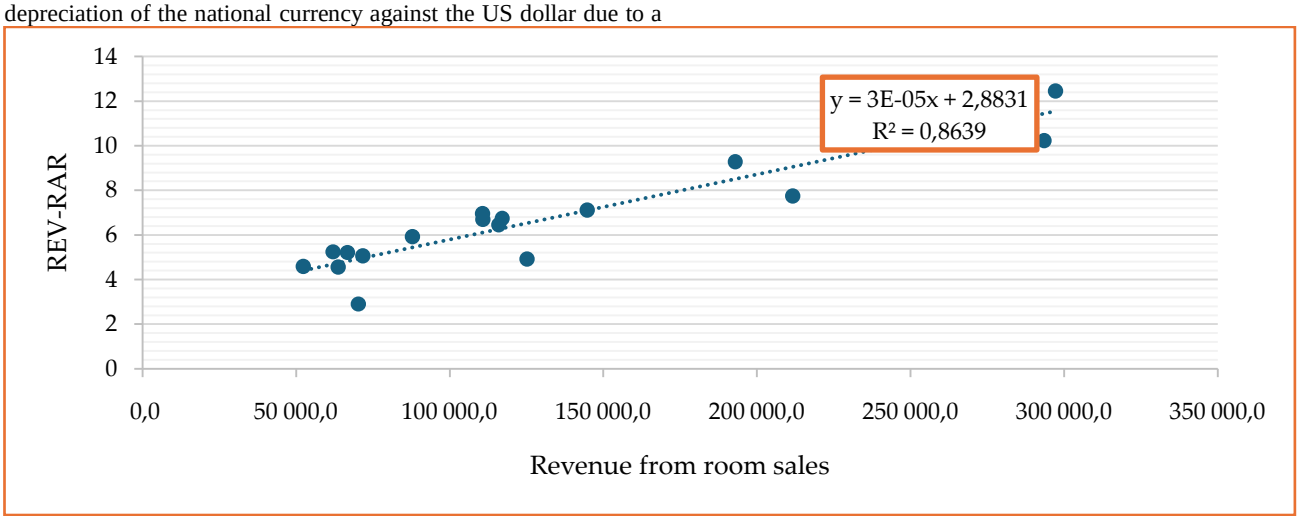


Figure 3. *Correlation-regression relationship between RevPAR and revenue from the sale of rooms by hotel facilities in the Republic of Azerbaijan in 2005-2023.* Source (6)

As the graph indicates, the correlation coefficient indicating the strength of the relationship between RevPAR and revenue from the sale of rooms by hotel facilities in the Republic of Azerbaijan is high, with $r = \sqrt{0,8639}$=0,9294622. The form of the relationship between these indicators is expressed by the linear regression equation y = 3E-05x + 2,8831. If we calculate the elasticity coefficient based on this dependence equation, we will obtain the following result.

$$E = \frac{\alpha \times \bar{x}}{\bar{y}} = \frac{3E-0 \times 135246,7}{6,829817} = 0,594$$

According to the elasticity coefficient, a 1% increase in revenue from the sale of rooms by hotel facilities in the Republic of Azerbaijan leads to an increase in RevPAR by 0.59%.

Conclusion

The hotel business, unlike other industries, is one of the industries most affected by the socio-economic processes taking place globally. The study revealed that the RevPAR indicator, as the main factor characterizing the performance of hotels in the Republic of Azerbaijan, decreased in the specified periods due to the global financial and economic crisis and the impact of the COVID-19 pandemic. It was found that there is a high correlation between the RevPAR indicator, which is formed on the basis of revenue per available room, that is the main factor in the revenue management system of hotel facilities, and revenue from the sale of rooms, expressed by the linear regression equation y = 3E-05x + 2,8831.

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Preliminary measurement of tongue pressure In high school students

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Abstract: *Considerable research has been conducted on measuring maximum tongue pressure, which is an index of tongue muscle strength that includes the relationship between tongue strength and swallowing function. Tongue pressure is the force with which the tongue presses a bolus of food against the palate and sends it into the pharynx. A low tongue pressure makes the aspiration of food more likely. In this study, we investigated the age-dependence of human swallowing function, as well as the swallowing function of female high school students in different courses, one in physical education and one in health and nursing.*
Keywords*: TONGUE, TONGUE PRESSURE, HIGH SCHOOL STUDENTS*

1. Introduction

During our nursing clinical training at the hospital, we met a patient who had developed aspiration pneumonia due to a decline in swallowing function associated with aging, and who was unable to take food by mouth. According to the Ministry of Health, Labor and Welfare's Vital Statistics, pneumonia is one of the top five causes of death and is thought to be a particularly dangerous disease for the elderly.

In the Basic Nursing course for first-year students in the Department of Health Nursing, we learned that needs such as breathing, eating, drinking, and excretion are essential for maintaining life, and that if these needs are not met, one's life will be immediately put at risk.

In addition, during a class for second-year students in the Department of Health Nursing, we participated in a welfare equipment experience session by Ecole, Japanese Standard Bedding Co., Ltd. (hereinafter referred to as Ecole). During the experience, we learned about a tongue pressure level indicator (Peco-Gina®, JMS Co., Ltd., Hiroshima, Japan), a training device that strengthens the tongue muscles necessary for swallowing. Tongue pressure refers to force by which the tongue presses a food mass against the palate and sends it into the pharynx. A decline in tongue pressure due to aging makes aspiration more likely.

For these reasons, we believe that it is important to take steps to prevent oral frailty so that people can continue to enjoy the meals they need to remain healthy, even as they age.

In this study, we examined whether performing Patakara exercises and swallowing exercises could help elderly people maintain and improve swallowing function, including tongue pressure.

2. Experimental

2-1 Advance Preparation

2-1-1 Advance Consultation with Ecole

We approached Ecole for their cooperation in conducting this research. The participants of Ecole Day Ujina, a half-day day service, consented to performing Patakara exercises and swallowing exercises and to have their tongue pressure levels checked by a tongue pressure level indicator (Peco-Gina®, JMS Co., Ltd., Hiroshima Prefecture) (Fig. 1). The tongue pressure level indicator is a device that allows them to train their tongue while watching a display screen. They can also train their tongue while playing games on a dedicated app.

The activities at Ecole Day Ujina were planned for every Wednesday in July, for a total of four days.



Fig. 1 *Tongue pressure level indicator*

2-1-2 Advice from a Certified Nurse for Eating and Swallowing Disorders

At the hospital where we conduct our nursing clinical training, we were told that the Patakara exercise could be done in a fun way by using a song familiar to the patient. There is an initiative in Hiroshima City called The Importance of Eating Through the Mouth that You Should Know. We designed swallowing exercises by referring to actual materials and the website of the Japan Dental Association[1].

2-1-3 Preparation for the Patakara Exercise and Swallowing Exercise Before the Visit

2-1-3-1 Swallowing Exercise

a. Neck Exercise, Uiuui Exercise, Pukupuku Exercise

By increasing the muscle strength of the lips, cheeks, the area around the mouth, and the tongue, the subject obtains several benefits: the function of the mouth improves, more saliva is produced, and the tongue moves more smoothly, which makes it easier for the subject to swallow food.

b. Tongue-Out Exercise

By increasing the muscle strength related to swallowing, symptoms such as aspiration are improved.

2-1-3-2 Patakara Exercise

"Pa" trains multiple facial muscles, the orbicularis oris, and the buccal muscles, and it prevents food intake and spillage. "Ta" and "ra" train the tongue muscles and lead to improved food bolus formation and food transport to the pharynx. "Ka" trains the levator veli palatini and improves nasopharyngeal closure and prevents aspiration.

We listened to songs familiar to the users of Ecole de Ujina in advance and created a parody of the Patakara exercise using the sound source of Go Go Carp (Fig. 2).



Fig. 2 *Patakara exercise, Go Go Carp version (in Japanese).*

2-1-4 Preparation of the Pamphlet and Video

When we created the pamphlet, we made it as easy to read as possible with an easy to read font size. We also made it easy to carry and laminated it to prevent it from getting wet or dirty and to increase its durability (Figs. 3 and 4).

When creating the video, we made the background white to help participants concentrate on the exercise. We also made the speed slow so that participants could easily do it, and we included subtitles to make the video easy to understand.



Fig. 3 *Pamphlet 1 with swallowing exercises (in Japanese)*



Fig. 4 *Pamphlet 2 with swallowing exercises (in Japanese)*

2-2 Visit to the Ecole de Ujina

2-2-1 First Weekly Visit

We explained the purpose of the study to six participants who agreed to participate in the study, and we checked their tongue pressure using a tongue pressure level indicator and the dedicated tongue training app Geta Tobashi Game. When the pressure probe of the tongue pressure level indicator was pressed between the upper palate and tongue, the geta in the app flies, and the distance is displayed. By using the Geta Tobashi Game with the tongue training app, we were able to check tongue pressure while having fun (Fig. 5).



Fig. 5 *Checking tongue pressure level*

Together with the participants, we performed swallowing exercises and the Let's Go Carp version of the Patakara exercises, using pamphlets and videos (Fig. 6). We handed out pamphlets to the participants on the days when they attended Ecole de Ujina and encouraged them to do the exercises at home.



Fig. 6 *Doing gymnastics*

When the program was conducted at home, the following issues emerged: the subjects had difficulty watching the videos because no devices such as tablets or smartphones were available, and the speed of the videos was too fast for the elderly to follow, which resulted in fewer repetitions of each exercise than the actual number of times. Therefore, on the visit during the second week, we attached a two-dimensional QR code (Fig. 7) to the pamphlet and we edited the video by changing the speed and the number of repetitions of the exercises so that the videos could be viewed both at Ecole dei Ujina and at home.

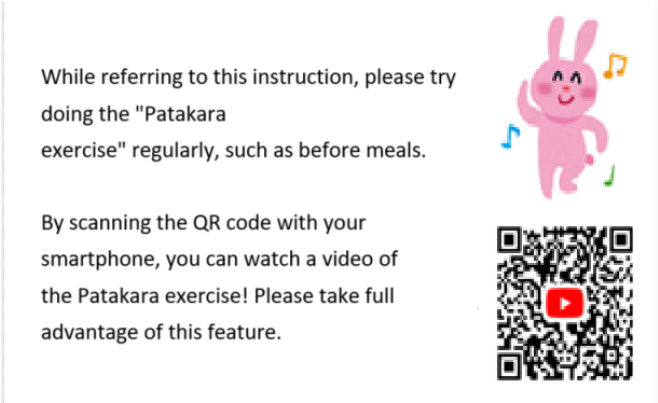


Fig. 7 2D QR code

2-2-2 Second Weekly Visit

We used a tongue pressure level indicator to check the tongue pressure levels of the six participants. Together with the participants, we performed swallowing exercises and Patakara exercises, Let's Go Carp version, using a pamphlet with a 2D QR code attached and a video with the speed and number of exercises corrected. We explained to the participants that they could watch the video at home by reading the 2D QR code. We also created a record sheet to encourage them to continue doing the exercises and explained that they should check it every morning, afternoon, and night when they performed the swallowing exercises and the Patakara exercises. We also asked them if they were doing the exercises at home.

2-2-3 Third Weekly Visit

The staff of Ecole de Ujina checked the tongue pressure levels of the participants, as was done in the second week, and performed swallowing exercises and Patakara exercises by watching the video via the 2D QR code. We also asked them if they continued doing the exercises at home.

2-2-4 Fourth Weekly Visit

As some participants were absent due to poor health, I checked the tongue pressure levels of three participants. Together with the participants, I watched a video by using a QR code and performed the swallowing exercises and Patakara exercises. I also asked if the participants had continued to do the exercises at home.

3. Results and Discussion

Ms. A, ①Female in her 70s, ②Level 1 assistance required, ③Normal diet, no choking. ④At home, she occasionally performed swallowing exercises and Patakara exercises. At Ecole de Ujina, she seemed to enjoy the exercises, and she engaged in conversation with the students. Her sitting posture was good. At her previous facility, she performed the Patakara exercises every day. On the mornings when she did not attend Ecole de Ujina, she walked in the pool.

Ms. B, ①Female in her 80s, ②Level 1 assistance required, ③Normal diet, choking. ④She performed swallowing exercises and Patakara exercises every day. At Ecole de Ujina, she looked forward to showing the students the results of her practice at home. Her sitting posture was good. On days when she did not attend Ecole de Ujina, she went to music class and practiced singing.

Mr. C: ①Male in his 90s, ②Level 1 nursing care required, ③Normal diet, no choking. ④At home, he occasionally performed swallowing exercises and Patakara exercises. This was his first time performing the Patakara exercises, and he worked enthusiastically with the students at Ecole de Ujina.

Mr. D: ①Male in his 80s, ②Level 1 assistance required, ③Cuts food and chokes. ④He did not perform swallowing exercises or Patakara exercises at home. He regularly engaged in singing karaoke and had previously participated in karaoke competitions. At Ecole de Ujina, he seemed to enjoy working with the students. During the second and fourth weeks, he was told that it was difficult to use the tongue pressure probe on the tongue pressure level indicator.

Mr. E: ①Male in his 80s, ②Level 2 nursing care required, ③Normal diet, no choking. ④His readings were low during the first week, and he declined to participate from the second week onwards.

Mr. F: ①Male in his 70s, ②Nursing care level 3, ③Cuts food ingredients and does not choke. ④His tongue pressure could not be confirmed during the fourth week as he did not come to the center due to poor health.

The distance the geta were thrown during the geta throwing game in the tongue training app for Mr. A through Mr. D, whose tongue pressures were confirmed for all four weeks, are shown in the graph (Fig. 8).

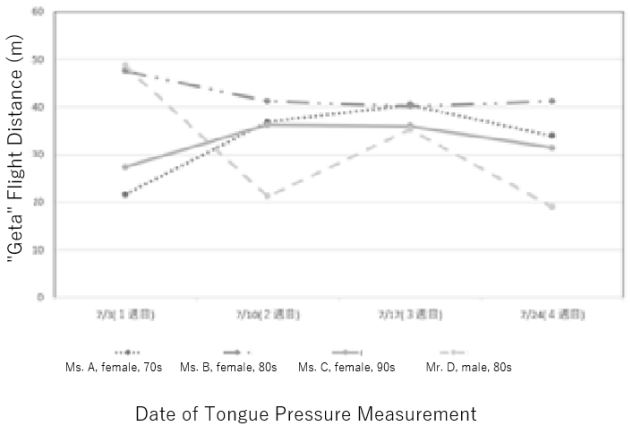


Fig. 8 *Distance measurement results using a Geta launching app for tongue training*

The tongue pressure level indicator (Peco-Gina®) recommends aiming for a tongue pressure level of 3 (30 m in distance) to prevent oral frailty.

Although there were days when the distance of the geta was slightly low for participants A, B, and C, it was approximately 30 m on average. It can be said that the participants were able to maintain

a tongue pressure level of 3 (30 m in distance) to prevent oral frailty. D's readings were low in the second and fourth week because it was difficult to use the tongue pressure probe of the tongue pressure level indicator. We believe that the actual tongue pressure was not confirmed accurately. Of the four participants, B continued to do, for three weeks at home, the swallowing exercises and Patakara exercises demonstrated by the students. B's tongue pressure level (distance of the geta) did not significantly increase, but his tongue pressure level was high for all four measurements. In addition, his tongue pressure level did not improve and was maintained over the short period of three weeks.

At Ecole de Ujina, all four students were motivated and were able to do the swallowing exercises and Patakara exercises with the students, using pamphlets and videos while enjoying conversation. At first, the speed of the video was too fast for elderly people to follow, and they struggled to keep up with the speech, so it was necessary to revise the video while taking into consideration the age of the participants.

We attached a 2D QR code to the pamphlet so that it could be viewed by the participants themselves, and we laminated the pamphlet on both sides so that it could be used repeatedly, but many participants did not have the equipment that was required to read the 2D QR code, and it was difficult to persuade them to continue doing the exercises every day at home. It was necessary to make the pamphlet and the equipment easy to understand, while taking into consideration the background and environment of each user. For these reasons, it is difficult to say that the tongue pressure level changed after the swallowing exercise and the Patakara exercises were performed.

In his talk, Mr. B said that he loved singing, had been attending music classes for many years, and learned to sing with his friends. Takano states, "Inside the larynx, there are muscles called the internal larynx that directly control the vocal cords, and muscles called the external larynx that raise and lower the larynx and hyoid bone. The movements of these muscles allow for the volume and quality of the voice, as well as expressions such as whispering and shouting." Singing and talking to people move these muscles. People who have many opportunities to talk with others strengthen their internal laryngeal muscles by doing so[2]. Considering this, we believe that oral muscles can be strengthened every day by attending music classes, having fun conversations with friends, and singing, and that this exceeds a tongue pressure level 3 (30 m in terms of distance), which is required to prevent oral frailty. As for Mr. D, we were not able to confirm his exact tongue pressure level, but as he regularly sings karaoke and has previously participated in karaoke competitions, we believe that he is continually making an effort to prevent oral frailty.

In addition, when we spoke to Mr. A, who had a relatively high tongue pressure level, we learned that on days when he was not attending Ecole dei Ujina, he would walk underwater at a swimming facility. Underwater walking is effective for improving cardiopulmonary function and overall muscle strength, and it is thought to strengthen the muscles in the mouth and to maintain tongue pressure.

Mr. A, Mr. B, and Mr. D are classified as requiring nursing assistance at level 1 or 2, which are the mildest levels of nursing care. These participants are considered to be capable of participating in social activities of their own volition. Regarding social frailty, Mori states, "The risk is reduced for elderly people who interact with friends on a daily basis, or who maintain social contact through hobbies"[3]. From this statement, we believe that while swallowing exercises and Patakara exercises can help maintain tongue pressure, going out into society in places where people gather, and talking and having fun by singing and exercising will help to strengthen the muscles of the mouth, shoulders, and throat, as well as strengthen tongue pressure, and will also improve cardiopulmonary function, thereby leading to the prevention of oral frailty.

4. Conclusion

This study verified that elderly people can maintain their swallowing function and their tongue pressure by performing swallowing exercises and Patakara exercises. In addition, we believe that conversing socially and singing can help people to naturally prevent oral frailty while having fun, and that continuing to eat delicious food by mouth can prevent frailty throughout the body and help people stay healthy.

We asked elderly people to continue to perform swallowing exercises and Patakara exercises, but it was difficult for them to do the exercises at home. We found that it was necessary to encourage elderly people to participate in society by attending day care centers and casual gatherings. Therefore, in the future, we would like to participate in volunteer activities to sing songs and do exercises with elderly people, and to contribute to the prevention of oral frailty.

We will likely encounter patients who are experiencing age-related declines in swallowing function during our future nursing clinical training at hospitals. We would like to tailor the efforts of this study to each patient and to help them to continue to eat delicious food by mouth.

Finally, we would like to express our deep gratitude to the Ecole Division of Nihon Kikanren Bedding Co., Ltd. and all the people at Ecole des Days Ujina who cooperated withthis research.

Acknowledgments

We express our deep gratitude to the Ecole Division of Nihon Kikanren Bedding Co., Ltd. and all the people at Ecole des Days Ujina who cooperated in conducting this research and Enago (www.enago.jp) for the English language review.

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"The Gas Bombs and the Disease and the Flying Pestilences": Beaumont's "Place of a Meeting" as a Depiction of the American Reality in the 1940's and the Early 1950's

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Abstract: *The vampire figure has been present in Western culture for centuries and its popularity has been steadily increasing. The vampire can be viewed as a universal shapeshifter who skilfully adapts to the pressing issues and challenging questions of the time. Through the figure of the vampire people express not only their utmost fears, doubts, and anxieties, but also their hidden temptations and desires. Beaumont's 1953 vampire story "Place of a Meeting" depicts a post-apocalyptic deserted world where vampires mourn the loss of human life thus becoming a representation of the cultural and historical landscape of the United States in the 1940's and the early 1950's.*
Keywords*: VAMPIRE, PLACE OF A MEETING, APOCALYPSE, WAR, BOMBS*

The vampire has become a staple of Western European and North American culture and haunts every sphere of life in Western society. Vampires lurk between the pages of works of literature, drive the plotlines of films, inspire clothing lines and cosmetic product, live in the worlds of politics and economics, and bring to life works of art. The figure of the vampire entered Western Europe from the Slavic lands in the 17th century and since then has been one of the most skilled cultural shapeshifters that has adapted to the changing times and has never lost its popularity and appeal. One possible explanation for this is that the vampire in Western culture has become a way for people to express, discuss, and speculate on their relevant fears, doubts, anxieties, and hidden, even forbidden, desires. Vampires often give "flesh and blood" to difficult, confusing, even unanswerable pressing questions that push society to venture into unknown and frightening, but also tempting territories. This paper focuses on Charles Beaumont's 1953 vampire story "Place of a Meeting" as a representation of the cultural, political, and economic turmoil that American society faced in the 1940's and the early 1950's. In Beaumont's story the vampires do not play the anticipated role of the antagonist. Rather, they serve three important functions: to tell the devastating story of yet another man-made apocalypse; to portray the emotions that a lifeless world covered by a "poison cloud" (Beaumont 326) would invoke; and to raise important questions about the current situation in the United States, the world, and the future of humanity.

When reading Stoker's *Dracula* or watching "Twilight," it is easy to disregard the fact that the modern Western vampire is a descendant of the Slavic vampire. According to Perkowski "both the word vampire and the demon to which it refers were introduced by the Slavs almost one thousand years ago" (18) and Melton points out that "while vampires and vampirelike creatures appeared in the mythology of many of the world's peoples, nowhere were they more prevalent than among the Slavs of eastern and central Europe" (641). A. N. Afanas'ev describes the Slavic vampire the following way:

> they are corpses who during their lifetime had been sorcerers, werewolves and, in general, people excommunicated by the church such as: suicides, drunkards, heretics, apostates and those cursed by their parents…At the dead of midnight, leaving their graves where they lie as undecayed corpses, the vampires take on various forms. They…raise cain and frighten travelers or they enter the peasants' cottages and suck blood from those sleeping, who always die from it afterwards…The pre-dawn cock's crow compels the vampire to disappear instantaneously or forces him to the ground blood-stained and completely unconscious. (Perkowski 19)

According to Felix Oinas "vampires are occasionally considered responsible for hardships that befall households and even whole villages: bringing on a drought, causing storms, crop failures, livestock plagues, and diseases" (Oinas 49). At the end of the 17th and beginning of the 18th century the Slavs inhabiting lands located on the borders of the Austro-Hungarian empire experienced several "vampire epidemics" characterized mainly by perceivably healthy people and cattle suddenly becoming ill and dying quickly afterwards. The panic-stricken population blamed these events on vampires, which resulted in graves being opened and dead bodies being mutilated or annihilated. The stories of these terrifying and controversial cases traveled to Western Europe, which as Melton points out "led directly to the development of the contemporary vampire myth" (641). Scholars such as Barber, Groom, Melton, and Perkowski have pointed to some of the most famous Slavic "vampire" cases that initially infiltrated and circulated through Western Europe such as the cases of Arnold Paole and Peter Plogojowitz. Ultimately, Arnold Paole and Peter Plogojowitz became the not-so-glamorous great-grandfathers of Stoker's Count Dracula.

While Perkowski discusses the role of the vampire as a scapegoat—a much needed supernatural explanation for inexplicable natural events, other scholars such as Groom point to the fact that the vampire is intrinsically connected to the relevant cultural, historical, political, and economic events of the time. Groom's *The Vampire: A New History* traces the development of the vampire figure in Western Europe from the 17th century to the present by relating the vampire to major events in terms of religion, politics, economics, medicine, public health, psychology, technological development, crime, environmentalism, and the understanding of gender, sex, and sexuality. With this in mind, the vampire figure can be analyzed as an embodiment of people's relevant and unresolved fears, questions, and even temptations. In this manner, Charles Beaumont's short vampire story "Place of a Meeting" (1953) becomes a mirror that reflects the anxieties of the American society triggered by the events that the United States faced in the 1940's and the early 1950's.

The 1940's and the early 1950's were a time of turmoil for the United States defined by war, fear, loss, and chaos. The American people faced "World War II, the Holocaust, atomic bombs, and the beginning of the Cold War" ("The 1940s"). The United States entered World War II as a result of the Pearl Harbor attack on December 7th 1941 and suffered a total of 418,500 (military and civilian) deaths during the war ("Research Starters"). Japan's unexpected attack on the US Pacific Fleet at Pearl Harbor, Hawaii either wounded or took away the lives of more than 3,500 US troops and civilians. In addition, the attack "severely damaged the fleet…and shocked the nation" ("Remembering Pearl"). Following the Pearl Harbor attack, in the United States "for several years there had been dissent among scientists and political leaders over the morality and necessity of using atomic bombs" and in 1945 President Truman faced difficult decisions pertaining to the United States' plans to use atomic bombs against Japan ("The Story"). Eventually, in July, 1945 the United States proceeded with conducting "Trinity"—the first ever live test of a nuclear detonation. About a month later, the United States dropped two atomic bombs on Japan and thus became the first and only country to use atomic bombs against another country. On August 6, 1945 "Little Boy" was dropped on Hiroshima. As a result, a big part of the city was destroyed and around 140,000 people died. Three days later, on August 9, 1945 "Fat Man" was dropped on Nagasaki

causing around 70,000 deaths ("The Story"). The number of deaths in Hiroshima and Nagasaki provided does not account for the number of people that died after the attacks from radiation-related illnesses.

In addition, the late 1940's and the early 1950's marked the dawn of the Cold War, "a period of geopolitical tension marked by competition and confrontation between communist nations led by the Soviet Union and Western democracies including the United States" ("Cold War"). For the United States the beginning of the Cold War was tied to heightened arms buildup, plans to create "superbombs," fear of nuclear destruction, the Red Scare, and the Korean War. When the Soviet Union tested their own atomic bomb in 1949, President Truman declared that "the United States would build an even more destructive atomic weapon: the hydrogen bomb, or 'superbomb'" ("Cold War"). Both the Soviet Union and the United States conducted multiple tests of powerful radioactive bombs. The persistent threat of nuclear attacks had a devastating effect on the everyday lives of the American citizens. Public spaces such as schools conducted nuclear attack drills; people were building bomb shelters in their backyards and the government was building bomb shelters for the political elite in top secret locations around the country; the film industry flooded the market with movies portraying the nightmarish effects of nuclear weapons and mass destruction ("Cold War").

In addition to the ever-present fear of nuclear annihilation, starting in 1947 the American people also faced the Red Scare with the House Un-American Activities Committee (HUAC) launching "a series of hearings designed to show that communist subversion in the United States was alive and well" ("Cold War"). The actions and the politics of the HUAC committee during the late 1940s and the 1950s, which can be defined as an "anticommunist hysteria," resulted in more than 500 "blacklisted" Hollywood actors, directors, and writers staying unemployed for a decade, thousands of federal employees being "investigated, fired and even prosecuted," professors with liberal views being fired, people testifying against their coworkers, and "loyalty oaths" becoming more and more common ("Cold War").

Even though the United States and the Soviet Union never engaged in direct military actions against one other, in 1950 the Cold War led the United States into sending troops to North Korea. The Korean War, also referred to by the United States as the "Forgotten War," lasted for about three years and around 36,600 American soldiers lost their lives ("Korean War"). The Korean War was "difficult to fight and unpopular domestically" ("NSC-68"). The American public perceived the war as pointless, especially given the stalled negotiations. The citizens' widespread dissatisfaction with the Korean War became one of the factors that destroyed President Truman's public support and led to the election of General Dwight D. Eisenhower as the next American President ("NSC-68").

As demonstrated, the 1940's and the early 1950's remained in American history as times of turmoil, violence, fear, and dissatisfaction. Charles Beaumont's short vampire story "Place of a Meeting" (1953) becomes an accurate depiction of the state of American society at that time. Beaumont (1929-1967), a Chicago-born writer, published "Place of a Meeting" for a first time in *Orbit* no. 2 (Beaumont 323). The story cleverly strays away from using popular themes, motifs, and elements from earlier well-known vampire-focused works by Polidori, Le Fanu, Poe, Goethe, Byron, and Keats, and presents an unusual and unexpected take on the vampire trope. Beaumont's reader does not encounter ghostly castles, mysterious red-eyed counts, unsuspecting and vulnerable maidens, or irresistible, but deadly she-vampires. "Place of a Meeting" shows vampires in a different light—as the only (and lonely) survivors of a devastating global man-made apocalypse. In many vampire-focused works of literature the world of the living has a rather unpleasant encounter with death through its interactions with the world of the (un)dead, represented by the vampire figure. These encounters have one recurring pattern—the world of the (un)dead, represented by the vampire, uses various means with the goal of draining the life force out of the world of the living, represented by the human. Sometimes these attempts are successful and sometimes they are not. Regardless, in most classic vampire-focused works of literature the (un)dead, the vampire, can be defined as the antagonist, and the human can be defined the protagonist. In Beaumont's story the vampires are not the antagonists and the people are not the protagonists; both the vampires and the people are victims of powerful weapons of mass destruction that have turned the world into a lifeless desert.

It is worth pointing out that Beaumont never specifically refers to the group that meets at the graveyard as "vampires"; he refers to them throughout the text either by their names or as "people." The author only gives subtle hints throughout the story based on which the reader realizes that Big Jim Kroner and his acquittances are undead blood-drinkers. These hints include the group meeting at a graveyard, the group's concern over nourishment once they realize all people are dead, references to "new blood" (Beaumont 326) and building up appetite, their "pale cheeks and red lips" (Beaumont 326) and "bloodless" hands (Beaumont 326), the air turning black and getting filled with "flappings and…flutterings and…squeakings" (Beaumont 326) when the group is leaving, Jim Kroner not looking at crosses, and Jim Kroner getting into his coffin, closing the lid, and going to sleep until the world gets populated again.

Beaumont's "Place of a Meeting" captures the American reality of the 1940's and early 1950's by using the vampire figure to develop the theme of mass destruction on a global scale. The atmosphere that Beaumont creates in his work is similar to what many Americans felt and saw every day at that time—loneliness, hopelessness, and decay:

> the wind had died, again, so there was no sound at all. Across the corroded wire fence the gray meadows lay strewn with the carcasses of cows and horses and, in one of the fields, sheep. No flies buzzed near the dead animals; there were no maggots burrowing. No vultures; the sky was clean of birds. And in all the intended rolling hills of grass and weeds which had once sung and pulsed with a million voices, in all the land there was only this immense stillness now, still as years, still as the unheard motion of the stars." (Beaumont 325)

The conflicts that the United States faced in the 1940's and the early 1950's were on a global scale and it is no accident that in Beaumont's story Jim Kroner's group includes participants from multiple cultures that speak various languages. The participants are responsible for covering and searching different parts of the world with the hope of finding people that are still alive. However, when asked if they found anybody alive, the vampires give the same devastating answer: "They're all dead" (Beaumont 324), "…Ain't nobody alive in the whole state" (Beaumont 325), "'No,' she said. 'No, no.'" (Beaumont 325), "…Nothin' nowhere" (Beaumont 325), "Everywhere is people dead" (Beaumont 325), "All dead, senor chief" (Beaumont 325), "Dead as doornails" (Beaumont 325), "…there was much head-shaking, many people saying, 'No, no.'" (Beaumont 325).

Beaumont's vivid description of the group's reaction once they realize that there is no human life left anywhere becomes a powerful depiction of a world that is no longer fragmented, divided, and territorial; Beaumont's world is united, but the unifying factor is its shared terror and helplessness in the face of the irreversible evil the devastating scope of which it had just realized: "He watched all the tall and short and old and young people from all over the world, pressed together now, a vast silent polyglot in this country meeting place…" (Beaumont 325). Beaumont's reason for this irreversible evil is entirely in line with people's real-life fears and anxieties related to the "atomic age," nuclear power, "superbombs," and the deadly effects of the explosions that not only destroy lives immediately, but cause illnesses, suffering, and death for decades: "…the gas bombs and the disease and the flying pestilences that had covered the earth in three days and three nights" (Beaumont 325). The graveyard where the vampires have

gathered, "…a country meeting place…always lonely and long-deserted" (Beaumont 325), becomes a microcosm that represents Beaumont's "deserted" (Beaumont 325) and "forgotten" (Beaumont 325) post-bomb reality in which carcasses, "dead trees" (Beaumont 326), "odors of rotting life" (Beaumont 324), and "the still-hanging poison cloud" (Beaumont 326) paint the landscape of a world defined by the piercing *absence of life*. Even though Jim Kroner and his group resemble living people—they talk, move, think, and feel—and thus might give the reader some hope that the world is not as empty and forgotten as they thought at first, Beaumont reminds his reader that this resemblance is deceiving, as Jim Kroner and his group are (un)dead and thus lifeless: "His voice was steady, but it lacked life" (Beaumont 326). Beaumont skillfully places the reader and the vampires on the same emotional plane in the midst of a deserted post-apocalyptic world defined by overarching death and silence; both the reader and the vampires feel shocked, frightened, sad, lost, and overwhelmingly alone: "A girl began to cry. She sank to the damp ground, and covered her face and made these crying sounds…The elderly man looked sad. But not afraid" (Beaumont 325), "'The world's all dead,' a child moaned" (326), "Monsieur Kroner, Monsieur Kroner, what will we do?" (Beaumont 326).

The ending of Beaumont's story points to the cyclical nature of history, which, unfortunately, has not helped humanity learn from its mistakes; rather than noting and consciously avoiding past devastating events, people continue to destroy life time and time again. This is evident in Kroner's response when the group asks him what they should do given that there are no living people anywhere in the world. Kroner states:

> Do? What some of us have done before…We'll go back and wait. It ain't the first time. It ain't the last…Same thing we'll do again and likely keep on doing. We'll go back and—sleep. And we'll wait. Then it'll start all over again and folks will build their cities—new folks with new blood—and then we'll wake up. (Beaumont 326)

The fact that Kroner has witnessed most of human history and the perpetual vicious cycles of life destruction and revitalization is demonstrated by the way Beaumont describes his hands: "...large hands, rough from the stone of midnight pyramids and the feel of muskets, boil-specked from night hours in packing plants and trucking lines; broken by the impact of a tomahawk and a machine-gun bullet…Old hands, old beyond years" (Beaumont 326). The ending of the story leaves the reader with the image of Kroner sleeping in his coffin under the foliage in a once again deserted and quiet graveyard in a once again deserted and quiet post-apocalyptic world where life shall blossom once again, only to be destroyed yet once again.

Beaumont's short story "Place of a Meeting" (1953) becomes a representation of the social, cultural, and political atmosphere in the United States in the 1940's and the early 1950's. World War II, the Cold War, and the Korean War made "war" one of the most frequently used words by the American people. The government not only tested, but actively deployed the destructive power of nuclear energy, leaders spoke of "superbombs," and the public watched radioactive explosions and horrifying mutants on the big screen, while building bomb shelters and going through emergency drills on daily basis. Additionally, people were fired, investigated, and prosecuted because of their alleged political beliefs and affiliations. During the 1940's and the early 1950's war in various shapes and forms abrasively invaded the lives of the American people and took away not only their loved ones, but also their sense of peace, safety, order, and trust. They vampires in Beaumont's story not only tell the devastating story of yet another man-made apocalypse and portray the emotions that a lifeless world covered by a "poison cloud" (Beaumont 326) would invoke; they also raise important questions about the current situation in the United States, the world, and the future of humanity related to bombs and "superbombs," war and mass destruction, violence and hate, irreversible loss and painful fear, piercing silence, and the challenging lessons that humanity sadly refuses to learn.

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Acknowledgments

This work was supported by the Bulgarian-American Fulbright Commission.

Application of the Python programming language in computer forensics

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Abstract: *This paper presents the application of Python in computer forensics, proposing various approaches for file system analysis, memory forensics, network monitoring, and malware detection. It examines Python's integration with forensic tools such as Autopsy, The Sleuth Kit (TSK), Volatility, and Scapy, highlighting its role in automating forensic investigations and enhancing efficiency. The research discusses the advantages of Python in forensic analysis, emphasizing its role in forensic automation, script-based evidence collection, and rapid data processing within various case studies.*
Keywords*: COMPUTER FORENSIC TOOLS, COMPUTER FORENSICS*

1. Introduction

Computer forensics is the branch of forensic science dedicated to identifying, preserving, analyzing, and presenting digital evidence from various electronic devices. The primary objective is to recover data, analyze system artifacts, and provide evidence for legal proceedings or incident response [1,2].

Python has become a fundamental programming language in the digital forensics' community due to its simplicity, flexibility, and wide range of libraries. It facilitates the automation of repetitive tasks, the development of custom modules, and the integration of forensic tools into cohesive workflows. Python's ability to interact with various forensic tools makes it the instrument for improving the efficiency and effectiveness of forensic investigations.

Python allows users to saving time and reducing the human errors. The investigators can enhance their analysis with specialized plugins or scripts. The programming language can easily interface with other tools, databases, and services, making it an excellent choice for integrating different forensic tools into a single workflow.

2. Computer Forensic Tools and case studies

Python scripts can automate the process of running commands and processing the results in computer forensic tools. Python automates the extraction of file metadata, perform searches for specific keywords, and generate reports without needing to manually interact with command-line interface.

TSK has a Python bindings library (PyTSK) that allows users to interact with disk images and filesystem structures programmatically. Python scripts can be written to parse filesystem data, recover deleted files, analyze file slack space, and explore partition structures. Python can be used to integrate TSK with other forensic tools or external data sources, creating a more comprehensive and customized workflow. The programming code imports data from forensic tools into a database, or to integrate with other tools like Volatility (memory forensics) or external analysis tools (e.g., hashing algorithms, antivirus engines).

Autopsy is a powerful open-source digital forensic tool built on The Sleuth Kit (TSK). While it provides a graphical interface, Autopsy also has a Python API that allows users to automate investigations, extract artifacts, and extend functionality. Below are practical case studies demonstrating how to integrate Python with Autopsy for digital forensics. Autopsy provides an extensible framework that allows developers to create custom modules and tools using Python. These modules automate data analysis, generate reports, and integrate external tools into Autopsy's platform. Python modules are used to automatically parse specific file types or search for custom patterns in the recovered data.

The study explores specific case studies that illustrate Python's impact on the speed, accuracy of forensic analysis, and how it improves the efficiency and effectiveness of forensic investigations.

Case Study 1: Automating File Hash Extraction for Malware Analysis (Fig.1)

```python
from org.sleuthkit.autopsy.ingest import IngestModule, IngestModuleFactoryAdapter
from org.sleuthkit.datamodel import SleuthkitCase, ReadContentInputStream, AbstractFile
import hashlib

# Known malicious hashes (example)
malicious_hashes = {
    "e99a18c428cb38d5f260853678922e03",  # Example MD5 hash
    "098f6bcd4621d373cade4e832627b4f6"
}

class HashCheckModule(IngestModule):
    def process(self, file):
        if file.isFile():
            # Compute MD5 hash
            md5_hash = hashlib.md5()
            input_stream = ReadContentInputStream(file)
            buffer = bytearray(1024)
            read = input_stream.read(buffer)
            while read > 0:
                md5_hash.update(buffer[:read])
                read = input_stream.read(buffer)

            file_hash = md5_hash.hexdigest()

            # Check if hash matches known malware
            if file_hash in malicious_hashes:
                self.logMessage(f"Malware detected: {file.getName()} ({file_hash})")

        return IngestModule.ProcessResult.OK
```

Fig. 1 *File Hash Extraction*[Грешка! Източникът на препратката не е намерен.].

Scenario: A disk image is scanned for known malware files by computing their hashes and comparing them against a malware database.

Solution: Python is used with Autopsy's API to extract file hashes from an image and compare them with a list of known malicious hashes.

The script reads each file, computes its MD5 hash, and checks it against a list of malicious hashes. If a match is found, an alert is logged. This helps in automating malware detection in forensic disk images. The investigator gets a report listing any detected malware based on hash comparison. It reduces manual effort in scanning for known malware files.

Case Study 2: Extracting Deleted Files for Investigation (Fig.2)

```python
from org.sleuthkit.autopsy.ingest import IngestModule
from org.sleuthkit.datamodel import SleuthkitCase, AbstractFile

class RecoverDeletedFilesModule(IngestModule):
    def process(self, file):
        if file.isFile() and file.isDeleted():
            self.logMessage(f"Deleted File Found: {file.getName()} at {file.getParentPath()}")
        return IngestModule.ProcessResult.OK
```

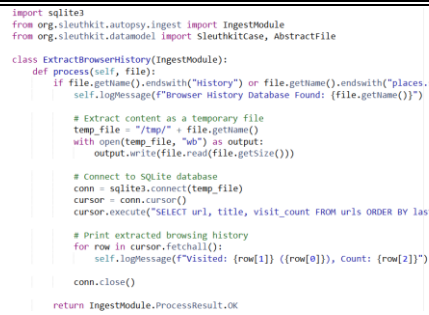
Fig. 2 *Extracting Deleted Files.*

Scenario: An investigator wants to recover deleted files from a disk image and analyze their contents.

Solution: Autopsy's API is used to search for files marked as deleted and extract them for analysis.

The script iterates through files in the disk image. It checks if the file is marked as deleted and logs its path. Investigators use this to restore deleted files for further examination. The forensic team gets a list of deleted files that may be relevant to the case. It helps in recovering evidence from formatted or tampered drives.

Case Study 3: Extracting Browser History for User Activity Analysis (Fig.3)



```
import sqlite3
from org.sleuthkit.autopsy.ingest import IngestModule
from org.sleuthkit.datamodel import SleuthkitCase, AbstractFile

class ExtractBrowserHistory(IngestModule):
    def process(self, file):
        if file.getName().endswith("History") or file.getName().endswith("places.sqlite"):
            self.logMessage(f"Browser History Database Found: {file.getName()}")

            # Extract content as a temporary file
            temp_file = "/tmp/" + file.getName()
            with open(temp_file, "wb") as output:
                output.write(file.read(file.getSize()))

            # Connect to SQLite database
            conn = sqlite3.connect(temp_file)
            cursor = conn.cursor()
            cursor.execute("SELECT url, title, visit_count FROM urls ORDER BY last_visit_time DESC")

            # Print extracted browsing history
            for row in cursor.fetchall():
                self.logMessage(f"Visited: {row[1]} ({row[0]}), Count: {row[2]}")

            conn.close()

        return IngestModule.ProcessResult.OK
```

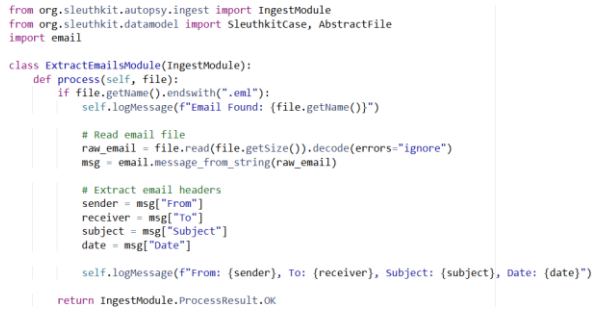
***Fig. 3** Extracting Browser History.*

Scenario: An investigator tracks user activity by extracting browser history from a forensic disk image.

Solution: Python is used with Autopsy to locate browser history databases and extract URLs.

The script scans for browser history databases (Chrome's History or Firefox's places.sqlite). It extracts URLs, titles, and visit counts from the database. Investigators uses this data to track user activity. It provides a list of visited websites, helping in cases of cybercrime, insider threats, or evidence collection [3, 4, 5].

Case Study 4: Extracting Email Artifacts for Investigation (Fig. 4)



```
from org.sleuthkit.autopsy.ingest import IngestModule
from org.sleuthkit.datamodel import SleuthkitCase, AbstractFile
import email

class ExtractEmailsModule(IngestModule):
    def process(self, file):
        if file.getName().endswith(".eml"):
            self.logMessage(f"Email Found: {file.getName()}")

            # Read email file
            raw_email = file.read(file.getSize()).decode(errors="ignore")
            msg = email.message_from_string(raw_email)

            # Extract email headers
            sender = msg["From"]
            receiver = msg["To"]
            subject = msg["Subject"]
            date = msg["Date"]

            self.logMessage(f"From: {sender}, To: {receiver}, Subject: {subject}, Date: {date}")

        return IngestModule.ProcessResult.OK
```

***Fig. 4** Extracting Email Artifacts.*

Scenario: An investigator analyzes email communications stored on a suspect's device.

Solution: Autopsy is used with Python to extract MBOX/EML email files and parse their contents.

The script scans for email files (.eml format). It extracts headers such as sender, receiver, subject, and date. Investigators use this to analyze email communications. It extracts important evidence from emails that might contain fraud, phishing attempts, or insider threats.

Case Study 5: Extracting Metadata from Images for Digital Evidence (Fig. 5)

```
from org.sleuthkit.autopsy.ingest import IngestModule
from org.sleuthkit.datamodel import AbstractFile
from PIL import Image
from PIL.ExifTags import TAGS

class ExtractImageMetadata(IngestModule):
    def process(self, file):
        if file.getName().lower().endswith((".jpg", ".jpeg", ".png")):
            self.logMessage(f"Image Found: {file.getName()}")

            # Extract content as a temporary file
            temp_file = "/tmp/" + file.getName()
            with open(temp_file, "wb") as output:
                output.write(file.read(file.getSize()))

            # Open image and extract EXIF metadata
            img = Image.open(temp_file)
            exif_data = img._getexif()

            if exif_data:
                for tag, value in exif_data.items():
                    tag_name = TAGS.get(tag, tag)
                    self.logMessage(f"{tag_name}: {value}")

        return IngestModule.ProcessResult.OK
```

***Fig. 5** Extracting Metadata from Images.*

Scenario: An investigator extracts metadata (such as GPS coordinates) from images found on a suspect's device.

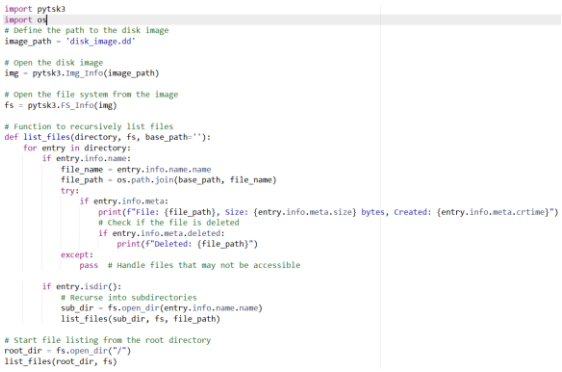
Solution: Python is used with Autopsy to extract EXIF metadata from images.

It extracts metadata from images, such as GPS coordinates, timestamps, and camera model and helps determine where and when an image was taken.

These Autopsy case studies show how Python automates digital forensics tasks such as file hash extraction, deleted file recovery, browser history analysis, email investigation, and metadata extraction. By using Python scripting, forensic investigators can save time, increase efficiency, and uncover crucial evidence faster.

Next case studies demonstrate how Python is used in conjunction with The Sleuth Kit (TSK) and Autopsy to enhance digital forensic investigations. Each case study is focused on solving real-world forensic challenges and highlights how Python scripts can automate and extend the capabilities of these tools.

Case Study 6: Automating Evidence Extraction with TSK and Python (Fig. 6)



```
import pytsk3
import os
# Define the path to the disk image
image_path = 'disk_image.dd'

# Open the disk image
img = pytsk3.Img_Info(image_path)

# Open the file system from the image
fs = pytsk3.FS_Info(img)

# Function to recursively list files
def list_files(directory, fs, base_path=''):
    for entry in directory:
        if entry.info.name:
            file_name = entry.info.name.name
            file_path = os.path.join(base_path, file_name)
            try:
                if entry.info.meta:
                    print(f"File: {file_path}, Size: {entry.info.meta.size} bytes, Created: {entry.info.meta.crtime}")
                    # Check if the file is deleted
                    if entry.info.meta.deleted:
                        print(f"Deleted: {file_path}")
            except:
                pass  # Handle files that may not be accessible

        if entry.isdir():
            # Recurse into subdirectories
            sub_dir = fs.open_dir(entry.info.name.name)
            list_files(sub_dir, fs, file_path)

# Start file listing from the root directory
root_dir = fs.open_dir("/")
list_files(root_dir, fs)
```

***Fig. 6** Automating Evidence Extraction.*

Scenario: The forensic task is with analyzing a disk image to recover files and identify any deleted files from a suspect's computer. The disk image has multiple partitions, and the forensic specialist recovers both live and deleted files by automating the extraction of relevant file metadata (e.g., file names, timestamps, file sizes) and deleted files to save time.

Solution: Using Python bindings for The Sleuth Kit (PyTSK), a Python script is developed to automate the analysis process. The script (Fig. 6) accesses the disk image and examine the file system, extract file metadata for all files, including those that are deleted, and generate a report that summarizes the findings.

The script uses PyTSK to open the disk image and access the file system. It recursively lists all files, extracting metadata (file name, size, creation time) for each file, including deleted files. The script identifies deleted files by checking the deleted attribute in the file's metadata. The script automates the process of recovering metadata and deleted files, significantly reducing the time spent on manual analysis.

Case Study 7: Hash Comparison for Malware Detection in Autopsy (Fig. 7)

```python
import hashlib
import os
from autopsy.lib import Autopsy
# Define the known malware hash database (e.g., SHA256 hashes of known malware files)
malware_hash_db = set([
    'd41d8cd98f00b204e9800998ecf8427e',  # Example hash (replace with actual)
    'e99a18c428cb38d5f260853678922e03'
])
# Function to calculate SHA256 hash of a file
def calculate_hash(file_path):
    sha256_hash = hashlib.sha256()
    with open(file_path, "rb") as f:
        # Read file in chunks of 4K
        for byte_block in iter(lambda: f.read(4096), b""):
            sha256_hash.update(byte_block)
    return sha256_hash.hexdigest()
# Function to compare hashes with the malware database
def check_for_malware(file_path):
    file_hash = calculate_hash(file_path)
    if file_hash in malware_hash_db:
        return True, file_hash  # Return True if malware hash is found
    return False, None
# Integration with Autopsy (e.g., scanning all files in the disk image)
def scan_disk_image_for_malware(disk_image_path):
    # Open the disk image in Autopsy and iterate through files
    for root, dirs, files in os.walk(disk_image_path):
        for file_name in files:
            file_path = os.path.join(root, file_name)
            is_malware, file_hash = check_for_malware(file_path)
            if is_malware:
                print(f"Malware Detected: {file_name}, Hash: {file_hash}")
                # Flag or mark the file as suspicious in Autopsy
                # Autopsy provides an API to flag files within its interface
                Autopsy.add_flag(file_path, "Malware Detected")
# Run the malware scanning function
scan_disk_image_for_malware('path_to_disk_image')
```

***Fig. 7** Hash Comparison for Malware Detection.*

Scenario: The forensic task is with analyzing a disk image to detect potential malware. The forensic specialist compares the hashes of files in the disk image against a known database of malware hashes. This process is prolonged if done manually, especially for large disk images.

Solution: A custom Autopsy module is developed in Python to automate the process of generating file hashes and comparing them with a known hash database of malware signatures.

The script calculates the SHA256 hash for each file in the disk image. It compares the calculated hash against a pre-existing database of known malware hashes. If a match is found, the script flags the file as potentially malicious, which can be reported within Autopsy. The script automates the comparison of file hashes with known malware signatures, speeding up the detection of malicious files. The integration with Autopsy allows to visualize and flag the suspicious files within the Autopsy interface, enabling quick follow-up analysis.

These case studies demonstrate the power of Python in enhancing the capabilities of The Sleuth Kit (TSK) and Autopsy. By automating repetitive tasks, recovering deleted files, detecting malware, and generating reports, Python significantly improves the efficiency, accuracy, and speed of digital forensic investigations. These practical examples show how Python can be applied to real-world challenges in digital forensics, from simple file metadata extraction to comprehensive forensic workflows.

Next case studies demonstrate how Python can be used in conjunction with Volatility for various memory forensics tasks, such as analyzing processes, detecting network connections, identifying suspicious DLLs, and uncovering rootkit activity. By automating these processes, Python enhances the forensic analysis, making it faster, more efficient, and less error-prone.

Below are practical case studies demonstrating how to use Python with Volatility, the popular memory forensics tool, to analyze memory dumps. Each case study includes a Python code snippet for specific tasks in memory analysis, focusing on different forensic needs.

Case Study 9: Analyzing Process Information with Volatility

Scenario: The goal is to analyze a memory dump to extract detailed information about the running processes at the time the memory image was captured. This identifies suspicious processes that are part of a malware attack or unauthorized activities.

Solution: Using Volatility with Python, the detailed information about the processes, including process ID, parent process ID, executable name, and the memory usage is extracted and then printed.

The Volatility framework is used to extract the list of processes in the memory dump. In this case, the linux.pslist plugin is applied to the memory dump of a Linux-based system. The script runs the volatility3 command-line tool using Python's os.popen() to interact with Volatility, extract the process information, and display it. The script outputs a list of processes, displaying information such as Process ID (PID), Parent PID (PPID), executable name, and the associated memory usage. The output to identify any unusual or suspicious processes running at the time the memory dump is examined and captured.

Case Study 10: Extracting Network Connections from a Memory Dump

Scenario: In this case, network connections and socket information from a memory dump is extracted to determine if any unauthorized network activity or malware communication occurred during the system's runtime.

Solution: Volatility's netstat plugin (for older versions of Volatility, or adapt plugins in Volatility 3) is used to extract network connections, including details such as IP addresses, ports, and the associated processes.

The script utilizes volatility3 to invoke the linux.netstat plugin, which extracts information about the system's active network connections. By using Python's os.popen() to execute the command, the output is captured and printed to the console. The script returns a list of network connections, showing information such as local and remote IP addresses, port numbers, and the associated processes. This information is used to identify potentially malicious network activity or unauthorized data exfiltration.

Case Study 11: Detecting Suspicious DLLs in Memory (Windows)

Scenario: The objective is to analyze a memory dump from a Windows system to detect any suspicious or injected DLLs. Malicious processes may inject DLLs into legitimate processes, making it important to examine the memory for such anomalies.

Solution: Volatility is used to list loaded DLLs in the memory image and then cross-reference them with known malicious DLL hashes or a whitelist.

The script first lists the loaded DLLs in a memory dump using the windows.dlllist Volatility plugin. It then calculates the hash of each DLL and compares it to a list of known malicious DLL hashes. If any of the DLLs' hashes match known malicious ones, they are flagged as suspicious. The script outputs the list of loaded DLLs in the memory dump. If any DLL matches the predefined malicious hash database, it is flagged as suspicious and printed for further investigation.

Case Study 12: Detecting Rootkits Using Volatility (Windows)

Scenario: The presence of a rootkit that might have hidden processes or files is detected. Rootkits often operate by manipulating the operating system to hide their presence.

Solution: Volatility is used to look for hidden processes or modules that are indicative of rootkit behavior. This is achieved using Volatility's pslist, pstree, and dlllist plugins.

The script runs the pslist and pstree plugins to list all processes and show the process tree. Rootkits often hide processes by tampering with the process list, so discrepancies between these outputs can be indicative of hidden or malicious activity. The dlllist plugin is used to list the loaded modules (drivers), which can help identify any hidden or malicious drivers loaded by rootkits. The output reveals any hidden processes or drivers, which may indicate the presence of a rootkit on the system. If suspicious processes or hidden drivers are detected, they can be further investigated for rootkit activity [6,7,8,9].

Below are practical case studies demonstrating how to use Scapy, a powerful Python library for network packet manipulation

and analysis. Each case study includes Python code to help with real-world forensic and security investigations.

Case Study 13: Network Traffic Sniffing and Analysis

Scenario: A cybersecurity analyst suspects unauthorized data exfiltration from a corporate network. They need to monitor network traffic to detect suspicious activity.

Solution: Use Scapy to sniff network packets, filter HTTP traffic, and identify potential data leaks.

The script captures IP packets and prints the source and destination IP addresses. It filters only IP traffic, but it can be modified to capture specific protocols like TCP, UDP, or HTTP. This is useful for detecting unauthorized connections or data transfers. The captured packets are reviewed to identify suspicious connections. Unusual outbound connections indicate data exfiltration.

Case Study 14: ARP Spoofing Detection

Scenario: An IT security team suspects an ARP spoofing attack on the network, where an attacker is trying to intercept traffic.

Solution: Scapy is used to detect ARP anomalies, such as multiple MAC addresses responding to the same IP.

The script monitors ARP replies and maintains an IP-to-MAC address mapping. If an IP is seen with a different MAC than before, it flags a potential ARP spoofing attack. This helps security teams detect MITM (Man-in-the-Middle) attacks. If an attacker is trying to spoof ARP responses, it will be detected and alerted. The security team can take countermeasures, such as blocking the attacker's MAC address.

Case Study 15: Port Scanning Detection

Scenario: A security analyst wants to identify if someone is scanning the network for open ports, a common reconnaissance technique used by attackers.

Solution: Scapy is used to detect repeated connection attempts to multiple ports.

The script monitors TCP traffic and tracks how many different ports each source IP is probing. If an IP scans more than 5 ports, it raises an alert. This is useful for detecting reconnaissance activity from attackers. If a hacker is scanning the network for vulnerabilities, the system administrator is alerted. Security teams block the attacker's IP or implement firewalls.

Case Study 16: Crafting and Sending Custom Packets

Scenario: A penetration tester sends a custom crafted SYN packet to test a firewall rule.

Solution: Scapy is used to create and send a TCP SYN packet to a specific target.

The script crafts a TCP SYN packet (used to initiate a connection) to a specified IP and port. This is useful for penetration testing or testing firewall rules. If the firewall is properly configured, it should block the request. The tester can verify if the firewall blocks SYN packets or allows unauthorized access. If the packet gets through, security policies need to be updated.

Case Study 17: DNS Spoofing Detection

Scenario: A network administrator suspects that a DNS spoofing attack is redirecting users to malicious websites.

Solution: Scapy is used to monitor DNS responses and check for inconsistencies.

The script captures DNS responses and checks for changes in IP resolution. If the same domain resolves to different IPs over time, it indicates DNS spoofing. This helps prevent phishing attacks and man-in-the-middle (MITM) attacks. The script flags potential DNS spoofing, allowing security teams to investigate further. Users avoid being redirected to malicious websites.

These case studies demonstrate how Scapy is used in cybersecurity investigations and forensic analysis. From sniffing traffic and detecting attacks to crafting custom packets, Scapy is a versatile tool for network security professionals.

3. Conclusion

These case studies show how Python can automate digital forensics tasks such as file hash extraction, deleted file recovery, browser history analysis, email investigation, and metadata extraction. By using Python scripting, forensic investigators can save time, increase efficiency, and uncover crucial evidence faster. The benefits of using Python with computer forensic tools are automation, customizability, extensibility, interoperability, and integrating different forensic tools into a single workflow.

The report is in implementation of the National Scientific Program "Security and Defense", adopted with RMS No. 731/21.10.2021, and financed by the Ministry of Education and Science of the Republic of Bulgaria according to Agreement No. D01-74/19.05.2022.

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