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TERNOPII NATIONAL ECONOMIC UNIVERSITY  
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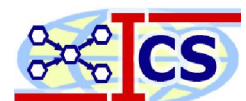
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**НДІ ІНТЕЛЕКТУАЛЬНИХ КОМП'ЮТЕРНИХ СИСТЕМ**  
**ТЕРНОПІЛЬСЬКИЙ НАЦІОНАЛЬНИЙ ЕКОНОМІЧНИЙ УНІВЕРСИТЕТ**  
У СПІВПРАЦІ  
**З ІНСТИТУТОМ КІБЕРНЕТИКИ ІМ. В.М. ГЛУШКОВА,**  
**НАЦІОНАЛЬНА АКАДЕМІЯ НАУК УКРАЇНИ**



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## DESIGN OF THE FUZZY CONTROL SYSTEM FOR THE WASTE HEAT UTILIZATION PLANTS DRIVEN BY THE THERMOACOUSTIC ENGINE

Yuriy Kondratenko <sup>1)</sup>, Volodymyr Korobko <sup>2)</sup>,  
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**Abstract:** The paper addresses the synthesis of fuzzy controllers for computerized control system of the waste heat energy (WHE) utilization plants that operate with a thermoacoustic engine (TAE). Based on the analysis of existing systems, the authors present the main tasks of the synthesized control system, describe its structure and main components. Created system is then tested on the experimental thermoacoustic installation. Using the obtained experimental data, the authors synthesize the mathematical model of the thermoacoustic plant and describe the methodology of its control by the adjustments in resonator length of the thermoacoustic device. Using the suggested approach the authors design a number of conventional discrete and fuzzy controllers and provide the comparative analysis of quality indicators of transient responses of the designed control systems. *Copyright © Research Institute for Intelligent Computer Systems, 2014. All rights reserved.*

**Keywords:** energy utilization, thermoacoustic plant, control system, fuzzy controllers

### 1. INTRODUCTION

The current state of society and industry leads to high energy consumption. High level of energy production causes the decrease in renewable mineral resources stocks and also the increase in global ecological problems, such as chemical pollution, thermal emissions and greenhouse gases. Therefore, the innovative energy efficiency technologies development and implementation is a primary task.

Today the thermal power plants (TPP), which operate through heat engines, provide most of energy. In simplified form energy balance of conditional TPP can be written as

$$Q_{fuel} = Q_{he} + Q_{wh} + Q_{loses} \quad (1)$$

Modern heat engines are able to convert only part of the fuel heat into mechanical energy  $Q_{he}$ . The work of heat engine is accompanied by the emission of heat in the environment  $Q_{wh} + Q_{loses}$ . Part of this emission that can be reused by existing TPP is the waste heat energy resources  $Q_{wh}$ . The heat that is technologically impossible or economically impractical to use creates the thermal pollution  $Q_{loses}$ .

The part of energy converted by the engine  $Q_{he}$  shows the degree of heat engine technical and

thermodynamic perfection. The value of  $Q_{wh}$  depends on the structural effectiveness, coolant temperature, TPP's thermo-physical properties, and existing technologies. Thus, applying the new saving technologies to increase the value of  $Q_{wh}$  in existing energy plants and systems is an important task.

Presently, there is a number of new technologies for energy utilization, among them the one based on thermoacoustic effect [1]. Thermoacoustics combines the fields of thermodynamics and acoustics and describes the process of interaction between heat and sound energy. The work of thermoacoustic devices (TAD) is based on the mutual transformation of heat and acoustic energies. The main feature of thermoacoustic systems is that unlike the other heat machines, the powerful acoustic pulses [2], generated by TAD are the carriers of mechanical energy and the "executive mechanism" of thermodynamic cycle.

Considering the thermoacoustic processes (TAP) reversibility, thermoacoustic devices can be divided into two main types [3-5]:

- thermoacoustic engines (TAE) that consume supplied heat energy and produce acoustic wave inside the resonator;
- thermoacoustic refrigerators (TAR) and heat pumps (TAHP) that consume energy from supplied



acoustic wave and produce cooling or heating power, respectively.

The design of WHE utilization plants based on the thermoacoustic effect includes two main parts. First is the TAE that converts supplied waste heat into acoustic energy inside the TAD resonator. The second part is the TAHP, which uses the acoustic energy and thermoacoustic effect to heat up the supplied WHE or another supplied coolant. Thus, the output temperature of TAHP could be over 100 degrees higher than the temperature of supplied coolant.

The efficiency of thermoacoustic devices highly depends on the optimal values of its internal parameters (viscosity, density, thermal conductivity) and the environment effects (temperature, pressure, etc.).

An effective work of TAD is possible only if the different nature values of the internal parameters (acoustic, hydrodynamic, thermal) are stabilized. Optimization of thermodynamic cycle, improvement of the hydrodynamic and heat transfer processes can increase the efficiency of thermoacoustic devices. Therefore, it is reasonable and necessary to develop the automatic system for thermoacoustic processes control.

## 2. DESCRIPTION OF EXPERIMENTAL PLANT FOR TAD ANALYSIS

The main published results in the field of automated monitoring and analysis of TAP are based on the electro-acoustic systems, which use the loudspeaker as the source of acoustic pulses inside the TAD resonator. In particular, in [5] the structure and algorithms of computer system are considered for loudspeaker driven thermoacoustic refrigerator energy and acoustic parameters analysis [1]. Methods of assessing the acoustic power in these systems are based on the measurement of pressure  $p(t)$  using the pressure sensors and evaluation of the oscillatory velocity  $v(t)$  in the resonator by measuring the acceleration  $a(t)$  of loudspeaker membrane using the accelerometer. This narrows the scope of use for such computerized systems only by the automation of electroacoustic installations.

The direct method [1] that combines the simultaneous measurements of  $p(t)$  (by the pressure transducer) and  $v(t)$  (by the laser Doppler velocity meter) is usually used for determination of the sound waves parameters in thermoacoustic systems. This approach allows determining the value of the acoustic pressure  $p(t)$  and the oscillatory velocity  $v(t)$  with high accuracy, but requires expensive equipment and the availability of transparent zone in resonator to undergo laser beams. These shortcomings limit the possibility of the direct method usage only by research systems, and make

its implementation in TAD automated control systems unreasonable.

Proposed by the authors, computerized system for monitoring and control of thermoacoustic processes implements the two sensors method [6] for acoustic wave's parameters estimation in the resonator of thermoacoustic device. This approach allows the avoidance of the drawbacks and limitations of the above stated methodologies and makes possible the creation of the universal system for thermoacoustic processes automated monitoring.

Fig. 1 shows the structure and main components of the computerized system [7] for the thermoacoustic processes parameters determination. Due to the thermoacoustic process features, the computer system must combine rapid data (acoustic pressure actuations, current and voltage oscillations) and slow data signals (temperature variations). Thus, it is necessary to use the distributed structure for the created monitoring system (Fig. 1).

The main elements of the system are: personal computer (PC), pressure ( $PS1, \dots, PS4$ ), temperature ( $TS1, \dots, TS4$ ), current ( $CS$ ) and voltage ( $VS$ ) sensors; programmable logic controller (PLC) ICPDAS  $\mu$ PAC 7186EX-SM that collects the thermal behavior data of TAD; microcontroller (MCU) STM32F407VGT6, that is used to collect rapidly changing data from the system pressure, current and voltage sensors and transfer it to the PC.

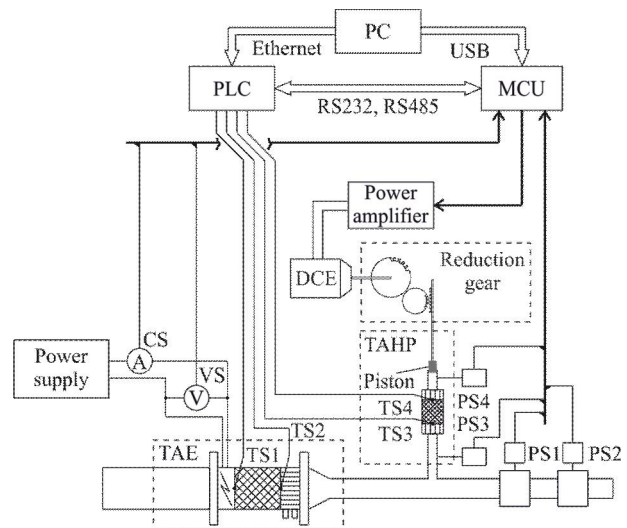


Fig. 1 – The computerized system for control of thermoacoustic devices

STM32F4 microcontroller has three analog-to-digital converters, which are characterized by 12-bit resolution and conversion frequency of up to 2.4 Msps. This provides high performance and applicability of the proposed computer system for any thermoacoustic unit, since the operating frequency range of TAD does not exceed tens of kHz. PLC performs data acquisition of the current

status of TAD peripheral equipment and sends it to PC through the Ethernet networks.

The designed system allows the communication between all components via RS232 network, also to enable the transfer of large amounts of data, PLC supports the Ethernet connection with PC and MCU can communicate with PC via USB. This grants maximum flexibility to designed distributed computer system.

Created software for PC allows storing the received from the controller information in the archive database; execution of the necessary algorithms for digital processing of measured signals, and displaying all available information on the user's screen.

Therefore, the proposed structure of distributed computer system allows the registration and ongoing monitoring of the thermoacoustic processes.

### 3. EXPERIMENTAL STUDIES OF THERMOACOUSTIC ENGINE

The tests of proposed by the authors computerized system were conducted using the experimental thermoacoustic engine (Fig. 2) [1,7], with a resonator length of 1010 mm and diameter of 46 mm, which was filled with air at atmospheric pressure. Engine was coupled with thermoacoustic heat pump (TAHP), which acted as a payload of the system (Fig. 1).

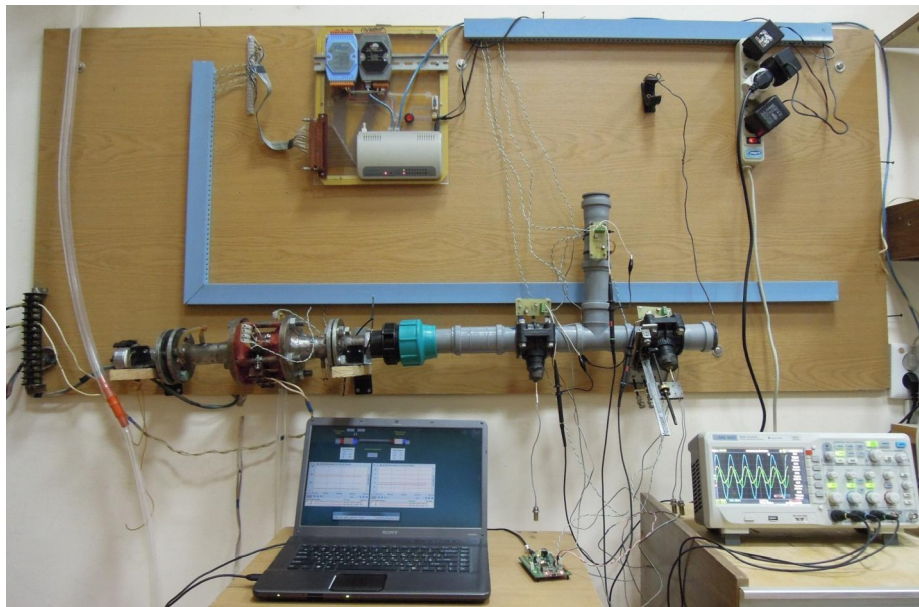


Fig. 2 – Photo of the experimental plant for TAD analysis

TAE convert's supplied heat  $P_Q$  into acoustic power  $P_{ac}$ , so its efficiency can be estimated as the ratio of established acoustic power to the supplied heat. In the experimental plant (Fig. 1) the nichrome heater is used as a source of the thermal energy  $P_Q$  and thus supplied power  $P_{supl}$  can be calculated through the consumption of electricity  $P_{el}$  by the heater (2), supplied by the power supply unit and measured by the current sensor ACS712ELCTR-05B-T, and the voltage divider.

$$\eta_{TAE} = \frac{P_{ac}}{P_{supl}} \cdot 100\% = \frac{P_{ac}}{P_{el}} \cdot 100\%, \quad (2)$$

To calculate the acoustic power  $P_{ac}$ , the information from two pressure sensors MPXV7007DP (PS1 and PS2 in Fig. 1), which are situated at a  $\Delta x=160$  mm distance from each other, is collected by the MCU. Based on the data obtained from PS1 and PS2 the acoustic power can be

calculated using the two sensor method [6]. This method allows the calculation of pressure  $p_0(t)$ , particle velocity  $v_0(t)$  and acoustic power  $P_{ac}(t)$  at the point that is situated in the middle ( $\Delta x/2$ ) between the points of pressure measurements. It should be noted that calculated by the described method values of particle velocity  $v_0(t)$  and acoustic power  $P_{ac}$  were verified by the data obtained directly from the hot-wire anemometer.

Distance from the engine edge to the first pressure sensor is 745 mm, and to the second – 905 mm. Control of thermal data of the system was carried out using the thermocouples TS (Fig. 1).

Fig. 3 shows the results of TAE experimental measurements. Fig. 3, a illustrates the parameters of acoustic waves that were calculated using two sensors method. Thermoacoustic engine starting process is shown in Fig. 3, b, where on the top there are rooted mean square values (3) of calculated pressure  $p_0(t)$  and particle velocity  $v_0(t)$  and on the

bottom – temperature changes in points TS1 and TS2 (Fig. 1).

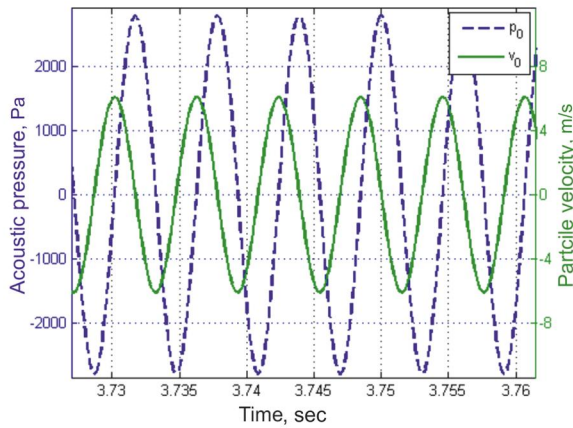
$$RMS(x) = \sqrt{\frac{1}{N} \sum_{k=1}^N x_k^2}, \quad (3)$$

where  $x_k$  – experimental data sample,  $N=10000$  samples – RMS period.

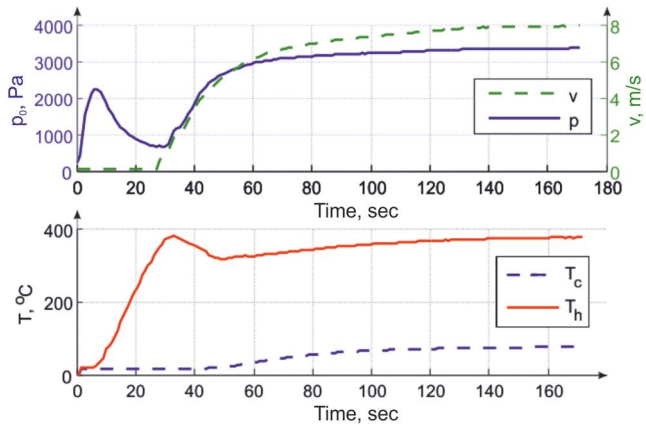
Calculated TAE efficiency values along with other experimental results are shown in Table 1. The experimental series include five tryouts with different supplied power. It should be noted that these values of efficiency are typical for air filled TAD working under atmospheric pressure.

**Table 1. Results of the experimental study of TAD acoustic energy parameters**

| Parameter        | Experiment number |       |       |       |       |
|------------------|-------------------|-------|-------|-------|-------|
|                  | 1                 | 2     | 3     | 4     | 5     |
| $T_H, K$         | 548.6             | 568.5 | 632.5 | 594.9 | 648.6 |
| $T_C, K$         | 287.8             | 303.8 | 320.1 | 322.5 | 349   |
| $I, A$           | 2.3               | 3     | 3.5   | 4     | 5     |
| $U, V$           | 23.1              | 31.1  | 37    | 41.5  | 51.8  |
| $P_{el}, W$      | 53.13             | 93.3  | 129.5 | 166   | 259   |
| $p_0, Pa$        | 543               | 1768  | 2021  | 2795  | 4128  |
| $v_0, m/s$       | 0.85              | 3.2   | 3.8   | 5.93  | 7.27  |
| $P_{ak}, W$      | 0.39              | 4.8   | 6.4   | 14.16 | 22.4  |
| $\eta_{TAE}, \%$ | 0.73              | 5.14  | 5     | 8.53  | 8.56  |



**a) instant values of pressure  $p_0(t)$  and velocity  $v_0(t)$**



**b) TAE starting process**

**Fig. 3 – Results of the experimental study of TAE working process**

Enhancements of TAE efficiency can be achieved by the structural changes in the engine, increase of the operating pressure in the resonator and by replacement of the TAE working fluid from air to helium.

Further research showed that in given configuration the maximum pressure magnitude inside the TAE resonator depends on the length of TAHP resonator branch [7]. Thus, the control of TAD working process can be made by the adjustments in TAHP resonator length. Therefore, further let's consider the synthesis of TAD control system based on the change of the TAHP resonator length.

#### 4. SYNTHESIS OF THE THERMOACOUSTIC PROCESSES CONTROL SYSTEM

Based on the results of experimental studies (Fig. 3), it can be concluded that the TAE can be described by the first order transfer functions that represent the pressure  $p(t)$  and particle velocity  $v(t)$  which are generated due to the supplied power  $P_{supl}(t)$ . The exact values of pressure (4) and

velocity (5) transfer functions (TF) were identified using the least squares regression method [8] with the desired functionality in the form (6).

$$W_p(p) = \frac{14.66}{48.72 p + 1}, \quad (4)$$

$$W_U(p) = \frac{5 \cdot 10^{-5}}{41.36 p + 1}, \quad (5)$$

It should be noted that TF  $W_U(p)$  (5) represents volume velocity in TAE resonator and it can be calculated as  $U(t)=v(t)A$  with  $A$  is the cross section area of TAE resonator.

$$\min_{k,T} J(k, T) = \min_{k,T} \sum_{j=1}^N \left[ \frac{k}{T} e^{-\frac{t}{T}} - y_j \right]^2, \quad (6)$$

where  $k, T$  – parameters of first order link,  $y$  – experimental sample,  $N$  – experimental sample length.

TAHP branch is represented by the transfer matrix  $W_{TAHP}(p)$  that is based on the Rott's

representation of continuity (7) and momentum (8) equations [1] and identified model (9) of temperature difference  $W_T(p)$  between the stack hot TS4 and cold TS3 ends (Fig. 1). For the given geometry of experimental thermoacoustic plant equations (7) and (8) can be represented by a matrix (10).

The change of the TAHP resonator length is simulated by the system that transforms direct

$$\frac{dp}{dx} = -\frac{1}{A} \frac{i\omega\rho_m}{1-f_v} u_1, \tag{7}$$

$$\frac{du_1}{dx} = -A \frac{i\omega[1+(\gamma-1)f_k]}{\gamma p_m} p + \frac{f_k - f_v}{(1-f_v)(1-\sigma)} \frac{1}{T_m} \frac{dT_m}{dx} u_1, \tag{8}$$

$$W_T(p) = \frac{7,18 \cdot 10^{-4} p + 6,05 \cdot 10^{-6}}{p^2 + 0,12 p + 5,49 \cdot 10^{-4}}, \tag{9}$$

$$W_{TATH}(p) = \begin{bmatrix} 0.903 + 0.002i & 1.006 \cdot 10^3 + 9.094 \cdot 10^4 i \\ -9.715 \cdot 10^{-9} - 2.024 \cdot 10^{-6} i & 0.903 + 0.002i \end{bmatrix}, \tag{10}$$

where  $\rho_m$  – density of the medium;  $\sigma$  – Prandtl number;  $T_m$  – function of the temperature field distribution along the resonator;  $p$  – acoustic pressure;  $u_1$  – volume velocity;  $f_v$  та  $f_k$  – Rott functions that depend on the geometry and thermal properties of the stack and gas mixture;  $\gamma$  – universal gas constant, for air  $\gamma=1.4$ ;  $A$  – cross sectional area of resonator;  $i$  – imaginary unit;  $\omega$  – acoustic wave frequency.

$$f_{res} = \frac{a}{\lambda} = \frac{\sqrt{\gamma k T / m}}{nL}, \tag{11}$$

where  $f$  – sound wave frequency;  $a$  – speed of sound;  $\lambda$  – sound wave length;  $k$  – Boltzmann constant;  $\gamma$  – the adiabatic coefficient of gases;  $T$  – absolute temperature;  $m$  – molecular mass of gas;  $L$  – resonator length;  $n$  – acoustic wave length multiplier.

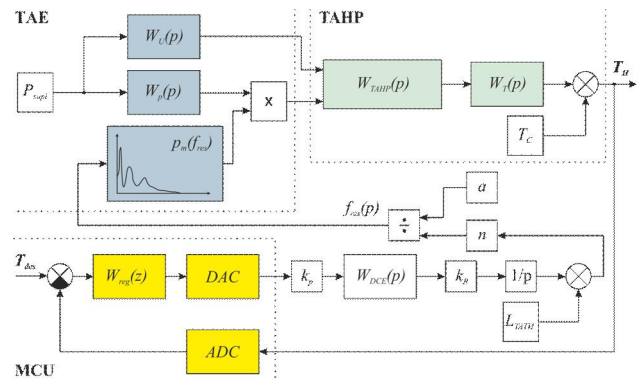
The resulting linear [9] model of TAD is shown in Fig. 4. The input values for the system are: supplied to TAE electric power  $P_{supl}$ , starting length of TAHP resonator  $L_{TATH}$ , value of cold end of TAHP stack  $T_C$ , value of speed of sound  $a=343$  m/s and desired temperature  $T_{des}$  of TAHP stack hot end.

The acoustic wave length multiplier  $n$ , for current setup is equal to 2 (half wave length resonator),  $k_R$  is the reduction gear coefficient that transforms rotational movement of the DC engine into the TAHP resonator end piston translational movement.

current (DC) engine  $W_{DCE}(p)$  rotational movement into linear using the reduction gear. The effect of resonator length change is simulated by the experimentally obtained nonlinear dependency of pressure magnitude  $p(t)$  from the acoustic wave frequency inside the TAHP resonator.

The relation between TAHP resonator length  $L_{res}$  and acoustic wave frequency  $f_{res}$  are caharacterized by equation (11).

The acoustic pressure magnitude is adjusted by the value of the nonlinear dependency  $p_m(f_{res})$ , which is normalized by the pressure value at the resonant frequency (11). The output of the system is the value of the TAHP stack hot end  $T_H(p)$ .



**Fig. 4 – The resulting model of the system for TAD control by the TAHP resonator length adjustment**

The simulation of synthesized TAD model working process is shown in Fig. 5.

It demonstrates that the implementation of control system decreases the transient response time (with 5% setting bounds) from  $t_{trans}^{TAD} = 365.6$  sec to

$$t_{trans}^{PD} = 301.3 \text{ sec.}$$

The desired value of TAHP stack hot end is set to  $T_{des}=45$  °C. Synthesized system uses the discrete [10] proportional-derivative (PD) regulator, whose transfer function is defined in the equation (10).

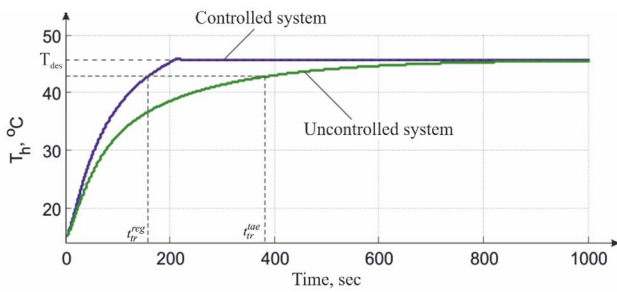


Fig. 5 – Simulation results of synthesized TAD model

$$W_{reg}(z) \Big|_{T_0=0.1} = \frac{6.037z - 5.374}{z - 0.06542} \quad (12)$$

It should be noted that the discretization period of  $T_0=0.1$  sec is equal to the sample time of thermocouple data acquisition module.

### 5. SYNTHESIS OF FUZZY CONTROLLERS FOR THE TAE DRIVEN PLANT

Fuzzy control provides a formal methodology [11] for representing, manipulating, and implementing a human’s heuristic knowledge about how to control a system.

Fuzzy controllers are applicable primarily to manage objects that either could not be described or could be described with great difficulties. However, even for control objects, for which mathematical model could be obtained, these regulators are often better than others, because they allow to obtain higher quality (fewer errors in transient and steady state) of automatic control.

The microcontroller based fuzzy controller [12] block diagram for thermoacoustic plant is given in Fig. 6, where the fuzzy controller embedded in a closed-loop control system is shown.

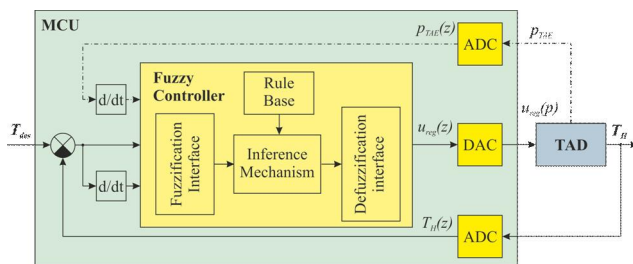


Fig. 6 – Block diagram of the TAD control system with MCU-based fuzzy controller

Authors designed [13] PD fuzzy controllers of Mamdani and Sugeno types for the control system of thermoacoustic plant. The input signals for controllers are the error signal between the desired and current temperature of hot end of TAHP stack ( $\varepsilon = T_{des} - T_H$ ) and the first derivative of the error signal. Input signals of fuzzy controllers are

described by five triangular terms, and the output signal  $u_{reg}$  is described by the seven terms for Mamdani controller (Table 2) and first order polynomial for Sugeno controller. The knowledge base of fuzzy system consists of 25 rules (Table 3).

Table 2. Terms of Mamdani fuzzy controller

| Term                                 | Membership function | Range of values  |
|--------------------------------------|---------------------|------------------|
| For input variable $\varepsilon$     |                     |                  |
| BN – Big Negative                    | Triangle            | [-1.5 -1 -0.5]   |
| SN – Small Negative                  | Triangle            | [-1 -0.5 0]      |
| Z – Zero                             | Triangle            | [-0.5 0 0.5]     |
| SP – Small Positive                  | Triangle            | [0 0.5 1]        |
| BP – Big Positive                    | Triangle            | [0.5 1 1.5]      |
| For input variable $d\varepsilon/dt$ |                     |                  |
| BN – Big Negative                    | Triangle            | [-1.5 -1 -0.5]   |
| SN – Small Negative                  | Triangle            | [-1 -0.5 0]      |
| Z – Zero                             | Triangle            | [-0.5 0 0.5]     |
| SP – Small Positive                  | Triangle            | [0 0.5 1]        |
| BP – Big Positive                    | Triangle            | [0.5 1 1.5]      |
| For output variable $u_{reg}$        |                     |                  |
| BN – Big Negative                    | Triangle            | [-1.5 -1 -0.67]  |
| MN – Middle Negative                 | Triangle            | [-1 -0.67 -0.33] |
| SN – Small Negative                  | Triangle            | [-0.67 -0.33 0]  |
| Z – Zero                             | Triangle            | [-0.33 0 0.33]   |
| SP – Small Positive                  | Triangle            | [0 0.33 0.67]    |
| MP – Middle Positive                 | Triangle            | [0.33 0.67 1]    |
| BP – Big Positive                    | Triangle            | [0.67 1 1.5]     |

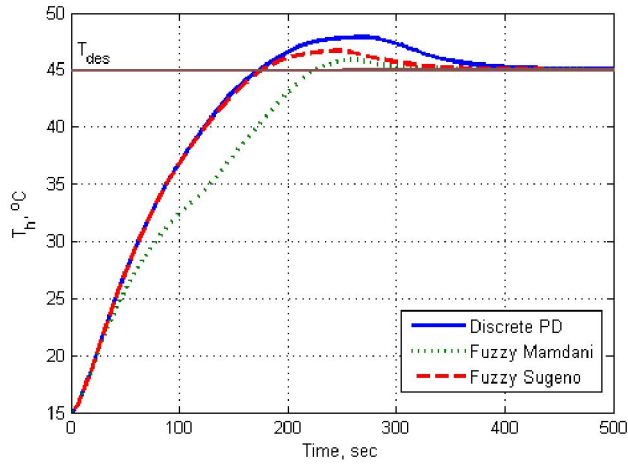
Table 3. Knowledge base of Mamdani fuzzy controller

|                      |    | Error derivative, $d\varepsilon/dt$ |    |    |    |    |
|----------------------|----|-------------------------------------|----|----|----|----|
|                      |    | BN                                  | SN | Z  | SP | BP |
| Error, $\varepsilon$ | BN | BN                                  | BN | BN | MN | SN |
|                      | SN | BN                                  | MN | MN | SN | SP |
|                      | Z  | SN                                  | SN | Z  | SP | SP |
|                      | SP | SN                                  | SP | MP | MP | BP |
|                      | BP | SP                                  | MP | BP | BP | BP |

Transient responses comparison of created Mamdani and Sugeno fuzzy controllers with two input variables is given in Fig. 7. Based on the analysis of results obtained (Fig. 7) it could be concluded that the Sugeno fuzzy controller enhances the control system with best quality indicators of transient response, including the response time of 149.39 sec and static error of 0.06°C.

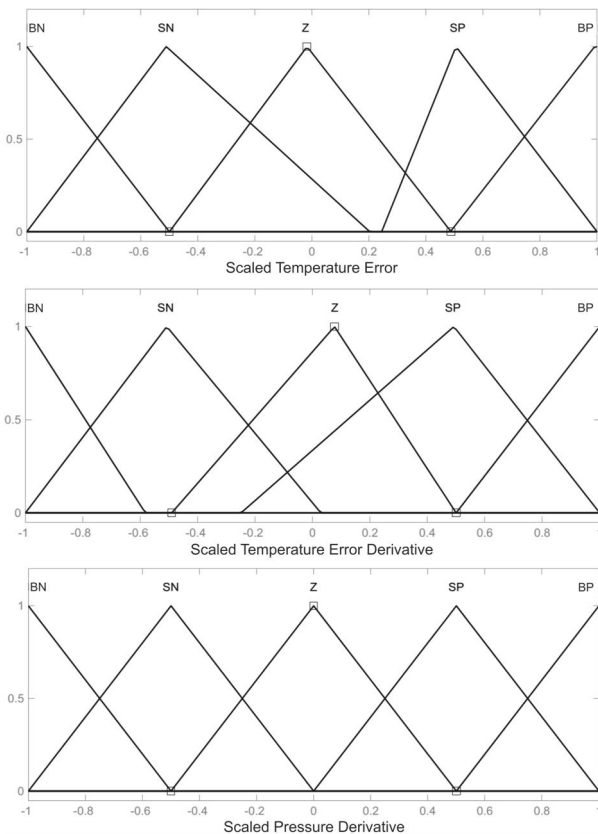
Application of fuzzy logic paradigms [13,14] for design of controllers for WHE utilization system driven by the TAE allows to create the hybrid controller that responds not only to changes in the values of the hot heat exchanger of TAHP branch ( $T_H$ ), but also to the value of the pressure derivative ( $p_{TAE}$ ) inside the TAE. Additional feedback is shown in Fig. 6 by the dash-dot line. Synthesized according to this principle hybrid Sugeno fuzzy controller has three input signals, each of which is described by

five triangular terms and their relations are characterized by the knowledge base, consisting of 125 rules. Seven first order polynomials form the output signal of the controller.



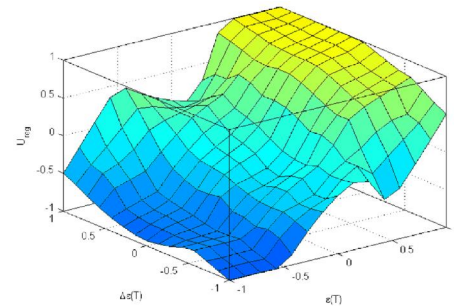
**Fig. 7 – Comparison of designed fuzzy and discrete PD controllers**

Input membership functions of the hybrid fuzzy controller are given in Fig. 8 and its characteristic surfaces are shown in Fig. 9. A comparative analysis of the quality indicators of the TAD control system transient response (Fig. 10) with PD and hybrid Sugeno fuzzy controllers are shown in Table 4.

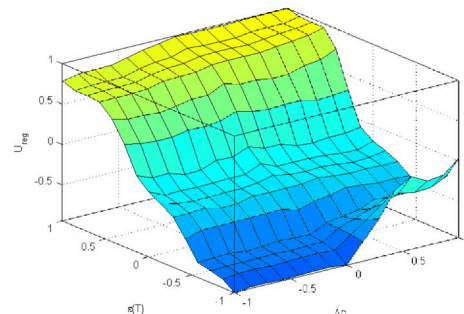


**Fig. 8 – Input membership functions of the synthesized hybrid fuzzy controller**

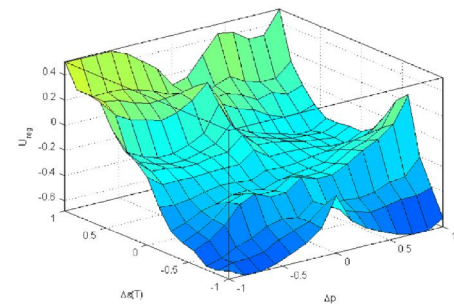
Designed hybrid fuzzy controller provides better dynamical characteristics of the WHE utilization system driven by the thermoacoustic engine. It should be noted that with the introduction of an additional variable to the regulating law it is possible to increase the robust properties of the synthesized control system.



**a)  $u_{reg} = f(d\varepsilon, \varepsilon)$**

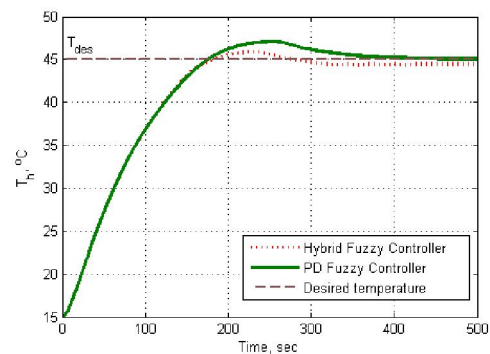


**b)  $u_{reg} = f(\varepsilon, dp)$**



**c)  $u_{reg} = f(d\varepsilon, dp)$**

**Fig. 9 – Characteristic surfaces of the synthesized hybrid fuzzy controller**



**Fig. 10 – Comparison of designed PD and hybrid Sugeno fuzzy controllers**

**Table 4. Results of the experimental study of TAD acoustic energy parameters**

| Parameter                    | Discrete PD | Fuzzy Mamdani | Fuzzy Sugeno | Hybrid Sugeno |
|------------------------------|-------------|---------------|--------------|---------------|
| Transient response time, sec | 301.3       | 197.65        | 149.39       | 146.77        |
| Overshot, %                  | 6.34%       | 1.97%         | 3.77%        | 1.97%         |
| Static error, °C             | 0.06        | 0.03          | 0.06         | 0,56          |

## 6. CONCLUSION

The article presents the design of optimum controller for waste heat utilization plant with thermoacoustic engine. Authors describe the series of regulators that by changing the length of the heat pump branch resonator can stabilize the output temperature of the thermoacoustic system. A comparative analysis of continuous PD controller with the fuzzy controllers of Mamdani and Sugeno types showed the feasibility of control devices on fuzzy logic for control of thermoacoustic devices.

The authors propose a hybrid fuzzy logic controller which also reacts to changes in the acoustic pressure of the thermoacoustic engine. Such controller grants to the control system best dynamic qualities in comparison to other regulators (Table 4).

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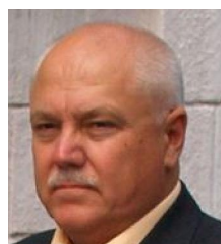
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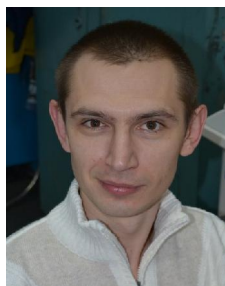
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## ENHANCED RECONFIGURABLE WEIGHTED ASSOCIATION RULE MINING FOR FREQUENT PATTERNS OF WEB LOGS

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**Abstract:** Systolic tree structure is a reconfigurable architecture in field-programmable gate arrays which provide performance advantages. It is used for frequent pattern mining operations. High throughput and cost effective performance are the highlights of the systolic tree based reconfigurable architecture. Frequent pattern mining algorithms are used to find frequently occurring item sets in databases. However, space and computational time requirements are very high in frequent pattern mining algorithms. In the proposed system, systolic tree based hardware mechanism is employed with Weighted Association Rule Mining (WARM) for frequent item set extraction process of the Web access logs. Weighted rule mining is to mine the items which are assigned with weights based on user's interest and the importance of the items. In the proposed system, weights are assigned automatically to Web pages that are visited by the users. Hence, systolic tree based rule mining scheme is enhanced for WARM process, which fetches the frequently accessed Web pages with weight values. The dynamic Web page weight assignment scheme uses the page request count and span time values. The proposed system improves the weight estimation process with span time, request count and access sequence details. The user interest based page weight is used to extract the frequent item sets. The proposed system will also improve the mining efficiency on sparse patterns. The goal is to drive the mining focus to those significant relationships involving items with significant weights. *Copyright © Research Institute for Intelligent Computer Systems, 2014. All rights reserved.*

**Keywords:** Frequent pattern mining, FPGA, reconfigurable architecture, systolic tree, Automatic weight estimation, WARM, Web logs.

### 1. INTRODUCTION

Items commonly appearing together in a Transactional database can be determined using frequent pattern mining. In the research literature to mine the frequent patterns, algorithms like Apriori, FP-growth, DynFP-growth, FP-Bonsai (The art of growing and pruning small FP trees) [15] and AFOPT [16] are used. The FP-growth algorithm stores all transactions in the database as a tree using two scans [1, 11]. It uses recursion to traverse the tree and mine patterns. It is difficult to implement recursive processing directly in hardware, as dynamic memory allocation typically requires some software management. For this reason, the dynamic data structures such as linked lists and trees are widely used in software implementations and these are very rarely used in a direct hardware implementation. Consequently, it would be very difficult to directly translate this FP-growth algorithm into hardware.

FPGAs (Field Programmable gate arrays) referred to as "programmable logic", are general-

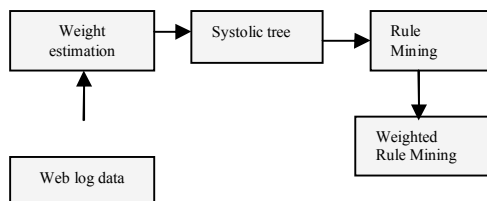
purpose hardware Silicon chips. In contrast to ASICs (application-specific integrated circuits), FPGAs have no pre-determined functionality. But they can be configured to implement arbitrary logic by combining gates, flip flops and memory banks. FPGAs can provide performance advantages with lower resource consumption (e.g., energy) and with low cost than conventional CPUs. Existing reconfigurable systolic tree architecture for frequent pattern mining describes a prototype using FPGA platform. Advantage of FPGAs over traditional computing platforms is the ability to parallelize algorithms at the operand-level granularity, as opposed to the module-level or higher [2]. Hence they minimize reliability concerns with true parallel execution and deterministic hardware dedicated to every task. FPGA-based approach can be several times faster than a software implementation of the FP-growth algorithm. The adoption of FPGA technology continues to increase as higher-level tools evolve to deliver the benefits of reprogrammable silicon to engineers and scientists at all levels of expertise.

A systolic tree is an arrangement of pipelined processing elements (PE) in a multidimensional tree pattern [3]. The significant features of systolic tree based reconfigurable architecture are high throughput and faster execution. The systolic tree is mapped in FPGA hardware which is similar to the FP-tree as used in software. The transaction items are updated into the systolic tree with candidate item matching and count update operations. Due to the limited size of the systolic tree, a transactional database must be projected into smaller ones each of which can be mined in hardware.

Association rule mining (ARM) is one of the most essential types of knowledge representation and pattern extraction which brings out the implicit relationships among the items present in large number of transactions. It finds out the association rules that satisfy the predefined minimum support and confidence from a given database.

Traditional model of ARM is adapted to handle WARM problems where each item is allowed to have a weight [4]. The goal of using weighted support is to make use of weights in the mining process. Introduction of weights during mining is to prioritize the selection of target itemsets according to their significance in the dataset, rather than measuring frequency (the rate of occurrence of item sets) alone.

The application of data mining techniques on the Web is now the focus of an increasing number of researchers. Web mining discovers information from Web documents and services. Web log mining is a promising tool to study user behaviors, which could further benefit web-site designers with better organization and services. Proposed system is designed to perform weighted rule mining for Web logs and automatic weight estimation scheme is used. Each Web page is assigned a weight value with reference to the request count and access sequence. Enhanced systolic tree based approach is used in the proposed system to mine frequent item sets in Web log data as shown in Fig. 1.



**Fig. 1 – Enhanced systolic tree approach for Web log data.**

Rest of the sections is organized as follows. Section 2 discusses related works of the systolic tree based rule mining systems. Web-log analysis and

weight estimation process is described in Section 3. The design and construction of a systolic tree, mining process and need for database projection is discussed in Section 4. In Section 5 is discussed the enhanced systolic tree based weighted rule mining approach. In Section 6, experimental evaluation is presented and the comparison for memory requirement and efficiency analysis between systolic tree based rule mining and systolic tree based weighted rule mining is given. Finally the conclusion and future enhancement is given in Section 7.

## 2. RELATED WORK

Many efforts have been made in hardware-based frequent pattern mining algorithms in recent days. A parallel implementation of the Apriori algorithm on FPGA [5] focuses on significantly reducing the processing time, through the use of a new extension to the systolic array architecture. Due to the processing time involved in reading the transactional database multiple times, the hardware implementation is 4 times faster than the fastest software implementation. The authors of parallel FPGA further explored the parallelism and developed a bitmapped CAM architecture which provides 24 times performance gain over the software version [6].

More number of candidate itemsets and a large database would create a performance bottleneck incurred in Apriori based hardware schemes. The Hash based and Pipelined (HAPPI) architecture proposed in [7, 10] for hardware enhanced rule mining uses the pipelining methodology which outperforms the Apriori architecture introduced by Z. K. Baker and V. K. Prasanna [5] when the number of different items and the minimum support values are increased.

Narayanan et al, portrayed hardware architecture for a Decision Tree Classification (DTC) algorithm, and showed that optimizing the Gini score computation significantly increases the overall performance [8]. Among the several solutions developed, DTC is a popular method that yields high accuracy while handling large datasets.

The classical models ignore the difference between the transactions, and the weighted association rule mining does not work on databases with only binary attributes. A new measure using link-based models called w-support takes the quality of transactions into consideration rather preassigned weights [9].

Web log files are analyzed to get the information that are useful for improving the services offered by Web portals and information access and retrieval tools, giving information on problems occurred to

the users. Mining frequent patterns from Web log data can help to optimize the structure of a Web site and improve the performance of Web servers. Web users can also benefit from these frequent patterns. Frequent pattern mining techniques are discussed for discovering different types of patterns in a Web log [13]. For obtaining frequent access patterns from the web log data and to provide valuable information about the user's interest, FP-growth algorithm is used [17]. A new algorithm called Combined Frequent Pattern Mining (CFPM) is proposed by Liping Sun and Xiuzhen Zhang [14] to cater for Web log data specifically.

An efficient mining methodology for WARM has been proposed [12] by Wei Wang et al. WARM assigns numerical attribute for every item. This judges the weight of the item in a particular weight domain. The issues of discovering significant binary relationships in transaction datasets in a weighted setting is addressed in [4] where each item is allowed to have a weight. This uses the idea of WARM [12] to bring out an improved one. This algorithm is both scalable and efficient in discovering significant relationships in weighted settings.

### 3. WEB-LOG ANALYSIS AND WEIGHT ESTIMATION

#### 3.1. WEB-LOG ANALYSIS

Web mining focuses on automatically discovering information and knowledge through the analysis of Web contents, Web structure and Web usages. Since the Web is huge, heterogeneous and dynamic, automated Web information and knowledge discovery calls for novel technologies and tools, which may take advantage of the state-of-the-art technologies from various areas, including machine learning, data mining, information retrieval, database and natural language processing [13].

Web mining techniques are used to analyze the Web information resources. Web content mining and structure mining methods are used to analyze the Web page contents. The user access information is maintained under the Web logs in Web server environment. Usage mining techniques are used to analyze the Web logs to extract user access patterns. The Web content management and link connectivity are improved using the access patterns [14].

The Web page request details are maintained in the Web logs. Page URL, IP address, requested time, session ID and span time are updated for each page request in the log list.

The systolic tree based rule mining system uses the Oracle relational database to store the service and access log details. Each page request is updated as a separate entry with unique session ID for the

user. Part of the Web log data from a host site is loaded into the database and this migration of data in the database is called as data populate process. This process takes a time slot based on the number of records to be populated in the database. The second step is the data cleaning process where noisy and redundant data are all removed. At the end of the cleaning process, session conversion which arranges all page requests of a single session ID into a single transaction is arrived. Access sequence details provide the sequence of pages requested in terms of page URL with respect to requested time for every individual session ID of an IP address. Table 1 shows a piece of such access sequence detail arrived for an institutional Web log data. Session details provide along with IP address the URL of each page visited and the number of pages visited for every individual session ID. The total number of sessions for a particular duration in the Web log and the respective total number of pages for all the sessions are also arrived in the session details. A piece of session detail is shown in Table 2. This session information is used in the rule mining process.

**Table 1. Access sequence details (for one session ID of an IP address)**

| Sl.No | Requested Time            | Page URL                              |
|-------|---------------------------|---------------------------------------|
| 1.    | 01/March/2011<br>01:43:23 | /ece.html                             |
| 2.    | 01/March/2011<br>01:49:36 | /educontactus.html                    |
| 3.    | 01/March/2011<br>01:51:09 | /eee.html                             |
| 4.    | 01/March/2011<br>01:54:09 | /college%20brochure/br<br>ochure.html |

**Table 2. Session details**

| Sl. No. | Session ID | IP Addr.      | Page1               | Page2                   | --   | Page n            |
|---------|------------|---------------|---------------------|-------------------------|------|-------------------|
| 1.      | 2257103    | 50.90.19.76   | /civil.html         |                         |      |                   |
| 2.      | 2257104    | 67.202.41.3   | /rank.html          | /edufeedba..            |      |                   |
| 3.      | 2257105    | 115.98.7.131  | /rank.html          | /chairmansm<br>essa.... | --   | /toobea<br>uti... |
| 4.      | 2257106    | 117.193.226.. | /eee.html           |                         |      |                   |
| 5.      | 2257107    | 66.249.71.115 | /admission<br>.html | /gallery.html           | ---- |                   |

The weight estimation process for each page URL is carried out with span time, request count and access sequence details.

#### 3.2. WEIGHT DEFINITIONS

Transaction is a set of weighted items, each of which may appear in multiple transactions with different weights [4].

### 3.2.1. WEIGHTED ATTRIBUTES

A ( $a_1, a_2, \dots, a_k$ ) are variables selected to calculate weights. Depending on the domain, there could be any variable ranging from item's price in a supermarket domain to visitor page dwelling time in a Web log mining domain. There are two types of weights namely the *item weight* and the *item set weight*.

### 3.2.2. ITEM WEIGHT

*Item weight* is a value attached to an item representing its significance and denoted as  $w(i)$ . For example in the Web log mining setting where each item is a page visited in a click-stream/transaction, the weight can be related to a users average dwelling time on that page. In other words, the item weight is a function of selected weighting attributes therefore denoted as  $w(i) = f(a)$ .

### 3.2.3. ITEMSET WEIGHT

Based on the item weight  $w(i)$ , the weight of an itemset, denoted as  $w(is)$ , can be derived from the weights of its enclosing items. One simple way is to calculate the average value of the item weights, denoted as:

$$w(is) = \frac{\sum_{k=1}^{|is|} w(i_k)}{|is|}, \quad (1)$$

Item weight is a special itemset weight when the itemset has only one item.

### 3.2.4. TRANSACTION WEIGHT

*Transaction weight* is a type of itemset weight. It is a value attached to each of the transactions. Usually the higher the transaction weight, the more it contributes to the mining result.

In the proposed system, weights are assigned for the Web pages. Automatic weight estimation scheme is used in this system. Each Web page is assigned a weight value with reference to the request count and sequence. Access sequence based weight estimation model is used in the system. The weight values are used in the weighted rule mining process.

### 3.2.5. WEIGHTING SPACE

*Weighting space WS* is the context within which the weights are evaluated

1) *Inner-transaction space WSt*: this space refers to the host transaction that an item is weighted in.

2) *Item space WS<sub>I</sub>*: this space refers to the space of the item collection that covers all the items appears in the transactions.

3) *Transaction space WS<sub>T</sub>*: This space is defined for transactions rather than for items.

### 3.2.6. WEIGHTED SUPPORT

Weighted support *WSP* of an itemset. A set of transactions  $T$  respects a rule  $R$  in the form  $A \rightarrow B$ , where  $A$  and  $B$  are non-empty sub-itemsets of the item space  $I$  and they share no item in common. Its weighted support is the fraction of the weight of the transactions that contains both  $A$  and  $B$  relative to the weight of all transactions. This can be formulated as:

$$wsp(AB) = \frac{\sum_{k=1}^{|WS_T| \& (AB) \subseteq t_k} Weight(t_k)}{\sum_{k=1}^{|WS_T|} weight(t_k)}, \quad (2)$$

The transaction weight ( $t_k$ ) is derived from weights of the items presented in the transaction. It is the average weight of the items presented in the transaction.  $WS_i(t_k)$  is the inner-transaction space for the  $k_{th}$  transaction in transaction space  $WS_T$ .

$$weight(t_k) = \frac{\sum_{i=1}^{|WS_i(t_k)|} weight(item(i))}{|WS_i(t_k)|}, \quad (3)$$

This value is substituted in equation (2) to calculate the weighted support of a potentially significant itemset.

### 3.3. ACCESS LOG BASED WEIGHT ESTIMATION

The access log based weight is estimated using the Web page access information for a Web site and Weight definitions. The access log maintains the session id, IP address, page URL and requested time details. Single entry is maintained for each page hit. The Web server assigns the session at the time of user entry into a Web site. The unique session id is used to identify the pages that are accessed by the same user under the same session period. The access log details are converted into session list. The session list is prepared by grouping all the pages that are accessed in the same session. The session list maintains single entry for each session. The pages that are visited in a session are arranged in order of their requested sequence. The session sequence table is used to estimate the access log based weights for

the Web pages. Fig. 2 shows the pseudo code which describes the access log based weight estimation process.

```

Begin
  for i=1 to pc
    alwi=0.0;
    twi=0.0;
    for j=1 to 10
      wj=pscij/tpcj;
      twi=twi+wj;
    next
    alwi=twi/10;
  next
End

```

Fig. 2 – Weight Estimation algorithm.

The access log based page weight is estimated with the page sequence count and total page count information. In the above algorithm **alw** is access log weight, **psc** is the page sequence count, **tpc** is total page count for each request sequence and **tw** refers the sum of intermediate weights. “i” in the algorithm refers to rows i.e. each page URL and “j” refers to columns i.e. request sequence (for a fair count of 10). The algorithm may be extended for a maximum of n number of pages visited by an user. The access log weight is assigned for each page in the Web site.

#### 4. SYSTOLIC TREE, PATTERN MINING AND DATABASE PROJECTION

##### 4.1. DESIGN AND CREATION OF SYSTOLIC TREE

Systolic tree structure is used for frequent pattern mining. In VLSI terminology it is an arrangement of pipelined processing elements (PEs) in a multidimensional tree pattern. It is configured to store the support counts of the candidate patterns in a pipelined fashion. Given a transactional database, the relative positions of the elements in the systolic tree should be the same as in the FP-tree [3]. The transaction items i.e. the Web page request sequence is updated into the systolic tree with candidate item matching and count update operations.

A systolic tree structure consists of the following PEs:

1. **Control PE.** The root PE of the systolic tree does not contain any item. Any input/output data of the systolic tree must go through it first. One of its interfaces connects to its leftmost child.

2. **General PE.** All other PEs are general PEs. Each general PE has one bidirectional interface connecting to its parent. The general PE which has

children has one interface connecting to its leftmost child. The general PEs have siblings may have an interface connecting to its leftmost sibling. They may contain an item and the support count of the stored item.

Each PE has a level associated with it. The control PE is at level 0. The level of a general PE is equal to its distance to the control PE. The children of a PE have the same level.

Each general PE has only one parent which connects to its leftmost child directly. The other children connect to their parents indirectly through their left siblings. A systolic tree which has W levels with K children for each PE has  $\sum_{i=0}^W K^i$  PEs.

A PE has three modes of operation: WRITE mode, SCAN mode and COUNT mode [3]. The systolic tree is built using the WRITE mode Algorithm. Input items are streamed from the root node in the direction set by the defined WRITE mode algorithm. The support count of a candidate itemset is extracted in both SCAN mode and COUNT mode. This process is called as candidate itemset matching.

##### 4.2. PATTERN MINING USING SYSTOLIC TREES

To mine frequent patterns in the systolic tree, a collaborating hardware cum software platform is required. The software sends a candidate pattern to the systolic tree [2]. Once all items in a candidate itemset are sent to the systolic tree, a control signal signifying the COUNT mode is broadcasted to the whole systolic tree. After some clock cycles, the systolic tree sends the support count of the candidate pattern back to the software. The software compares the support count with the support threshold and decides whether the candidate pattern is frequent or not. After all candidate patterns are checked with the support threshold in software, the pattern mining is done. The approach to get the support count of a candidate pattern is called candidate itemset matching. The main principle of matching is that any path containing the queried candidate itemset will be reported to the control PE.

##### 4.3. NEED FOR DATABASE PROJECTION

It is not always possible that a tree-based representation will fit in the available hardware resources (either memory or logic) for any given database. If the case is such that the memory or logic is not large enough to hold the whole tree, it is necessary to split the database into multiple smaller databases with fewer frequent items. If the technique of database projection is not used, then candidate itemset matching will take enormous time when the number of frequent patterns is large. Each of the

projected database has no more than  $N=\min(K,W)$  frequent items and is guaranteed to fit into the FPGAs [3].

### 5. ENHANCED-SYSTOLIC TREE AND WARM

A number of data mining algorithms have been introduced to the community that perform summarization of the data, classification of data with respect to a target attribute, deviation detection and other forms of data characterization and interpretation.

Applications of association rule mining include cross marketing, attached mailing, catalog design and customer segmentation. An association rule discovery algorithm searches the space of all possible patterns for rules that meet the user-specified support and confidence thresholds. Looking back at Fig. 3, we have shown the process involved in constructing the Enhanced-Systolic tree (A tree which possesses the items with weights) and Weighted Association Rule Mining based on it, in the form of a Data Flow Diagram (DFD). For comparison and evaluation purpose, association rule mining is also performed from ordinary systolic tree constructed before weight assignment.

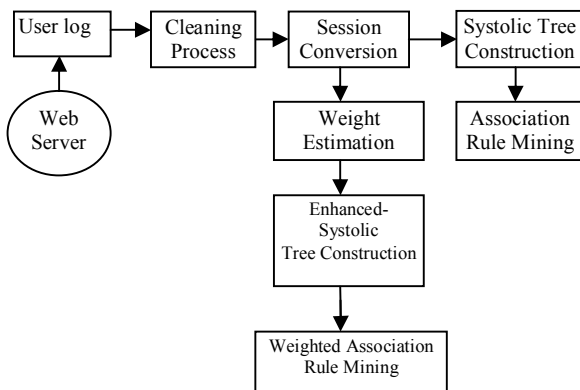


Fig. 3 – Enhanced-Systolic tree based WARM (DFD).

#### 5.1. Weighted Association Rule Mining (WARM)

An itemset is denoted large if its support is above a predefined minimum support threshold. In the WARM context, we say an itemset is significant if its weighted support is above a pre-defined minimum weighted support threshold.

Support and confidence are used in association rule mining. Based on support threshold and confidence threshold, frequent patterns are mined. In WARM, itemsets are no longer simply counted as they appear in a transaction. This change of counting

mechanism has made it necessary to adapt traditional support to weighted support (use of equation 2). The goal of using weighted support is to make use of the weight in the mining process and prioritize the selection of target itemsets according to their significance in the dataset, rather than their frequency alone [4]. Hence, systolic tree based algorithm is enhanced with weighted rule mining concepts. The page weights (item weight) are used in the weighted rule mining process. Based on the estimated capacity of the systolic tree, the page request frequencies (count) and weight values are updated in the systolic tree for mining. The frequent patterns are extracted with the weight values. Hence, the weighted support and weighted confidence are estimated and the systolic tree is updated for mining weighted association rules.

The systolic tree based weighted rule mining for Web log involves the following steps.

- Step1: Populate user access log data into oracle database.
- Step2: Perform the data cleaning process with redundant data elimination.
- Step3: Prepare the session details from the cleaned log data.
- Step4: Estimate the page weights based on the page access sequence.
- Step5: Prepare the candidate sets using the attribute and their frequency values.
- Step6: Perform the capacity estimation process for the systolic tree.
- Step7: Update the itemsets and frequency values along with item (page) weights into the systolic tree.
- Step8: Estimate the weighted support and weighted confidence values.
- Step9: Fetch the rules using minimum support and minimum confidence.

### 6. EXPERIMENTAL EVALUATION

#### 6.1. MATERIALS AND METHODS

The targeted device for simulation is a Xilinx Spartan-3E FPGA package interfaced with an Intel Core I5, 3.2 GHz processor machine with 2 GByte RAM and 500 GByte hard disk. Software requirements are Windows XP platform with front end C and back end Oracle 11g. Spartan 3E FPGA is a sequential and volatile device. Parallel FPGA implementation will be much faster than the sequential model used here which when combined with WARM gives much faster and accurate results. In parallel FPGA computer, thousands of operations can be performed in parallel during every clock cycle. The latest generation FPGA is a Xilinx Virtex7 FPGA, which is a parallel and nonvolatile

one that can perform thousands of tasks in parallel. It is highly performance oriented than the previous FPGA generations.

### 6.2. PERFORMANCE COMPARISON

Pages visited only once by only one visitor will have the least weightage and it is obviously not a frequent item. It will not be updated in the systolic tree for mining. This aids in reducing the memory space in additive and also improves the mining efficiency.

The performance analysis based on parameters such as memory requirement and runtime is carried out between the systolic tree based association rule mining (STARM) [3] and systolic Tree based WARM (STWARM) models. Evaluation on a Web log data of an educational institution which is considered for the data present in the Table 1 and Table 2 has given the results that the STWARM model reduces the memory requirement by 30 % than the STARM and the run time is reduced by 25 % in STWARM than the STARM. This is depicted in Fig. 4.

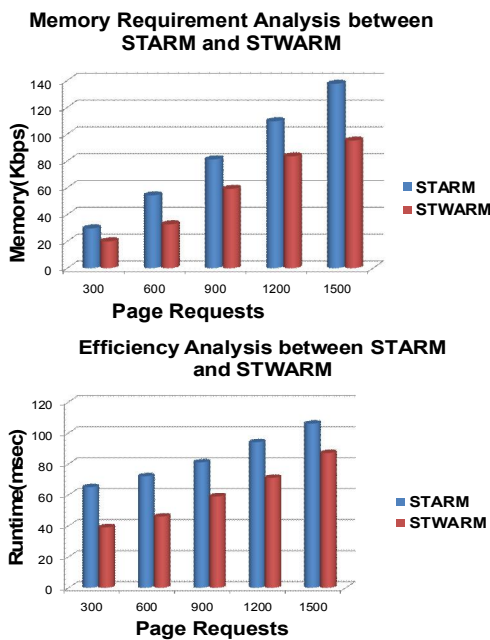


Fig. 4 – Performance analysis between STARM and STWARM for a Web log data.

STWARM makes use of the write, scan and count mode algorithms in STARM [3] for constructing systolic tree in hardware FPGA platform for mining the frequent patterns. STWARM also includes weights assigned to each page with the help of weight estimation algorithm (Fig. 2). Web log data is applied to STARM instead of a transactional database. The purpose of introducing the concept of weights in STWARM is

that it eliminates the irrelevant pages by mining frequent pages which fall above the weighted support threshold. In STARM, only support threshold is used to mine all the frequent pages reaching the threshold whereas STWARM mines only the relevant pages based on weights of the page.

Web usage mining carried out on Web log data is useful in many ways. The main purpose of this model is the usage in educational institutions to find out the unwanted pages visited by the students during a suspected duration which obviously spoils their progress. This means that, those few unwanted URLs which are mined with greater weighted support for that duration has the most weightage in spoiling the behavior of the students. The access of those URLs can be denied by the institution. This system may also mine the pages which are informative to the students, based on which future decisions can be made. Hence this model serves essential purpose for mining institutional Web logs, even though such a type of reconfigurable weighted rule mining can be implemented for Super market data as well for finding the most user preferable items, which have attracted them more. This helps in reordering the arrangement of items in shelves of super market based on weightage, so that they are well visible to the customers, which increases the sales. The Web logs in the servers of any industries or organization can also be mined for useful and most important information, based on which the organization can know about the behavioral pattern of their employees in order to keep them more involved and interactive.

### 7. CONCLUSION

The association rule mining techniques are used to extract frequent patterns. Systolic tree is used to organize candidate sets with frequency values. Due to the limited size of the systolic tree, a transactional database must be projected into smaller ones each of which can be mined in hardware efficiently. Systolic tree based rule mining scheme is enhanced for weighted rule mining process. The inability of ARM for treating units differently is solved by integrating weights in the mining process. The weighted rule mining techniques are used to fetch the frequently accessed Web pages with its weight values where page weights are used to denote the importance of the Web page. The proposed system improves the weight estimation process with span time, request count and access sequence details. The user interest based page weight is used to extract the frequent itemsets. Automatic weight estimation scheme is used in the system. Minimum weighted support and weighted confidence is used for frequent pattern

mining process to find the most interested pages in the Web site. WARM also scales up as the dataset size increases and it is used to improve the Web site contents.

Systolic tree based weighted rule mining system reduces the memory requirement by 30 % and run time by 25 % than systolic tree based rule mining system. The system proposed also improves the efficiency of sparse patterns. The system can be enhanced to mine frequent patterns on data streams, to perform parallel rule mining process, to support Web personalization and the usage mining process can be integrated with content mining model.

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## SEAMLESS AND SECURE INTEGRATION OF SOCIAL MEDIA, E-PORTFOLIO AND ALUMN SERVICES INTO UNIVERSITY INFORMATION ARCHITECTURE

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**Abstract:** This document describes the concept and prototype for an “assembling” IT integration portal to be used in higher education. Through the use of profiles, good usability and display of concentrated information students should be bound to the portal and university throughout their studies and their life.

The proposed solution, to use Elgg as an information portal and social media platform, bridges the gap between the closed nature of university IT infrastructure and user-friendly, communication enhancing advancements of state-of-the-art web applications. *Copyright © Research Institute for Intelligent Computer Systems, 2014. All rights reserved.*

**Keywords:** social media; customized sites; university information architecture; HCI; interface design; Elgg; mashup; widget; single sign on; database exchange; alumni; e-portfolio; lifelong relation; serviceoriented architecture; Web service.

### 1. INTRODUCTION AND GAP

IT systems in higher education still offer a great potential for improvement in information quality for their users. Vital information concerning students lives are distributed among different systems: Grades, timetables, course registrations, return dates for lend books from the library, e-mail, news, calendars or course-relevant exchange of information are not only managed in different systems, but also buried deep inside multi-step processes. The different systems all come with their own concepts of operation and login. A fast overview of important data is thereby difficult to get for their users.

At this point, a great potential is lost. Interesting insights, which could be extracted from combination of information, are not generated. Sought after interdisciplinary connections inside the student body are restrained, as contact information is hard to find – even though every student owns a university email account and course participant lists are available inside the data structure.

Furthermore, current systems ignore both the locational context as well as the heterogeneous user group.

As a result most students use external social networks and exchanges information there – bypassing potentially interested university parties. This finding puts university in front of multiple

problems: Reasonable extensions of content on external platforms can be legally and organizationally problematic. Allocation of information on external platforms circumvents bonding to university, as users start to bond to these external platforms instead of the university.

Framework conditions, terms of use, continuity and development of external platforms cannot be influenced by the university. The lack of resources from the university would be invested into a commercial provider, who is possible to vanish, vaporizing invested data and capital.

Last but not least the current situation opposes the paradigm of forming a lifelong partnership with university that is especially anchored in Anglo-American universities. Often students are cut off from their information immediately with exmatriculation by deactivating their accounts, which is not only problematic regarding informational self-determination. Most of all, university immediately loses the communication channel built for years with former students.

### 2. RESEARCH METHODOLOGY

For the demonstrated approaching this paper Social Media Systems were elaborated. They provide a wide variety of functions for collaboration and interaction. That covers explicit as well as implicit knowledge distribution und knowledge

development in large organizations. Driving Social Systems in Universities provide substantial impact on academic as well as on social learning outcomes, but also on employees satisfaction and Alumni relations [1].

To face above problems the project karriereLEBEN at University of Applied Sciences Magdeburg-Stendal researched and developed an “assembling” IT integration concept. Influenced by service-oriented architecture (SOA) this approach should provide room for highly diverse IT systems and be supplemented by an information-integrating architecture, that condenses fundamental information context-sensitive and focused on target-groups. This “assembled” distillate is offered and conjoined at a web-based platform.

Methodically the design-oriented Information Systems research process [2] was used and detailed as follows:

1. System analysis of special IT architecture and solutions [3], their comparison and generalization
2. Design-driven development of the integrational concept and associated prototypical implementation [4]
3. Evaluation in concrete application environments with relevant target groups
4. Diffusion

As central research questions the following problems were identified:

- How is it possible to integrate existing systems and data sources to create a more user-friendly approach to university IT Infrastructure?
- How to bridge the gap between a secure IT architecture, a seamless authentication and a service oriented openness and flexibility of an intranet system.

From a conceptual project perspective the following questions influenced the system design:

- How can a lifelong bonding and identification with university be reached with Social Software?
- What services encourage user activity?
- How to optimize fundraising with intranet social media software?

### **3. APPROACH, TECHNOLOGIES AND APPLICATION**

The goal to reach is a so-called “one stop shop”, both for the user and the organization to retrieve all information on one platform. Relevant information from diverse sources will be distilled, conditioned and presented. To offer additional functionality, information will be deep-linked directly to appropriate systems. Through the collection of information into one portal and the application of

SingleSignOn (SSO) there will be only one login for all systems. By using metadata from this login it is possible to present information target-group specific and context-sensitive.

The integration of an internal social network helps in forming a sense of exclusiveness. Additionally a role-based rights management aids in progress of studies. Beginning with enrollment the users status inside the portal rises proportionally to his progress, enabling new modules on the way.

By creating personal profiles, users can show off their interests and make it easier for others to find them. These profiles are a great benefit to both student body and CareerService. Students are allowed to present themselves within the context of university. University can verify provided information and apply its reputation to every student. CareerServices can target specific student groups for offers of internships and jobs more directly. Even inside the institution a tighter network will be formed: Research groups can find active participants, professors can advertise job opportunities and theses to a relevant audience.

#### **3.1. PROTOTYPE**

A prototype of the mentioned approach was built at University of Applied Sciences Magdeburg-Stendal and evaluated with early adopter user groups. The prototype is running on an Ubuntu 12.04 LTS host in a demilitarized zone of the universities network. It is based on Elgg [5] and a MySQL database. Elgg is an open source social networking engine, that allows anyone to build and host their own web-based social network. With help of self-developed plugins and widgets Elgg demonstrates the introduced usability concept in cooperation with a personal desktop (Fig. 1). This desktop contains a variety of widgets that are connected to the different IT systems inside the University and filter the desired information. The user is able to create his personal space and entry-point into the different systems.

Furthermore contacts to former and current students and personnel can be established. Bulletin boards, blogs, email, chat and groups offer many forms of communication. The user profile can be extended into an advanced and feature rich E-Portfolio [6] that will be used as a learning, communication or research environment. This accumulated portfolio could be used later as a public career instrument, for student job applications or as a project, practice, research and teaching demonstration. It could contain curriculum vitae, works, certificates and grades, electronically certified from the university. The web-reputation of the university also helps in making the portfolio

visible and easy to find in search engines on the Web.

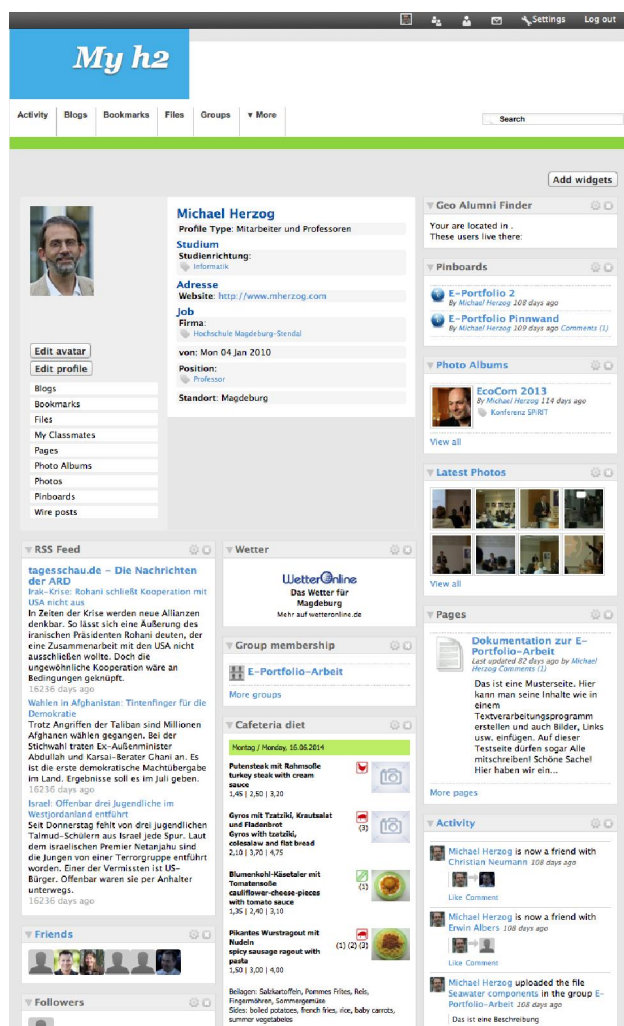


Fig. 1 – Personal desktop with user profile.

### 3.2. DESIGN

To not only technically but also visually embed the prototype into the university's infrastructure, the screen design of the prototype was adopted to match the visual design of the university website.

This harmonization also creates a more seamless experience for the users of the prototype, as they do not have to learn a new visual language and navigational approach if they are already familiar with the university's website.

The visual concept also follows the idea of a flexible mashup widget environment [7]. Every function is realized in a flexible micro window that users can move and adjust to their individual preferences. This individuality allows a seamless feeling of freedom for the user who is able to reorganize the screen, add new functions or delete unwanted widgets. Monitoring of these user preferences and function usage will allow optimization of the default system settings and improvement of widget functions.

### 3.3. AUTHENTICATION

To securely identify members of the university and allow non-members to sign up, the prototype utilizes a staged LDAP and database handler for registration and authentication.

The LDAP handler authenticates current members of University while the database handler authenticates non-members. Students, faculty and staff need only to use their central university account at registration, accept the terms of use and the LDAP handler will automatically import all relevant data from the central LDAP server into Elgg's user-database.

Non-members need to fill in all their user data themselves. Non-members of university are either alumni or friends, which include guests, companies or sponsors. They use a special registration form. Because the prototype does not have influence on current and future user-name policies of the university, it simply adds some characters to usernames not originating from LDAP, to safely distinct them from current or future university members.

At authentication, the prototype first asks the LDAP handler and only falls back to the database handler on denial. On every successful LDAP authentication all user data will be updated from the central LDAP repository. Copying the users data to our own database makes it possible to still allow access to users who signed up as members of university and have since left, even though the university's policy is to delete their LDAP account on leave. They only need to reset their password – as we never received it from LDAP – and can then login again.

### 3.4. UNIVERSITY INFORMATION ARCHITECTURE

The introduced portal could realize a smart fit into the general strategy of the university. Students are integrated into respective processes and thereby bond to university. Moreover they directly and indirectly collect information to be used by CareerServices.

In terms of usability the platform aims for simplification through reduction [8] by concentrating relevant information into one central place and thus by reducing the number of systems a user has to search to find this information. In current SingleSignOn systems only repetitive login is prevented, but users still need to jump from system to system to find information. The platform will connect participating systems and extract information into a single place.

Furthermore, external services in which the user does currently not use the central university account

can be incorporated into this SSO. This contrasts current applications of SingleSignOn systems, Central Authentication Service (CAS) [9] and Shibboleth [10] at university that only allow inclusion of services using the exact same local user name.

Inside the prototype's account manager users are allowed to connect user names of external services to their local account and allow inclusion of external services user data.

Users thereby not only activate access to external systems but also decide which systems to use via SSO and what data to include into the local internal university services.

Network architecture in Fig. 2 shows the services connected to the prototype. While all accounts inside the university network use the central university account, external services of Career Center and Libraries use their own accounts. If the user wants to only read information from these systems, there is no requirement to enter account information into the account manager. The prototype directly connects to the database of these services by means of an SSL tunnel and presents query results directly to the user. For example, the user can see current job and internship listings of the Career Center right inside the prototype. The system will even preselect relevant listings using data from the users E-Portfolio.

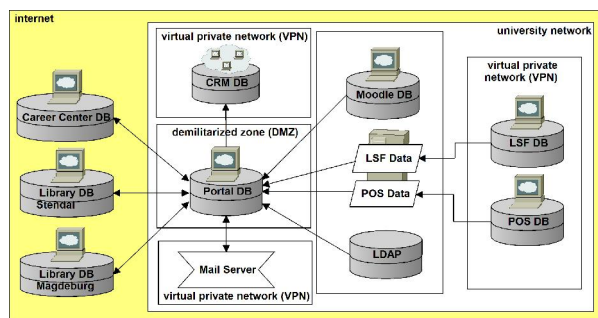


Fig. 2 – Connected services model.

The university network is split into different subnets. Being a globally accessible service, the prototype is located inside a demilitarized zone (DMZ), while the rest of the shown services are located inside the internal network. For Customer Relationship Management (CRM), LDAP, Moodle and Webmail connections are allowed via corresponding firewall rules. LSF [11], containing timetable and room allocation information and POS [12], containing grade and credit information, are inside a specially secured network without access to the prototype.

In a first version of the prototype LSF and POS databases were exported daily into read-only CSV files and provided to the prototype via a dedicated

fileserver. This security barrier was introduced so that users are guaranteed to only read and never write this sensitive information. However, due to real-time interaction and data privacy protection concerns, it was changed to access the data via SOAP and webparsing.

### 3.5. METHODS OF ACCESSING DATA

To integrate data sources into the prototype the following methods are used. They are sorted from most to least feasible for use in our prototype.

#### 1) Web API

An API provides the most useful connection to the host's data. A good API abstracts implementation specific details away from the data and thereby makes it easy to create and maintain access, as changes in the underlying storage of data can be hidden behind the API.

In many cases APIs also have good documentation, providing further assistance to the developer. In case of LSF and Moodle this is realized using the SOAP protocol.

#### 2) Direct database connection

This type of connection is mostly used in the prototype. It enables the prototype to access all of the data on the servers in real-time. However, it has the drawback of being very implementation specific. Initially one has to understand the exact implementation and structure inside the database. This needs then to be recreated as specific database queries in one's own software and will likely break if the original database is changed by an update.

#### 3) Read-only database dumps

This method is often seen in university IT projects. The database of interest is dumped daily onto a fileserver. At a later time, the exported data is accessed and then imported into one's own database. The reason given for this approach is that it is impossible for the reading server to write back into the original database – which is important for data that needs to be highly reliable such as grades – as it only accesses a read-only file on a different fileserver. However, the authors would like to point out that this approach opens up a new attack vector on file servers to gain the data.

#### 4) Scraping

As a last resort web scraping is used for information sources that do not offer any data connection. With the scraping method, HTML output of a database or webportal is analyzed and the needed information is extracted. This method has several drawbacks. First of all, it requires a lot of initial and maintenance work. Each scraper has to be custom fit to the website it is scraping from and every change on the original websites output requires a new adaption of the scraper.

Secondly, if the data to be accessed is non-public and protected by any form of authentication this has to be reflected in the scraper – which is often non trivial to implement. In the worst case the scraper needs to emulate an actual user on a browser, which tends to need a lot of system resources and therefore does not scale nicely to a large userbase.

### 3.6. ROLES

Display of information is based on roles. Users are grouped as Students, Faculty, Staff, Alumni and Friends.

The role system prevents users from accessing information that they should not access, because roles will be granted from LDAP only. If the user authenticates his status will automatically be updated on every login.

Through the lifetime of a user his role could change: From student to alumnus or from staff to friend. This change is reflected in the desktop's appearance. For example, when a student becomes an alumni, widgets displaying the current study progress turn into GeoAlumniFinder. Alumni and friends will also be included into the ranking of top supporters and will be displayed information regarding support programs and calls for sponsors.

The staffs are informed about new alumni and friends who are not yet in the CRM system and can decide if they should be added to the CRM database.

### 3.7. SOCIAL MEDIA COMPONENTS

Social Media components should improve communication at and around campus.

Except for Webmailer and e-learning portal Moodle none of the currently connected or implemented services offer any means for communicating with other users.

However, communication in Moodle is restricted. It is impossible to directly reach fellow students without selecting the proper course first, making it virtually impossible to comfortably communicate with loose contacts.

Based on social media open source platform Elgg the prototype allows for far more ways of communication. All users are discoverable inside the system and can be added to the users friends list. The users are also kept up to date with permanent display of incoming messages and a newsfeed displaying all updates from friends.

The users have a lot of possibilities to communicate, to create and to share content: blogs, groups, messages and their own E-Portfolio.

The E-Portfolio helps users to enhance their profile. By displaying certificates from POS, LSF

and Moodle students are allowed to demonstrate their performance and achievements to a broad community. These certificates can easily be combined with the student's curriculum vitae to create an interesting online profile for possible employers.

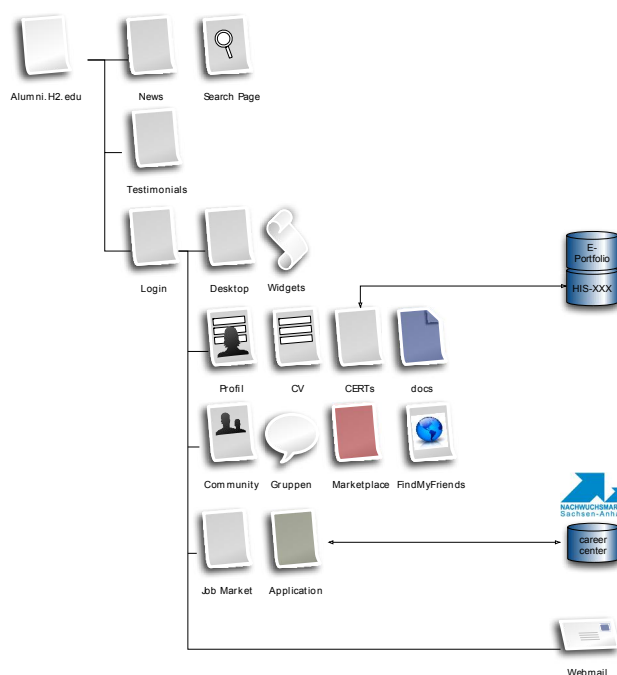


Fig. 3 – Portal navigation and database structure.

### 3.8. E-PORTFOLIO

Following guidelines from Magdeburg-Stendal University of Applied Sciences' Center for Didactic the prototype was extended with more E-Portfolio functionality. As described in chapter A, Elgg offers a lot of functionality to turn the user profiles into an E-Portfolio. Baumgartner's evaluation of E-Portfolio Software shows that Elgg is a good candidate to be used as such [6]. Fueled by these findings, further implementation was done to propose the usage of this prototype as the university's E-Portfolio platform. In his evaluation, Baumgartner also outlines criteria for a good E-Portfolio and evaluates Elgg's fit with these. Elgg's worst performance according to his evaluation is in the field of the major category 2 "Reflecting, testing, verifying and planning", however the authors of this paper found these content based criteria to be out of scope for the current development.

In our implementation a lot of work has been done to extend the functionality in the field of "Representing and publishing" where the PinboardPlugIn offers the required features.

A more detailed description of implementation specifics can be found in I.4.

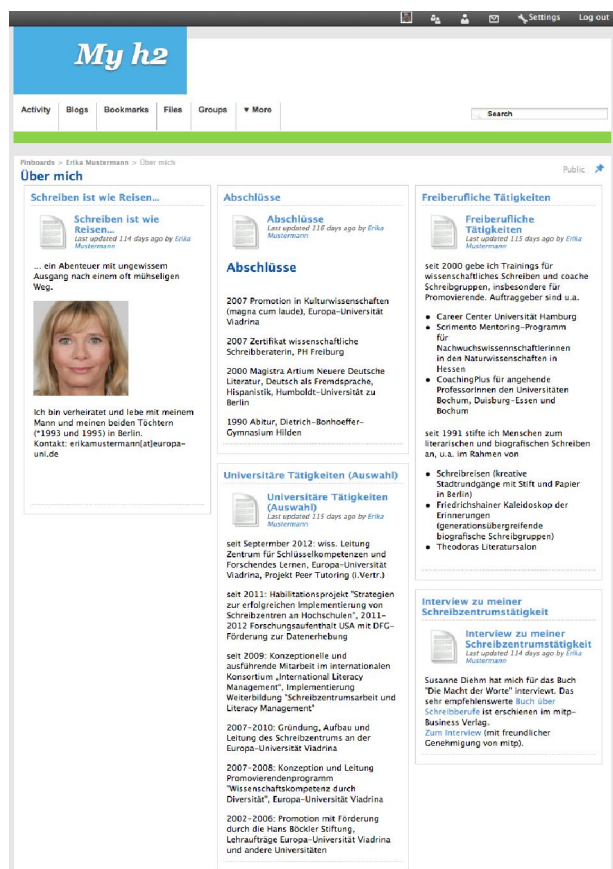


Fig. 4 – Teaching portfolio example.

an Elgg handler, which gets called by the Linux utility cron. However it only works if you have a second host to backup to [13].

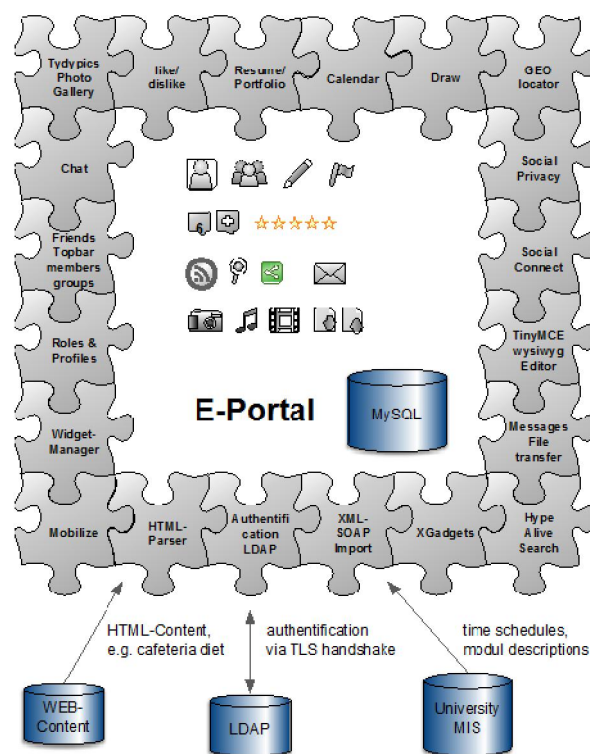


Fig. 5 – Used plugins and functionality.

### 3.9. ELGG PORTAL ADAPTION

To prevent the plugins from directly affecting the core of Elgg, all of the prototypes functionality was implemented writing, using and extending plugins for Elgg. This also helps to avoid SQL injection and XSS attacks, as by using proper plugins and coding against the Elgg API, forms and inputs are abstracted into Elgg's Input/Actions and Views/Output concept and database queries are not directly written in SQL but use Elgg's protected methods and classes.

Currently used plugins are shown in Fig. 5. Due to the highly modularized approach of Elgg, the amount of plugins to implement the prototypes functionality is rather high. This offers great flexibility but also results in a lot of adaption work to make the plugins and theme compatible with each other.

### 3.10. PLUGINMODULE DEVELOPMENT

The following is a list of specific implementation details and used plugins, to give deeper insight into this approach and implementation (see Fig. 5).

#### 5) Backup

The deployed community version of Elgg (1.8) got a full backup functionality with data folder and mysql dump. The scheduled backup is controlled via

Instead of this functionality a full server backup approach was implemented using the university's backup infrastructure based on TIVOLI storage manager.

#### 6) Authentication

To allow members of university to login with their official university account, this plugin connects after an TLS handshake and via a secure connection to the OpenLDAP server of the university. At first login and a successful LDAP query, the user is asked to accept the terms of use and privacy policy. Only then his profile is created. Mapping of LDAP attributes with those of the Elgg portal is done in the plugin settings.

To assign the user role, the Profile Manager plugin [14] from the Elgg Community needs to be installed and activated as well. Without this dependency the OpenLDAPplugin can not be activated.

After registration, with each login via username or e-mail address the LDAP-attributes get updated from the LDAP server.

The OpenLDAPplugin is executed before the normal portal login method and falls back to it, so that Alumni and Friends – who do not have their account stored in university LDAP – can be authenticated with the portal's own user database.

### 7) *Extended Registration plugin*

Alumni and Friends need to explicitly register with the portal and confirm their e-mail address via an activation link. This plugin extends the portal's registration page with a checkbox, so that users need to accept the portal's term of use and privacy policy. The plugin also implements a method to avoid username duplicates between the university's LDAP and the portal's own database, as described in II B.

### 8) *Resume and Portfolio*

In regards of the E-Portfolio, Elgg by default provides the artifacts Blogs, Bookmarks, Filestorage and the creation of own pages. Personal pages can be edited using the built-in editor and it is possible to link to one's own files. It is even possible to create sub-pages that can be easily found through a navigation structure.

With the Profile Manager an admin can include additional forms so that users can use them on their profile pages, for example course of study, address and profession.

To use these functionalities didactically for learning purposes, the PinboardPlugIn [16] was added. It allows the user to create pinboards wherein he can include all of his artifacts as widgets. These can be displayed in varying layouts and it is possible to determine precisely who can view or edit any of one's pinboards, by using Elgg's advanced roles management and custom member lists.

By using multiple pinboards it is possible to build similar structures as are found in more classical E-Portfolio systems. A structural example for an E-Portfolio from the pedagogical viewpoint is shown in Fig. 6. The prototypical implementation includes pages with up to three columns and a Blog a long side the textual content, to document progress in a chronological manner and to receive comments from other users.

- ▼ Profile
  - My CV
  - Evaluation results
- Dimensions
- ▼ My teachings and it's developments
  - Blog
  - Development targets and more
- ▼ Theoretic and literature work
  - My study accomplishments
  - Texts / Contents
  - Blog

**Fig. 6 – E-Portfolio example for educational purposes – table of contents [15].**

### 9) *SOAP Import*

For LSF and Moodle a SOAP-based webservice can be activated [17]. Public information such as the

schedule of lectures or the search for individuals can be queried from LSF via a SOAP-client without authentication and displayed in the portal. For non-public information like the user's personal schedule a SOAP-based authentication is required. The authentication request as well as the query and the result are held in an XML-structure. After an XSLT-transformation using a parser the result is displayed in the portal.

### 10) *Mobilize and Corporate Design*

The theme is realized as a plugin as well. It is possible to simply copy all CSS files and their folder structure of the core into the view structure of the plugin. These files can then be adapted to the university design. After purging the site-cache the plugin's CSS files will overload the core files.

In parallel the Mobilize Theme [18] is loaded, which automatically switches the layout to a mobile friendly view on mobile devices.

### 11) *Digital yearbook*

This plugin also requires the Profile Manager plugin from Elgg Community, into which all programs of university have to be entered. Inside the Profile Manager each course of study can be marked as a Tag, so that all users can be listed based on their course of study.

The Digital yearbook plugin extends this functionality by enabling an additional list grouped by year of matriculation. It can also highlight currently online users from the same year as the user, as long as he has marked his matriculation inside his profile.

### 12) *GeoAlumniFinder*

The GeoAlumniFinder provides the functionality of finding friends from the prototype whose location is close to one's own. The prototype uses a freely available country and city database from Maxmind [19] and corresponding GeoIP2 PHP API [20] to find the user's location based on his IP. Afterwards the determined location is compared with the listed residence in public profiles.

### 13) *Cafeteria diet*

This plugin provides a widget with the cafeteria's current menu. As the University of Applied Sciences Magdeburg-Stendal has two locations with own cafeterias, MensaPlan captures the user's location and displays only the menu of the nearest canteen. The actual menu is scraped from the canteen's website and adjusted to the portal style.

## 4. COMPARISON WITH OTHER APPROACHES

### 4.1. COLLEGE MOBILE APPS

Students enjoy simpleness and flexibility of college apps like tub2go [21]. Location based and time dependent they get news and concentrated



information from their university. However, there is no integrated social media and it is usually not possible to communicate with classmates and alumni in a context integrated way. Also, the universities do not get detailed information about their users. They are anonymous by default and need only to authenticate for special information e.g. grade overviews. In conclusion, universities lose information for communication, marketing, and fundraising opportunities.

## 4.2. FACEBOOK MOBILE APPS

The Leuphana University of Lüneburg follows its students into the most used social media network Facebook. There, the university offers part of her study service as a Facebook app [22] to reach students. It is a good solution to spread the general news and there are also groups and user profiles. For the alumni management however the most important question is: Who guarantees that Facebook still exists in 50 years? Therefore, the Leuphana has her own portal [23] for students and alumni. This portal is specialized to create own profiles for the career center and the graduate's yearbook.

## 4.3. MAHARA E-PORTFOLIO

Mahara is a specialized online tool to create personal E-Portfolios [24]. It is currently highly regarded in the academic scene because of its connection to the moodle LMScommunity. However, most of its functionality is already implemented in Elgg [14], [16]. Furthermore our initial tests of Mahara show that Elgg offers some real advantages: A field experiment with two groups of students (n=16, n=21) revealed several improvements in the areas of functions, tools, access, and usability. Within a Mahara two days training with lecturers, two other field experiments with our E-Portfolio portal were conducted (n=12, n=6). This test was lead by an external E-Portfolio expert of the University of Hamburg, Ivo van den Berk, in a workshop held at Magdeburg Stendal University in April 2014. Test results showed that Elgg portal 1.8. implementation with our project extensions tests better in most of the criteria evaluated than the hosted version of Mahara 1.8 as provided by "mahara.de". It prevailed in ease of use, comprehensibility, flexibility, user role concept and access, seamless integration, conflict management and overall look & feel.

## 5. OUTLOOK / PERSPECTIVES

### 5.1. CONCLUSIONS

The first iteration of the prototype was well received within the group of staff and students it has been tested with. The most valued features were the

easy access to information in one place and easy means of communication. Informal interviews suggested that these two features could lead to increased user activity and that social communication features could lead to prolonged bonding to the system and therefore to the university.

Furthermore, the case of extending the prototype with E-Portfolio functionality has shown that the original approach of creating a modular in-house development has opened up the possibility to create additional benefits within the system that were not inside the scope of the original design and that this approach is therefore a fruitful one.

## 5.2. FUTURE WORK

The integration of different university IT systems into the prototype and before mentioned user tests have demonstrated how difficult and at the same time how crucial this integration is for the user experience. This barrier could be lowered by recent plans to update current university LSF and POS systems to the new and integrated HISinOne solution, however – as there currently is no standard to deal with these kinds of information – it is also possible that the change will generate more adaption specific work.

In conclusion, integration of existing systems and data sources of university IT infrastructure into user-friendly applications seem feasible by introducing a web-facing portal as an aggregator and gateway into internal systems.

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## FAST SOLVER FOR INTERIOR POINT METHOD OF SVM TRAINING BY PARALLEL GMRES AND HSS

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**Abstract:** Support Vector Machine (SVM) is one of the latest statistical models for machine learning. The key problem of SVM training is an optimization problem (mainly Quadratic Programming). Interior Point Method (IPM) is one of mainstream methods to solve Quadratic Programming problem. However, when large-scale dataset is used in IPM-based SVM training, computational complexity happens because of computationally expensive matrix operations. Preconditioner, such as Cholesky factorization (CF), incomplete Cholesky factorization and Kronecker factorization, is an effective approach to decrease time complexity of IPM-based SVM training. In this paper, we reform SVM training into the saddle point problem. By parallel GMRES and recently developed preconditioner Hermitian/Skew-Hermitian Separation (HSS), we develop a fast solver HSS-pGMRES-IPM for the saddle point problem from SVM training. Computational results show that, the fast solver HSS-pGMRES-IPM significantly increases the solution speed for the saddle point problem from SVM training than the conventional solver CF. *Copyright © Research Institute for Intelligent Computer Systems, 2014. All rights reserved.*

**Keywords:** Interior Point Method, fast solver, parallel GMRES, Hermitian/Skew-Hermitian Separation, Support Vector Machine, Quadratic Programming.

### 1. INTRODUCTION

Support Vector Machine (SVM) is one of the latest statistical models for machine learning [1-6]. SVM is invented by Vladimir N. Vapnik of Columbia University, and soft margin SVM is published in 1995. The key problem of SVM training is an optimization problem [7, 8] which includes Linear Programming and Quadratic Programming.

While Linear Programming can be highly efficiently solved by methods such as Interior Point Method (IPM), active set and Simplex method, Quadratic Programming can be solved by multiple existing methods such as IPM, active set, augmented Lagrangian and Conjugate Gradient. In these methods, IPM is one of mainstream methods to solve Quadratic Programming from SVM training.

However, when large dataset is trained by IPM based SVM, computational difficulty happens because of computationally expensive matrix operations. Decreasing the time complexity of IPM based SVM training can be realized by methods such as chunking, decomposition, sequential minimal optimization and factorization.

IPM calculates the best solution by searching the interior of the optimization space [9-13] in Linear

Programming [14] and Quadratic Programming [9]. IPM can be implemented by multiple algorithms, and Mehrotra predictor-corrector algorithm is the most popular one among them [15-20]. The main idea of Mehrotra predictor-corrector algorithm is to firstly calculate a search direction by the first-order predictor term, then to calculate the second-order corrector term, and finally to combine the predictor term and the corrector term into the complete search direction.

The most time-consuming part of IPM based SVM training is to solve the linear systems. In Mehrotra predictor-corrector algorithm, solving the linear systems happens twice in every iteration. Directly solving the linear systems by the non-factorization solver Gauss Jordan Elimination (GJE) is expensive, which needs the time complexity of  $O(n^3)$  [21-25].

Factorization can be applied to decrease the time complexity of IPM based SVM training. Theoretically, factorizations such as LU factorization, LDU factorization, full rank factorization, QR factorization, LDL factorization, Cholesky factorization (CF) and Kronecker factorization can be apply to IPM [26-28]. For IPM based SVM training, since the kernel matrix  $Q$  is

positive semi-definite matrix, CF is the conventional method to factorize the kernel matrix. The time complexity of CF is  $O\left(\frac{1}{3}n^3 + 2n^2\right)$ .

Hermitian/Skew-Hermitian Separation (HSS) is a newly developed method for matrix factorization. Can HSS accelerate IPM based SVM training? In this paper, we reform SVM training into the saddle point problem, we develop a fast solver HSS-pGMRES-IPM for the saddle point problem from SVM training, and theoretical analysis and computational results are also provided.

## 2. METHODS

In this section, we briefly introduce HSS-pGMRES for the saddle point problem, we reform SVM training into the saddle point problem, and we develop a quick solver, HSS-pGMRES-IPM, for solving the saddle point problem from SVM training.

### 2.1. HERMITIAN/SKEW-HERMITIAN SEPARATION-PARALLEL GMRES FOR SADDLE POINT PROBLEM

Saddle point problem is a linear system with the form:

$$\begin{bmatrix} F & D^T \\ D & -E \end{bmatrix} \begin{bmatrix} du \\ dp \end{bmatrix} = \begin{bmatrix} R_d \\ r_d \end{bmatrix}, \quad (1)$$

where  $F$  and  $E$  are usually symmetric matrices [29],  $du$  and  $dp$  are unknown variables, and  $R_d$  and  $r_d$  are right-hand-sides. Saddle point problems appear with high-frequency in scientific and engineering applications. Golub reviewed solution methods for saddle point problem in [29], and his solution methods for saddle point problem include Schur complement reduction, null space methods, coupled direct solvers, stationary iterations, Krylov subspace methods, preconditioner and multilevel methods [29].

Newly developed matrix splitting based methods such as HSS provide an efficient way to solve saddle point problems [30-32]. Golub *et al.* developed HSS in [33], parameter optimization for HSS is proposed in [34], and preconditioned HSS is studied in [35-40].

To efficiently solve a linear system with the structure of saddle point problem in equation (1) with the symmetric part  $H$  and the skew-symmetric part  $S$ , we firstly solve an uncoupled linear system:

$$(H + \alpha I_n) \cdot du^{k+\frac{1}{2}} = f_{uc}^k, \quad (2.1)$$

$$(E + \alpha I_m) \cdot dp^{k+\frac{1}{2}} = g_{uc}^k. \quad (2.2)$$

where  $\alpha$  is a parameter, and  $f_{uc}^k$  and  $g_{uc}^k$  are right-hand-side. Then we solve a coupled linear system:

$$(\alpha I_n + S) \cdot du^{k+1} + D^T \cdot dp^{k+1} = f_c^k, \quad (3.1)$$

$$-D \cdot du^{k+1} + \alpha p^{k+1} = g_c^k. \quad (3.2)$$

where  $\alpha$  is a parameter, and  $f^k$  and  $g^k$  are right-hand-side. By Schur complement reduction, we obtain:

$$\begin{aligned} & [D(I_n + \alpha^{-1}S)^{-1}D^T + \alpha^2 I_m] \cdot dp^{k+1} \\ & = D(I_n + \alpha^{-1}S)^{-1}f^k + \alpha g^k. \end{aligned} \quad (4)$$

Since the coefficient matrix  $[D(I_n + \alpha^{-1}S)^{-1}D^T + \alpha^2 I_m]$  of equations (4) is a large and sparse matrix, GMRES is suitable to solve  $dp^{k+1}$ . After  $dp^{k+1}$  is solved, then we obtain  $du^{k+1}$ . The details of HSS is described in Algorithm 1:

#### Algorithm 1: The Hermitian/Skew-Hermitian Separation

- Initialization of HSS
- while  $R < tol_{HSS}$ 
  - Solve the coupled system equations (2)
  - Solve the uncoupled system equations (3)
  - end while

From Algorithm 1, we can see that the Hermitian/Skew-Hermitian Separation is built by a single loop, while the number of iteration is controlled by the tolerance  $R < tol_{HSS}$ . In every iteration, two linear systems are solved: the coupled system of equation (2) and the uncouple system of equation (3).

Convergence analysis of HSS (Algorithm 1) is analyzed in [35], the number of iterations can be found in [29, 32-37, 39, 41, 42], and the convergence speed of HSS (Algorithm 1) is decided by  $tol_{HSS}$ . However, the linear systems are unnecessary to be solved exactly, and the tolerance of the iterative solver for the linear systems can be loosened to increase the solution speed, which results in inexact HSS.

As we discussed, the uncoupled system of equations (4) in HSS (Algorithm 1) can be solved by sparse solvers such as GMRES, and the speed of the sparse solver decides the efficiency of HSS. We have developed a parallel Gram-Schmidt process based GMRES to simultaneously calculate vector projection in Gram-Schmidt process of GMRES.

Parallel Gram-Schmidt process based GMRES (pGMRES) is applied to HSS (Algorithm 1) to construct a fast solver HSS-pGMRES for saddle point problem. HSS-pGMRES consists of two loops: the outer loop for HSS and the inner loop for pGMRES, and the details of HSS-pGMRES are described in Algorithm 2:

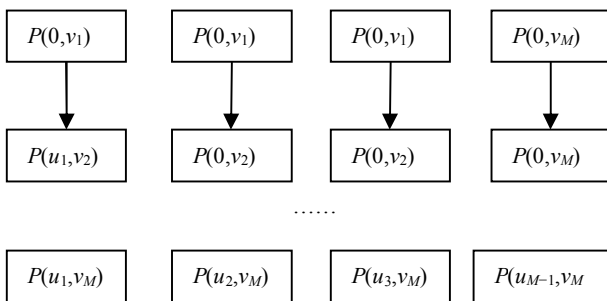
**Algorithm 2: Hermitian/Skew-Hermitian Separation-pGMRES**

- Initialization of HSS
- while  $R < tol_{HSS}$ 
  - Solve the couple system equation (2)
  - Solve the uncouple system equation (3)
  - Initialization of pGMRES
  - while  $R_k < tol_{GMRES}$ 
    - $w_0^{k+1} = A \cdot v^k$
    - Calculate  $v_{i+1}^{k+1}$  by parallel Gram-Schmidt Process
    - Calculate  $y_k$
  - end while
  - $u^k = u^0 + V_k y_k$
- end while

From Algorithm 2, we can see that HSS-pGMRES is built by a double loop: the outer loop of HSS and the inner loop of pGMRES. The number of outer iterations is controlled by the tolerance  $R < tol_{HSS}$ , and the number of outer iterations is controlled by the tolerance  $R_k < tol_{GMRES}$ . The inner loop pGMRES is responsible for solving the uncoupled linear system of equation (3), and every iteration of the outer loop HSS is responsible for solving the coupled linear system of equation (2).

In the conventional GMRES, we need  $k$  times computation of vector projection in  $k$  iteration of the inner loop GMRES and  $n$  iteration of the outer loop HSS (Algorithm 1). Therefore, we need total  $\frac{m(m+1)n}{2}$  computation of vector projection with time complexity  $O(m^2n)$  to build all orthogonal sets.

In HSS-pGMRES (Algorithm 2), we calculate the vector projection simultaneously in  $k$  iteration of the inner loop GMRES and  $n$  iteration of the outer loop HSS (Algorithm 1) in Fig. 1.



**Fig. 1 – Parallel Grad-Schmidt process based pGMRES.**

As Fig. 1 is showing, we only need  $mn$  computation of vector projection with time complexity  $O(mn)$  to build the orthogonal set  $u$ .

**2.2. SADDLE POINT EQUATION FROM IPM-SVM TRAINING**

The primal form of SVM training can be represented by Quadratic Programming problem [43]:

$$\begin{aligned} \min_x & \frac{1}{2} x^T Q x - e^T x, \\ & a x = 0, \\ & 0 \leq x \leq C, \end{aligned}$$

where  $x$  is the array of the Lagrange multipliers,  $a$  is the diagonal matrix of labels, and  $C$  is a parameter.

After Lagrange multiplier transformation, we obtain KKT conditions [44]. For details of algebra process from primal-dual problem to KKT conditions, the reader is referred to [9].

$$\begin{aligned} X s &= \sigma \mu e \\ (C - X) z &= \sigma \mu e \\ a^T x &= 0 \\ -Q x + a y + s - z &= -e \\ 0 \leq x \leq c, s \geq 0, z \geq 0 \end{aligned}$$

By Mehrotra predictor-corrector algorithm [9, 45], we obtain the linear system in both the predictor step and the corrector step:

$$\begin{bmatrix} -Q & a & I & -I \\ a^T & 0 & 0 & 0 \\ S & 0 & X & 0 \\ -Z & 0 & 0 & (C - X) \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta s \\ \Delta z \end{bmatrix} = \begin{bmatrix} r_c \\ r_b \\ r_s \\ r_z \end{bmatrix}, \quad (5)$$

where  $r_c$ ,  $r_b$ ,  $r_s$  and  $r_z$  are the right-hand-side. Eliminating  $\Delta s$  and  $\Delta z$  from the linear systems [43], we obtain the augmented linear system:

$$\begin{bmatrix} -(D + Q) & a^T \\ a & 0 \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} = \begin{bmatrix} R_c \\ R_b \end{bmatrix}.$$

Also, the stop condition must be carefully selected for efficient convergence. For details of IPM implementation is comprehensively discussed in [9].

**2.3 HSS-PGMRES-IPM FOR SVM TRAINING**

In this subsection we apply HSS-pGMRES to solve the saddle point problem of equation (1) from IPM based SVM training. To efficiently solve a linear system with the structure of saddle point problem of equation (1) with the symmetric part  $-D - \frac{1}{2}Q - \frac{1}{2}Q^T$  and the skew-symmetric part

$-\frac{1}{2}Q + \frac{1}{2}Q^T$ , we firstly solve an uncoupled linear system:

$$\left(-D - \frac{1}{2}Q - \frac{1}{2}Q^T + \alpha I_n\right) \cdot dx^{k+\frac{1}{2}} = f_{uc}^k, \quad (6.1)$$

$$\alpha \cdot dy^{k+\frac{1}{2}} = g_{uc}^k. \quad (6.2)$$

where  $\alpha$  is a parameter, and  $f_{uc}^k$  and  $g_{uc}^k$  are right-hand-side. Then we solve a coupled linear system:

$$\left(\alpha I_n - \frac{1}{2}Q + \frac{1}{2}Q^T\right) \cdot dx^{k+1} + a^T \cdot dy^{k+1} = f_c^k \quad (7.1)$$

$$-a \cdot dx^{k+1} + \alpha y^{k+1} = g_c^k. \quad (7.2)$$

where  $\alpha$  is a parameter, and  $f^k$  and  $g^k$  are right-hand-side. By Schur complement reduction, we obtain:

$$\left[ a \left( I_n - \frac{1}{2\alpha}Q + \frac{1}{2\alpha}Q^T \right)^{-1} a^T + \alpha^2 I_m \right] \cdot dy^{k+1} = a \left( I_n - \frac{1}{2\alpha}Q + \frac{1}{2\alpha}Q^T \right)^{-1} f^k + \alpha g^k. \quad (8)$$

Since the coefficient matrix  $[a(I_n + \alpha^{-1}S)^{-1}a^T + \alpha^2 I_m]$  of equation (4) is large and sparse matrix, GMRES is suitable to solve  $dy^{k+1}$ . After  $dy^{k+1}$  is solved, then we obtain  $dx^{k+1}$ . The details of HSS-pGMRES-IPM is described in Algorithm 3:

**Algorithm 3: HSS-pGMRES-IPM for SVM Training**

- Initial IPM: calculate  $(x^0, y^0, s^0, t^0)$  which satisfy the constraints
- while  $R_t < tol_{IPM}$ 
  - Solve  $(\Delta x^{pre}, \Delta y^{pre}, \Delta s^{pre}, \Delta t^{pre})$  from equation (1) by HSS-pGMRES (Algorithm 2)
  - Calculate the step size  $\alpha$  which satisfy the constraints
  - Solve  $(\Delta x^{cor}, \Delta y^{cor}, \Delta s^{cor}, \Delta t^{cor})$  from equation (1) by HSS-pGMRES (Algorithm 2)
  - Update the search direction by the formula:

$$\begin{aligned} & (\Delta x, \Delta y, \Delta s, \Delta t) \\ &= (\Delta x^{pre}, \Delta y^{pre}, \Delta s^{pre}, \Delta t^{pre}) \\ &+ (\Delta x^{cor}, \Delta y^{cor}, \Delta s^{cor}, \Delta t^{cor}) \end{aligned}$$

Update the optimization variable:

$$\begin{aligned} x^{k+1} &= x^k + \alpha \Delta x^k, \\ (y^{k+1}, s^{k+1}, t^{k+1}) &= (y^k, s^k, t^k) + \alpha (\Delta y^k, \Delta s^k, \Delta t^k), \end{aligned}$$

end

From Algorithm 3 we can see, HSS-pGMRES-IPM is built by triple loops: the outer loop of IPM, the middle loop of HSS and the inner loop of pGMRES. The number of outer iterations is controlled by the IPM tolerance  $R_t < tol_{IPM}$ , the number of middle iterations is controlled by the tolerance  $R < tol_{HSS}$ , and the number of outer iterations is controlled by the tolerance  $R_k < tol_{GMRES}$ . The inner loop and the middle loop HSS-pGMRES are responsible for solving the predictor linear system of equation (1) and the corrector linear system of equation (1), and every iteration of the outer loop IPM is responsible for calculating the forward step  $(\Delta x, \Delta y, \Delta s, \Delta t)$ .

**2.4 CONVERGENCE OF HSS-PGMRES-IPM**

As we discussed previously, the fast solver HSS-pGMRES-IPM (Algorithm 3) consists of triple loops: the outer loop IPM and the middle and inner loop HSS-pGMRES. The general convergence theory of the outer loop IPM is described in [9], and the convergence analysis of the middle and inner loop HSS-pGMRES can be found in [35, 41, 42].

In the implementation of the fast solver HSS-pGMRES-IPM (Algorithm 3), three separated tolerances for every loop exist: the tolerance for the outer loop  $tol_{IPM}$ , the tolerance for the middle loop  $tol_{HSS}$  and the tolerance for the inner loop  $tol_{GMRES}$ . The three tolerances are unnecessary to be treated equally. The tolerance for the outer loop  $tol_{IPM}$  is often replaced by the number of total iterations  $k < K$ . The tolerance for the middle loop  $tol_{HSS}$  can be loosed, which is inexact HSS.

**3. COMPUTATIONAL RESULTS**

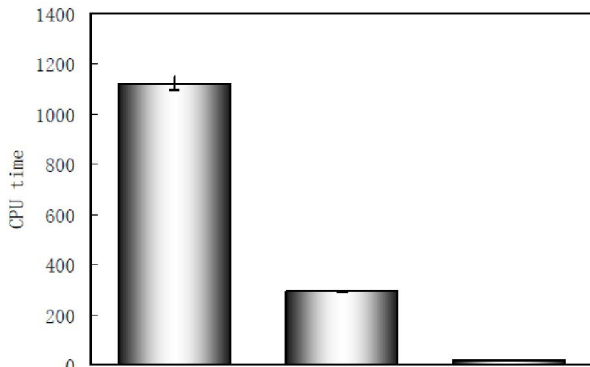
In this section, the performance of HSS-pGMRES-IPM (Algorithm 3) is illustrated by an example of SVM training problem.

**3.1. The Problem**

The dataset, ‘‘Classification of Human Lung Carcinomas by mRNA Expression Profiling Reveals Distinct Adenocarcinoma Sub-classes’’, comes from the cancer datasets of the Broad Institute of MIT [46]. The dataset includes 203 samples with 12600 genes in each sample. Kernel function is set as:  $K(A, B) = (\langle x_i, x_j \rangle - \min(x_i, x_j))$ . We develop the SVM code on MATLAB, and we develop the code of the fast solver HSS-pGMRES-IPM (Algorithm 3) for SVM training, and existing codes are referenced [14, 47]. The workstation is Intel i5-2310 at 2.90GHz with 4GB memory.

### 3.2. THE PERFORMANCE OF HSS-PGMRES-IPM

To comparing time cost of the non-factorization solver GJE, the conventional factorization solver CF and the fast solver HSS-pGMRES-IPM (Algorithm 3) for SVM training, we set all conditions exactly the same except the solution method for the predictor linear system and the corrector linear system of equation (1). The time cost is plotted in Fig. 2.



**Fig. 2 – Time cost of SVM training with the non-factorization solver GJE (the left column), the conventional factorization solver CF (the middle column) and the fast solver HSS-pGMRES-IPM (the right column).**

From Fig. 2 we can see, with maintaining the training accuracy of  $90 \pm 5\%$ , the non-factorization solver GJE spends  $1121.9 \pm 25.4$  seconds, the conventional factorization solver CF costs  $292.9 \pm 3.0$  seconds, and the fast solver HSS-pGMRES-IPM (Algorithm 3) needs only  $19.7 \pm 0.0$  seconds.

To quantitatively comparing the solution speed among these solvers, we define the acceleration rate among two solvers as the following:

$$rate = \frac{t_i}{t_j}$$

where  $t_i$  is the time cost of the first solver,  $t_j$  is the time cost of the second solver, and  $rate$  is the calculated acceleration rate. The calculated acceleration rates for the three solvers: the non-factorization solver GJE, the conventional factorization solver CF and the fast solver HSS-pGMRES-IPM (Algorithm 3) are listed in Table 1.

From Table 1 we can see, the fast solver HSS-pGMRES-IPM (Algorithm 3) is approximately 56.95 times faster than the non-factorization solver GJE, and the fast solver HSS-pGMRES-IPM (Algorithm 3) is about 14.87 times faster than the conventional solver CF. From Fig. 2 and Table 1 we can see, the fast solver HSS-pGMRES-IPM (Algorithm 3) significantly accelerates the solution

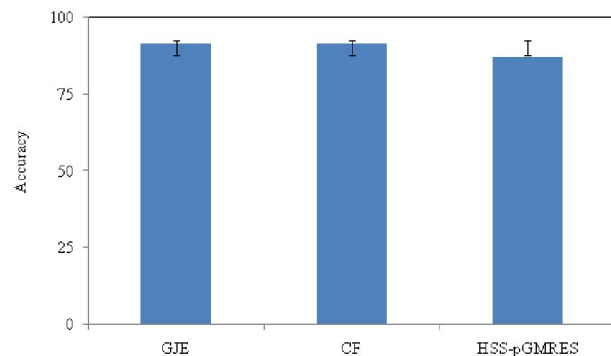
speed of saddle point problem from IPM based SVM training.

**Table 1. Calculated acceleration rate among the three solvers: the non-factorization solver GJE, the conventional factorization solver CF and the fast solver HSS-pGMRES-IPM.**

|                | GJE  | CF   | HSS-pGMRES-IPM |
|----------------|------|------|----------------|
| GJE            | 1.00 | 3.83 | 56.95          |
| CF             | –    | 1.00 | 14.87          |
| HSS-pGMRES-IPM | –    | –    | 1.00           |

### 3.3. THE SCALABILITY OF HSS-PGMRES-IPM BASED SVM TRAINING

To evaluate the scalability of three solvers the non-factorization solver GJE, the conventional factorization solver CF and the fast solver HSS-pGMRES-IPM (Algorithm 3) on small datasets, 250 genes are selected from the original dataset but keeping the number of sample of 203. The computational results of SVM training accuracy are plotted in Fig. 3.



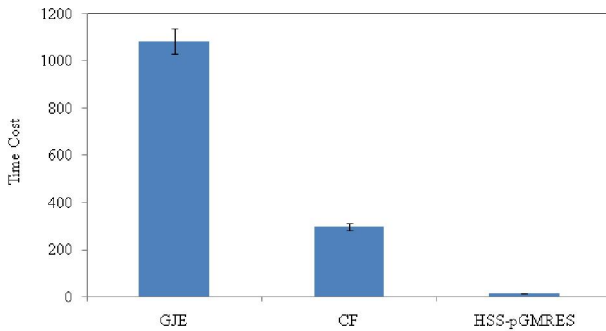
**Fig. 3 – The accuracy of the three solvers the non-factorization solver GJE, the conventional factorization CF and the fast solver HSS-pGMRES-IPM on SVM training accuracy.**

From Fig. 3 we can see, the difference among SVM training accuracy from the three solvers the non-factorization solver GJE, the conventional factorization CF and the fast solver HSS-pGMRES-IPM (Algorithm 3) are insignificant. The accuracy of the fast solver HSS-pGMRES-IPM (Algorithm 3) slightly decreases while the non-factorization solver GJE and the conventional factorization solver CF keep stable.

When training the small dataset by SVM, the time cost of the three solvers the non-factorization solver GJE, the conventional factorization solver CF and the fast solver HSS-pGMRES-IPM



(Algorithm 3) are measured. The computational experiments are repeated for three times, the average and the standard deviation are calculated. The calculated average time cost and the standard deviation are plotted in Fig. 4.



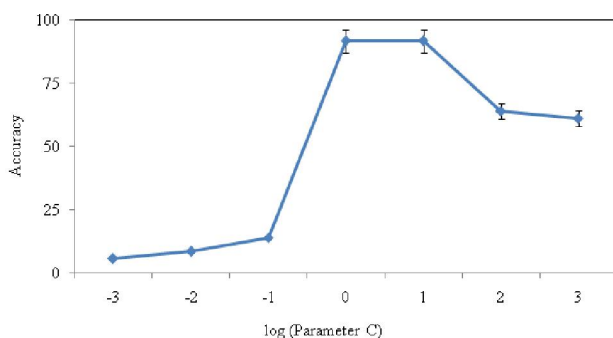
**Fig. 4 – Effect of the parameter C of the fast solver HSS-pGMRES-IPM based SVM on time cost.**

Comparing Fig. 2 with Fig. 4, no significant difference is presented between the time cost of the non-factorization solver GJE in Fig. 2 and that of in Fig. 4, of the conventional factorization solver CF and of the fast solver HSS-pGMRES-IPM (Algorithm 3).

The time cost of the solvers is decided by the size of the kernel matrix  $Q$ , and the size of the kernel matrix  $Q$  is decided by the number of samples. From Fig. 2 to Fig. 4, although the number of genes decreases, the number of samples keeps the same. Therefore, the size of the kernel matrix  $Q$  in Fig. 2 and Fig. 4 is the same, which leads to identical time cost between Fig. 2 and Fig. 4.

### 3.4. THE EFFECT OF PARAMETER C ON ACCURACY

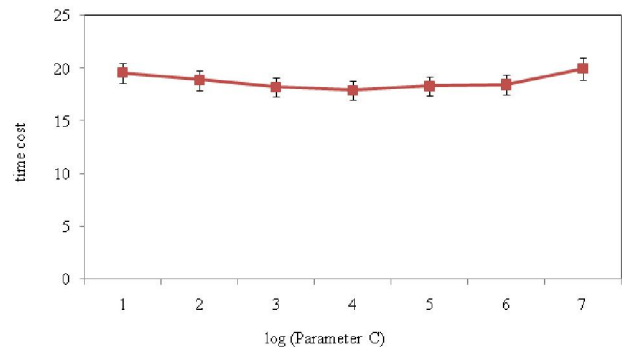
How to select Parameter  $C$  of SVM is an long-term but important problem. We test the performance of HSS-pGMRES-IPM (Algorithm 3) with different selection of Parameter  $C$ . Results are listed in Fig. 5, which is similar to our former research results.



**Fig. 5 – Effect of Parameter C of HSS-pGMRES-IPM based SVM on training accuracy.**

From Fig. 5 we can see, different selection of Parameter  $C$  significantly affects the performance of HSS-pGMRES-IPM (Algorithm 3) based SVM, and parameter  $C$  should be selected at middle of the value range.

We also calculate the time cost of HSS-pGMRES-IPM (Algorithm 3) based SVM with different selection of Parameter  $C$ . The values of Parameter  $C$  are selected from  $10^1$  to  $10^7$ , the tests are repeated for three times, and the average and the standard deviation are calculated, and the results are plotted in Fig. 6.



**Fig. 6 – Effect of Parameter C of HSS-pGMRES-IPM based SVM on Time Cost.**

From Fig. 6 we can see, different selection of parameter  $C$  does not affect the time cost of HSS-pGMRES-IPM (Algorithm 3) based SVM. The standard deviation of every selection from different Parameter  $C$  is small, which also proves that the time cost of HSS-pGMRES-IPM (Algorithm 3) based SVM is not significantly affected by Parameter  $C$ .

## 4. DISCUSSION

In this paper, by taking advantages of saddle point reformulation, we developed a fast solver, HSS-pGMRES-IPM, for SVM training problem. However, as discussed in [29], multiple other approaches exist for solving saddle point problem. However, HSS presents higher efficiency than the conventional approaches [32-36, 39, 41, 42], and similar acceleration is reported in this paper.

Since the linear systems from IPM are involved by HSS-pGRMES, and the fast solver applies to SVM, two problems should be considered: one is condition number of kernel matrix  $Q$ , and the other is the round off error in the solution of IPM with HSS-pGMRES.

Although no further mathematical explanation or proof, [48] describes that, if ill conditioning of  $Q$  in infeasible IPM for LP, there is in a serious loss of accuracy when solving the Newton equations. Unfortunately, kernel matrix  $Q$  is a matrix coming

from the dataset, measures to change it are limited. [43] provides suggestion to ameliorate the problem: to change the kernel function.

Scaling dataset provides no help to decrease condition number. Let's try  $q(q > 0)$  scaled dataset  $A = (x_{ij})$  and dot product  $\langle x_i, x_j \rangle$  as kernel function as example. Firstly, let scale the dataset:  $qA = (qA_{ij})$ . Secondly, let compute dot product  $\langle qx_i, qx_j \rangle = q^2 \langle x_i, x_j \rangle$ . That is, before scaling the kernel matrix  $Q$ , after scaling the kernel matrix is  $q^2Q$ . Finally, let's compute condition number.

$$\|Q\|_2 = \left( \sum_{i=1}^m \sum_{j=1}^n |y_{ij}|^p \right)^{\frac{1}{p}}.$$

Since the kernel matrix  $Q$  is non-negative,  $|y_{ij}| = y_{ij}$ . Then,

$$\|Q\|_p = \left( \sum_{i=1}^m \sum_{j=1}^n |y_{ij}|^p \right)^{\frac{1}{p}}.$$

By definition of norm,

$$\|q^2Q\| \cdot \|(q^2Q)^{-1}\| = \|q^2Q\| \left\| \frac{Q^{-1}}{q^2} \right\|.$$

According to the definition of matrix norm [49],

$$\begin{aligned} & \|q^2Q\| \cdot \left\| \frac{Q^{-1}}{q^2} \right\| \\ &= q^2 \|Q\| \cdot \frac{1}{q^2} \|Q^{-1}\| \\ &= \|Q\| \cdot \|Q^{-1}\|. \end{aligned}$$

That is, scaling does not really help to change condition number of the kernel matrix.

HSS-pGMRES-IPM (Algorithm 3) is a fast solver for SVM training. However, more theoretical study of HSS-pGMRES-IPM (Algorithm 3) for SVM training is needed to investigate the stability conditions for different datasets. Also, the linear systems in gene expression dataset are not huge, which is in size of  $mn$ , where  $m$  is a constant less than 10, and  $n$  the number of sample of dataset.

## 5. CONCLUSIONS

In this paper, we reformed SVM training into the saddle point equation, and we developed the fast solver, named HSS-pGMRES-IPM (Algorithm 3), for SVM training. Computational results show that the fast solver HSS-pGMRES-IPM (Algorithm 3) based SVM is significantly faster than the conventional factorization CF based SVM.

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## DETERMINING THE OPERATING DISTANCE OF AIR ULTRASOUND RANGE FINDERS: CALCULATIONS AND EXPERIMENTS

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**Abstract:** Estimating the operating distance of air ultrasound range finders by using the suitably modified radar equation and experimental verification of the developed computational procedure is discussed. It is shown that, despite notable differences between operating conditions of radars and air ultrasonic range finders, the radar equation is applicable to the considered case, and calculations of the relevant terms for this case are presented. The experimental assessment was carried out by evaluating the probability of detection at various distances from the custom built device. The calculated and experimental results seem to agree well despite using a number of values with high degree of uncertainty. The described procedure can be used at the design stage of air ultrasound range finders in order to reduce the number of prototypes before finalizing the design to a single prototype. *Copyright © Research Institute for Intelligent Computer Systems, 2014. All rights reserved.*

**Keywords:** air ultrasound, range finding, radar equation, operating distance.

### 1. INTRODUCTION

Air ultrasound range finders are used for distance measurements in construction and surveying (ultrasonic tape measures [1]), for proximity sensing [2], and for collision avoidance in parking aids [3] and autonomous vehicles [4]. Some other applications, which are being developed at the moment, include ultrasonic sensing of surface profiles [5], distributed intrusion detection systems [6] and walking aids for people with visual impairments [7].

These devices are frequently built around inexpensive ultrasonic modules, such as SRF-04 [8], which commonly operate using a pitch-catch mode, and consist of transmitting and receiving ultrasonic transducers and their supporting electronic circuitry. (Some of the modules operate in the pulse-echo mode using a single transducer only.) The electronic circuitry produces an excitation pulses when externally triggered, and returns a level change at its output when a returning signal with amplitude over the particular threshold is detected. The external controller then measures the ultrasound propagation time and calculates the distance to the object using either the known or assumed ultrasound velocity.

Meeting the design specifications of an ultrasonic range finder can be very tricky because it is not uncommon for the manufacturers and vendors of the same ultrasonic modules, to claim notably different operating distances for their products. Indeed, the same module might confidently detect the presence of a solid wall located perpendicularly to the transducer's axis, while at the same time failing to detect a typical parking pole, even at a much smaller distance. A procedure for determining the operating range for newly designed devices does not seem to be readily available publicly, which makes it difficult to meet the desired specifications without a few rounds of trials and error corrections.

On the other hand, the operating range of radars can be found using the well understood radar equation [9]. In this paper we present a procedure for determining the operating distance of air ultrasonic range finders that is based on the radar equation. We discuss qualitative and quantitative differences between the two a.m. devices, and show how to calculate the required parameters based on datasheets of typical ultrasonic transducers. Calculated results are compared to the experimental ones that are obtained by detecting a man at different distances to a custom built air ultrasound range

finder which features various transducers and excitation voltages.

## 2. COMPARING RADAR OPERATION TO THAT OF THE AIR ULTRASOUND RANGE FINDER

Active radars operate by sending electromagnetic waves towards objects that reflect some of the wave energy back. These waves are generated by the transmitter and then radiated into the space using an antenna. Next, some of the transmitted energy is scattered in various directions by the target. These echoes, reflected back towards the radar, are collected by the receiving antenna and passed on to the receiver for further processing, which commonly includes detection of the object's presence and evaluation of the distance to it, if detection has occurred.

The operating range of radar can be found from the radar equation, which was derived under the following major assumptions [9]:

- 1) If high-frequency energy is emitted by an isotropic transmitter, then it spreads uniformly in all the directions; therefore, areas with the same power density will form spheres where the transmitted energy is distributed evenly across the area  $A = 4\pi R_a^2$ , where  $R_a$  is the distance to the antenna;
- 2) If the radiated power is redistributed to provide better radiation in the particular direction of interest, then this results in an increase of the power density in this direction proportional to the antenna's directional gain  $G$ ;
- 3) Both the transmitter and receiver use the same antenna with the same  $G$ ;

- 4) The echo power depends upon the transmission power density at the target position and how much of it is reflected back in the direction of the receiver. It is equal to the product of the power density at the target and its effective radar cross-section (scattering coefficient of the target)  $\sigma$ ;
- 5) The echo power spreads out in the same way as the transmitted power (i.e., its power density is inversely proportional to  $R_a^2$ ). When propagation of both the transmitted and reflected waves is considered, then the returned power density thus becomes inversely proportional to  $R_a^4$ .

The radar equation, derived from these assumptions, is given below [9]

$$R_a = \sqrt[4]{\frac{P_s * G^2 * \lambda^2 * \sigma}{P_E * (4\pi)^3 * L_{ges}}}, \quad (1)$$

where  $P_s$  is the transmitted power,  $\lambda$  is the radar wavelength at the operating frequency,  $P_E$  is the received power that is sufficient in order to detect the target, and  $L_{ges}$  is the loss factor that covers propagation losses.  $P_E$  equals to the product of the echo power density at the receiver's antenna and its effective area.

Qualitatively, the operations of radar and air ultrasonic range finder are similar to each other. Pitch-catch operating mode, commonly employed for air ultrasonic range finders, is preferred over the pulse-echo mode because of the lower dimension of the dead zone.

Quantitatively, the differences between the two came from the common operating conditions of these devices (Table 1).

**Table 1. Typical relations between the operating parameters**

|  | Distance to the target        | Linear size of the target        | Linear size of the antenna   | Operating wavelength $\lambda$              |
|--|-------------------------------|----------------------------------|------------------------------|---|
| <b>Radar</b><br>( $c = 3 * 10^8$ m/s)                  | $R_a \gg$<br>tens-hundreds km | $L_o \approx$<br>tens-hundreds m | $L_a \gg$<br>tens-hundreds m | 30 mm typical<br>(US airport radar @10 GHz) |
| <b>Air ultrasonic range finder</b><br>( $c = 340$ m/s) | $R_a \approx$<br>few m        | $L_o \gg$<br>few m               | $L_a \approx$<br>tens mm     | 8 mm typical<br>( @ 40 kHz )                |

The most important difference comes from the fact that radar operates at much higher distances compared to the sizes of the objects and antennas, whilst air ultrasonic range finders are equipped with a tiny antenna compared to the operating distance and size of the target. Despite this, both devices operate in the far field of the antenna, which suggests that their respective operating distance equations should be similar.

Let us consider the validity of the assumptions, which lead to the radar equation, but now for air

ultrasonic range finders. Air ultrasonic transducers are usually characterized not by their directional gain but by their radiating angle. It is assumed that all of the transmitted ultrasound energy is spread inside this angle evenly. Therefore assumptions 1 and 2 above need to be adjusted as appropriate. Assumption 3 remains valid since the two ultrasonic transducers, typical to air ultrasonic range finders, are commonly used in exactly the same way as the single radar antenna. Assumption 4 remains valid since the effective radar cross-section allows for reducing an arbitrarily complex surface profile to a

single number. However, when this concept is applied to air ultrasonic range finders, the substantial size of the object, which is commensurable to the distance to the target, may complicate theoretical considerations of backscatter compared to the radar case. Assumption 5 describes the excitation and echo propagation as spherical waves, which should at least hold as the first order approximation for air ultrasonic range finders.

Overall, the radar equation derived to quantify the propagation of electromagnetic waves over substantial distances seems to be suitable for the case of air ultrasonic range finders provided that its terms are calculated correctly.

### 3. DETERMINING TERMS OF THE RADAR EQUATION FOR AIR ULTRASOUND RANGE FINDERS

#### 3.1. TRANSMITTED POWER $P_s$

The power of acoustic (including ultrasonic) waves can be calculated from their pressure,  $p$ :

$$P_s = \frac{p^2 \times A}{Z}, \quad (2)$$

where  $A$  is the area where the pressure is applied and  $Z$  is the acoustic impedance of the propagation medium ( $Z = \rho c$ , where  $\rho$  is the air density and  $c$  is the sound velocity in air, 1.19 kg/m<sup>3</sup> and 346.6 m/s at 25°C respectively [10, sect. 2.1.1 and 2.4.1]).

Ultrasonic transducers are commonly characterized by their standard pressure level (SPL, dB) produced under the excitation voltage of 10  $V_{RMS}$  relative to the reference pressure of 20  $\mu$ Pa. From this definition, the transmitted acoustic pressure,  $p_t$ , equals to

$$p_t = \frac{V_{RMS}}{10V} \times 20\mu Pa \times 10^{SPL/20}, \quad (3)$$

where  $V_{RMS}$  is the excitation voltage. The SPL is stated at some distance from the ultrasonic transducer (typically 30 cm). The area,  $A$ , at which the pressure is applied, can be approximated from the total beam angle,  $\alpha$ , of the transducer (Fig. 1):

$$A = \pi \times (0.3m \times \tan(\alpha/2))^2, \quad (4)$$

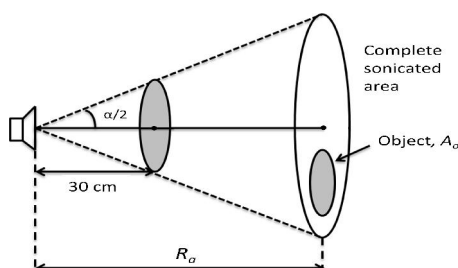


Fig. 1 – Spatial distribution of the transmitted energy.

#### 3.2. DIRECTIONAL GAIN $G$

The gain of a round antenna or transducer can be calculated from its area  $A_t$  ( $A_t = \pi d^2/4$ ,  $d$  is the diameter) and operating wavelength  $\lambda$  [9]:

$$G = \frac{4 \times \pi \times A_t \times K_a}{\lambda^2}, \quad (5)$$

where  $K_a$  is the efficiency of the transmitting/receiving transducers (the typical value for ultrasonic transducers is 30% [11]). The radar equation assumes that transmission and reception are undertaken using the same antenna in the pulse-echo mode. Despite having two separate transducers in the pitch-catch configuration for air ultrasonic modules, they commonly have the same diameters. If this is not the case, then the radar equation's term  $G^2$  should be replaced with  $G_T \times G_R$ , where  $G_T$  and  $G_R$  are the directional gains of the transmitting and receiving transducers respectively.

#### 3.3. EFFECTIVE RADAR CROSS SECTION $\sigma$

Generally this factor is very difficult to calculate for real objects; consequently, its value for radar is usually approximated by some value measured from similar objects or by combining simulated and measured data [12]. In the case of air ultrasonic range finders, the calculations can be even more complicated, e.g., because of the varying shapes of human bodies. Here, we suggest using the cross-sectional area of the object that belongs to the sonicated area,  $A_o$  (Fig. 1), as the first order approximation.

#### 3.4. RECEIVED POWER SUFFICIENT FOR THE DETECTION OF THE OBJECT $P_E$

This parameter is receiver-specific as it depends upon the noise level at its input, type of transmitted signal (e.g., sine wave burst or chirp) and processing algorithm (e.g., use of matched filtering before threshold detection). The transducer should generate the minimum voltage,  $V_D$ , required to make object detection happen. The receive sensitivity of the ultrasonic transducers,  $S$ , is commonly stated in dBs relative to a 1 V/ $\mu$ bar level. Therefore the acoustic pressure at the receiver,  $p_r$ , required for object detection should be at least

$$p_r = \frac{V_D}{10^{S/20}} \left[ \frac{\mu bar}{V} \right] = 0.1 \frac{V_D}{10^{S/20}} \left[ \frac{Pa}{V} \right], \quad (6)$$

Finally, the sought after  $P_E$  can be calculated from equation (2) using the area of the transducer,  $A_t$ , and air acoustic impedance,  $Z$ .

### 3.5. LOSS FACTOR, $L_{ges}$

This term includes all of the losses experienced by the wave during its propagation. The attenuation of ultrasound in the air,  $\alpha$ , at 20°C and 101.325 kPa strongly depends upon humidity, ranging from 0.46 dB/m to 1.3 dB/m [10, section 2.4.1].

Inclusion of the attenuation term into the radar equation would affect the linearity of the latter because the attenuation depends upon the as-of-yet unknown radar range. For this reason, we first calculated the operating range assuming  $L_{ges} = 1$ , and then calculate the corrected value, applying the losses during propagation in both directions, and using both the minimal and maximal  $\alpha$ :

$$R'_a = \frac{R_a}{\sqrt[4]{(10^{\alpha \cdot R_a})^2}} = \frac{R_a}{\sqrt{10^{\alpha \cdot R_a}}} \quad (7)$$

This correction overestimates the losses for  $R'_a$ , thus giving the bottom boundary for the operating distance.

### 4. CALCULATING THE EXPECTED OPERATING RANGE FOR A PARTICULAR ULTRASONIC RANGE FINDER

The calculations (and later experimental assessment) were carried out for a pulse-echo air ultrasonic range finder developed in our laboratory [13]. We select 0.6 mV for the output of the transducer during reception as the object detection threshold voltage.

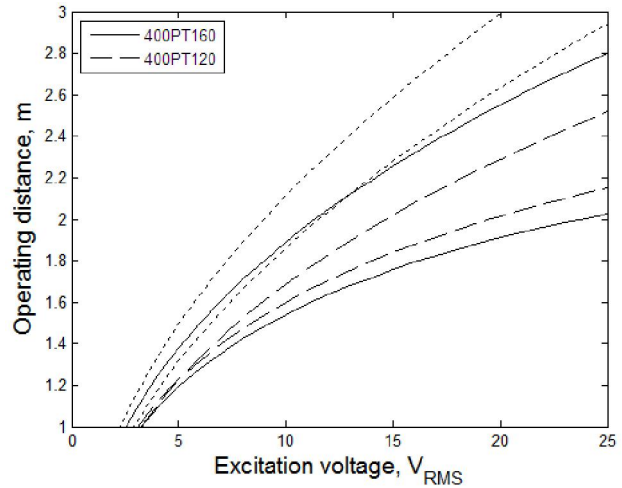
Two excitation voltage levels (10  $V_{RMS}$  and 20  $V_{RMS}$ ) and two different transducers (Table 2) were used, which yielded four different options for the range finder operation in the pulse-echo mode.

We detected a man standing at various distances from the transducer in an axial direction; man's cross-sectional area,  $A_o$ , was approximated by a value of 0.75  $m^2$  (from a rectangle made of the 0.5 m effective width and 1.5 m effective height).

The calculated values for the 400PT160 transducer excited by 20  $V_{RMS}$  were as follows:  $P_S = 0.150$  W,  $G = 10.4$ ,  $\sigma = 0.75$   $m^2$ ,  $P_E = 5.74$  nW,  $L_{ges} = 1$ , yielding  $R_a = 2.99$  m.

**Table 2. The specifications of the ultrasonic transducers taken from their datasheets [14,15]**

|   | 400PT120 | 400PT160 |
|---|----------|----------|
| Diameter (mm)   | 12.7     | 16.2     |
| Transmitted sound pressure level (SPL) (per 10 $V_{rms}$ applied at 30 cm axial distance from the centre of the transducer) | 115 dB   | 117 dB   |
| Receive sensitivity   | -68 dB   | -65 dB   |
| Total beam angle (@ -6 dB)  | 85°      | 55°      |



**Fig. 2 – Operating distances versus the excitation voltage for two different transducers under the minimal and maximal ultrasound attenuation in air (dotted lines show distances without accounting for attenuation).**

**Table 3. The detection range of a person with a cross-sectional area of 0.75  $m^2$**

| Operating conditions | Calculated operating range |                         |
|----------------------|----------------------------|-------------------------|
|                      | without attenuation $R_a$  | with attenuation $R'_a$ |
| 400PT120 @ 10 V      | 1.86 m                     | 1.69 m / 1.54 m         |
| 400PT120 @ 20 V      | 2.63 m                     | 2.29 m / 1.91 m         |
| 400PT160 @ 10 V      | 2.11 m                     | 1.89 m / 1.60 m         |
| 400PT160 @ 20 V      | 2.99 m                     | 2.55 m / 2.02 m         |

The calculated operating distances versus the excitation voltage for all of the considered operating conditions are plotted in Fig. 2. It displays the effect of overestimation of losses under the applied procedure – under maximal losses the operating distance of the 400PT160 transducer became even smaller than that of the 400PT120 one.

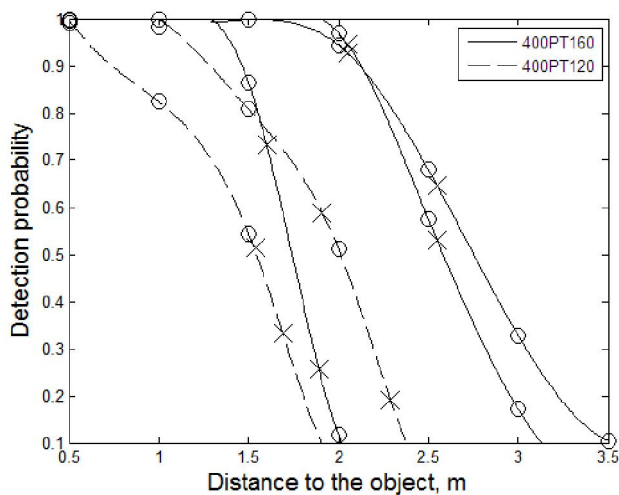
Numerical values for calculated distances under all of the operating conditions that were tested experimentally are presented in Table 3 to enable later comparison with the experimental data.

### 5. EXPERIMENTAL ASSESSMENT OF THE OPERATING RANGE OF THE DEVICE

During the experiments a particular transducer was placed at around 1 m above ground, and was directed towards a man who faced the transducer [13]. 1000 ultrasonic pulses were generated with a 100 ms delay between each other, and the number of instances that led to detection of the echo was recorded. The probability of object



detection was estimated as the ratio of the number of detections to the number of trials (1000). After every measurement, the man walked a further 0.5 m away from the transducer and this process was repeated several times. The estimated detection probabilities are plotted in Fig. 3 using spline interpolation between the experimentally derived points. Crosses show the operating distances, calculated for the lowest and highest ultrasound attenuation (right column of Table 3). The curves have a range of distances where the object was detected with confidence (if probability is close to 1, then correct detection), and a range of distances where the object was not detected (if probability is below 0.1, then object missed). Between these two ranges the probability of detection decreases smoothly with increasing distance as one would expect. All of the theoretically calculated operating ranges of the device (Table 3, right column) were found to belong to the transient region of the curves presented in Fig. 3. We believe that this region is where they ought to belong to if the theoretical calculations were correct.



**Fig. 3 – Detection probabilities for various operating conditions (curves for the 20 V<sub>RMS</sub> excitation voltage are to the right to these for the 10 V<sub>RMS</sub> excitation; circles depict the experimentally estimated points; crosses are placed on the curves at the distances taken from the right column of Table 3; experiment with 16 mm transducer excited by 20 V<sub>RMS</sub> was conducted twice hence two curves).**

## 6. DISCUSSION

### 6.1. WAS IT POSSIBLE TO INCREASE THE ACCURACY OF THE ABOVE CALCULATIONS?

The following factors could be taken into the account:

- the size of the transducer's piezoelement is smaller (typically by about 10%) than the

diameter of the transducer; this correction would affect the transducer's area, and hence, gain;

- more accurate estimation would involve solving the nonlinear equation with the loss factor depending upon the operating distance;
- a better match between the calculated and experimental data would be expected if the relative humidity was measured at the time of the experiment in order to use the actual ultrasound attenuation in air.

However, because of significant uncertainty regarding some of the parameters used for calculations (e.g., ultrasound attenuation in air, the transducer's efficiency, etc.), we believe that there was no need for more accurate calculations.

### 6.2. WHAT FACTORS, IMPORTANT TO AIR ULTRASOUND RANGE FINDERS, WERE LIKELY TO BE OVERLOOKED IN THE CALCULATIONS?

These likely were:

- scattering of ultrasound waves over the object with dimensions commensurate with the operating distance; this factor alone could have probably varied by an order of magnitude, depending on the profile of the object, compared to the flat rectangle used in the calculations;
- the limited bandwidth of the ultrasonic transducer(s) was not considered; it would spread out both the radiated and received waveforms in the time domain, most likely leading to some reduction in the operating distance;
- the radar equation does not account for the statistical nature of signal detection; the calculated distance will only be effective for particular values of detection and false alarm probabilities, which are valid for the P<sub>E</sub> value used in the calculations.

### 6.3. HOW MAY THE DESCRIBED CALCULATION PROCEDURE BE BEST USED DURING THE DESIGN?

Most of the terms that are involved in the calculations can only be evaluated with substantial uncertainty. For this reason this procedure should only be used as a very rough estimate at the first round of the design. The designed prototype is then to be evaluated experimentally, and the operating conditions (e.g., transducer types, excitation voltage) are to be adjusted accordingly in order to meet specifications. It seems that using the described calculation procedure will enable the completion of the design after a single prototyping stage.

## 7. SUMMARY AND CONCLUSIONS

The compatibility of the well-established radar equation with air ultrasound range finders was analysed first. Then, the relevant parameters were obtained from the typical datasheets for ultrasonic transducers and other available data. The operating range of a particular air ultrasound range finder was calculated for a set of various operating conditions, and was compared to the experimental results. Despite the many uncertain values that were involved in the calculations, the experimental and calculated results agreed well.

Therefore, the radar equation is applicable to the case of air ultrasound range finders provided that its terms are calculated appropriately.

The developed numerical procedure seems to be capable of reducing the required number of prototypes before finalizing the design to a single prototype.

The operating distance, as commonly stated by the manufacturers of air ultrasound range finding modules and devices, can be very misleading. It should instead be estimated experimentally, and include the references (a) to the target (e.g., a solid wall in the direction perpendicular to the module's axis), (b) to the relative humidity at the time of measurements and (c) to the probability of target detection (at least 0.90 or 0.95) in order to eliminate any unreasonable expectations for performance.

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## COGNITIVE SYSTEM OF THE HEPATORENAL SYNDROME SCREENING IN PERSONS WITH ALCOHOL ABUSE

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**Abstract:** Increase of alcohol consumption is observed in all countries of the world. Over the past 20 years, consumption of alcohol correlated with the level of mortality from liver cirrhosis. Under the hepatorenal syndrome we understand the primary lesion of the liver with subsequent involvement of kidney tissue in the painful process. In order to detect hepatorenal syndrome in medical practice the screening of laboratory markers is used which carried out manually. The use of medical information system can significantly improve the process of disease detection in patients. To the best knowledge of the authors there is no an analogue of medical information system for the screening of hepatorenal syndrome. The analysis of the process of screening of laboratory markers of hepatorenal syndrome allowed to create a client-server intelligent information system based on the Java SE platform using the management database system Firebird. The tests were carried out in Arkhangelsk City Clinical Hospital No. 1. The testing has shown that the time of diagnosis was reduced in comparison with traditional methods to 69% with the use of fewer specialists, while job satisfaction of physicians increased on 23%. The diagnostic accuracy of hepatorenal syndrome doesn't depend on the method of diagnosis. The testing of our software has showed that our results coincide with those of health professionals. *Copyright © Research Institute for Intelligent Computer Systems, 2014. All rights reserved.*

**Keywords:** hepatorenal syndrome; screening; workstation; styling.

### 1. INTRODUCTION

Computers and information technology became for a long time already an integral part of the most different spheres of a life, and the medicine didn't become an exception. Doctors advise patients on-line, the diagnostic apparatus is equipped by powerful processors, conferences and consultations are spent through the Internet. And nowadays a medical information technology gets the increasing urgency, and the medical software becomes more and more claimed.

Medical information systems implementation is capable to improve considerably working processes at the most different levels: beginning from the medical automated workplace creation in separate medioprofilactic institution before complex automation of polyclinics and hospitals at regional level.

The urgency of research issue is caused by that the hepatorenal syndrome problem is actively studied more than 100 years, however remain unresolved some question on treatment of such patients, therefore the high death rate remains.

In connection with the extremely unfavorable prognosis for the first type hepatorenal syndrome

and the given complication hepatocirrhosis prevalence at working-age people, it is required to reveal as soon as possible at an early stage its presence and in due time to institute corresponding therapy.

The increase in alcohol consumption is marked worldwide. Russia leads in the world on negative biomedical and social consequences of spirit consuming.

Analysis original sources of the research problem showed that the syndrome hepatolienal diagnosis is performed manually on the basis of laboratory studies and examination of patients by the doctors.

To our regret, any program, allowing automate the process hepatorenal syndrome screening, is not found that.

Automating process of revealing diagnostics hepatorenal syndrome is need to health workers. Our papers is devoted to develop one of such program and show results of improving result of work of health worker in this direction.

### 2. THE HEPATORENAL SYNDROME

In 1793 Matthew Bailey informed on connection of hepatocirrhosis with drinking. For the last 20

years alcohol consumption correlates with a death rate from a hepatocirrhosis. Annually 20 thousand persons in the world dies of hepatocirrhosis complications, 60 % from them are working-age people [1].

Hepatorenal syndrome (HRS) – is serious form of kidney failure functional character that develops in patients with advanced hepatic insufficiency, acute and chronic liver diseases (acute viral hepatitis, leptospirosis, yellow haemorrhagic fever, drugs poisons, poisons of hepatotoxic mushrooms and surrogate alcohol, liver cirrhosis with portal hypertension) in the absence of other causes of kidney failure (chronic kidney disease, urinary tract obstruction, receiving nephrotoxic drugs) [2].

The most common cause of HRS – is hepatic cirrhosis – the final stage of chronic liver disease. Life expectancy of these patients depends on the development of complications. The heaviest hepatocirrhosis complications are the hepatic coma, a thrombosis in system portal vein, a bleeding from the varicose veins of a gullet, hemorrhoids veins, the hepatorenal syndrome, a liver cancer formation [3].

Maintain these patients – is complex, demanding task of the doctor as the correct tactics of these patients, in some cases, allows patients to safely wait for a liver transplant, which is a radical and most effective treatment [4].

The hepatorenal syndrome (HRS) is primary lesion of a liver with the subsequent involving in disease process of a nephritic tissue. Depending on clinical presentations severity and prognosis A. Gines both co-authors distinguish I and II types hepatorenal syndrome. The first type hepatorenal syndrome, characterised by an unfavorable clinical course with lethality 80-90 %, is more often observed at an alcoholic hepatocirrhosis. The clinical course of II type hepatorenal syndrome is more favorably. It develops at a hepatocirrhosis without heavy cellular insufficiency, and lifetime varies from 1 till 7 years [5].

In connection with the extremely unfavorable prognosis for the first type hepatorenal syndrome and the given complication hepatocirrhosis prevalence at working-age people, it is required to define a set of typical laboratory signs, characteristic for the given syndrome for creation of the first type hepatorenal syndrome laboratory markers screening.

During research it is surveyed 61 persons at the age from 32 till 60 years with the experience of alcohol abuse from 7.5 till 18 years, passing treatment in Arkhangelsk (the first city hospital, the fourth city hospital, the seventh city hospital), suffering the alcoholic hepatocirrhosis, complicated hepatorenal syndrome. The control group was made by almost healthy 15 men at whom the chronic alcoholism and taking alcoholic drinks within the

last two weeks has been excluded clinically and anamnesticly. The hepatorenal syndrome catamnesis has been studied, the clinical, biochemical and instrumental methods of research and also a blood analysis on presence hepatitis markers HBV and HCV are made during research.

As a result of the research the following hepatorenal syndrome development predictors (prognostic parameters) have been revealed (Table 1) [6].

**Table 1. Clinical-laboratory signs occurrence frequency at patients with the first and the second types hepatorenal syndrome and control group.**

| Sign   | Patients with I type HRS |     | Patients with II type HRS |     |
|--|--------------------------|-----|---------------------------|-----|
|  | abs.                     | %   | abs.                      | %   |
| Duration of a hepatocirrhosis over 5 years         | 11                       | 50  | 8                         | 21  |
| Duration of the alcoholization period over 1 month | 8                        | 36  | 8                         | 21  |
| Presence of an accompanying infection              | 3                        | 14  | 1                         | 3   |
| Hemorrhagic syndrome                               | 4                        | 18  | 1                         | 3   |
| Marked icterus                                     | 9                        | 41  | 4                         | 10  |
| Hyperthermia                                       | 6                        | 27  | 2                         | 5   |
| Cavitary and peripheral edemata                    | 4                        | 18  | 2                         | 5   |
| Encephalopathy presence                            | 15                       | 68  | 16                        | 41  |
| Hypotonia less than 100/60 mm Hg                   | 9                        | 41  | 6                         | 15  |
| Resistant ascites                                  | 21                       | 96  | 11                        | 28  |
| Tachycardia over 100 blows per minute              | 18                       | 82  | 7                         | 18  |
| Leukocytes more than $15 \cdot 10^9$               | 11                       | 50  | 2                         | 5   |
| ESR over 30 mm\hour                                | 12                       | 55  | 17                        | 44  |
| Haemoglobin less than 90 g/l                       | 16                       | 73  | 1                         | 3   |
| Thrombocytes less than $150 \cdot 10^9$            | 16                       | 73  | 3                         | 8   |
| Bilirubin in 10 times above norm                   | 13                       | 59  | 3                         | 8   |
| Albumin less than 26,0 g/l                         | 18                       | 82  | 2                         | 5   |
| PTI less than 70%                                  | 14                       | 64  | 3                         | 8   |
| In total   | 22                       | 100 | 39                        | 100 |

In examined groups the average values of hematologic and biochemical indices, entering into routine examination at a hepatocirrhosis, are defined For revealing diagnostically significant laboratory signs (Table 2 and Table 3) [6].

The obtained data allows to reveal distinctive laboratory signs between the first and the second types hepatorenal syndrome.

The hemogram high-informative indices for diagnostics the first type hepatorenal syndrome are:

- haemoglobin decrease less than 90.0 g/l;
- thrombocytes level  $150 \cdot 10^9$  and more low;

- leukocytes level  $13 \cdot 10^9$  and above.
- In the biochemical status diagnostically significant for the first type is:
  - albumen decrease to 26.0 g/l and more low;
  - general and direct bilirubin increase in 10 times and more;
  - alkaline phosphatase increase not exceeding two norms;
  - lactate dehydrogenase (LDH) hepatic fraction increase in 2 times and more;
  - creatinine increase in blood in 1.5-2 times;
  - Na decrease in serum less than 128 mmol/l.

**Table 2. The table of the laboratory data average values at patients with the first and the second types hepatorenal syndrome and control group.**

| Sign                               | The control group<br>n= 10 | Patients with I type HRS | P1    |
|------------------------------------|----------------------------|--------------------------|-------|
| Leukocytes $\cdot 10^9$ (cell/l)   | 7.40±1.30                  | 12.80±1.41               | 0.010 |
| Haemoglobin (g/l)                  | 138.30±0.85                | 83.30±4.85               | 0.001 |
| Thrombocytes $\cdot 10^9$ (cell/l) | 246.20±12.50               | 138.90±11.70             | 0.001 |
| ESR (mm/h)                         | 12.00±2.61                 | 39.30±5.05               | 0.001 |
| Whole protein (g/l)                | 78.50±2.90                 | 66.00±3.11               | 0.010 |
| Albumin (g/l)                      | 38.70± 2.90                | 26.38±1.64               | 0.001 |
| Total bilirubin (mmol/l)           | 15.30±2.00                 | 311.68±39.90             | 0.001 |
| Direct bilirubin (mmol/l)          | 5.10±0.50                  | 235.86±32.19             | 0.001 |
| PTI (%)                            | 80.65± 1.49                | 63.55±4.98               | 0.010 |
| APTT (s)                           | 36.20±1.40                 | 58.50±2.50               | 0.001 |
| AST (mmol/l)                       | 32.00±3.80                 | 124.70±19.49             | 0.001 |
| Alanine-aminotransferase (mmol/l)  | 26.00±3.10                 | 51.02±8.03               | 0.010 |
| K (mmol/l)                         | 3.70±0.06                  | 3.59±0.35                | -     |
| Na(mmol/l)                         | 138.00±1.70                | 123.27±3.80              | 0.010 |
| Ca (mmol/l)                        | 2.40±0.20                  | 1.35±0.21                | 0.001 |
| Fibrinogen (g/l)                   | 3.50±0.20                  | 3.10±0.43                | -     |
| Alkaline phosphatase (un/l)        | 154.40±5.30                | 310.60±44.01             | 0.010 |
| GGTP (un/l)                        | 37.80±3.09                 | 423.67±75.72             | 0.001 |
| LDH (ME)                           | 276.40±3.20                | 660.50±16.04             | 0.001 |
| Creatinine (mcmol/l)               | 0.06±0.02                  | 0.22±0.03                | 0.010 |
| Urea (mol/l)                       | 6.30±1.10                  | 10.79±1.50               | 0.050 |

Indices constellation are statistically significant for screening the first type hepatorenal syndrome.

Thus, the developed hepatorenal syndrome screening with the help of accessible to any medioprofilactic institution laboratory research methods allows to raise diagnostics quality, with high probability degree to diagnose hepatorenal syndrome (I type or II type) to doctors of any speciality without the expert in stationary and ambulatory conditions, to solve questions

concerning the prognosis and timely effective medication, to designate development hepatorenal syndrome preventive maintenance ways, to reduce period of patient stay with hepatorenal syndrome for a check-up and the expenses connected with it. Possessing sufficient simplicity and availability, low labor intensiveness, screening has high information value and can be applied to revealing of patients the first and the second types hepatorenal syndrome.

**Table 3. The table of the laboratory data average values at patients with the first and the second types hepatorenal syndrome and control group.**

| Sign                               | Patients with II type HRS | P2    | P1 P2 |
|------------------------------------|---------------------------|-------|-------|
| Leukocytes $\cdot 10^9$ (cell/l)   | 9.40±0.67                 | -     | 0.050 |
| Haemoglobin (g/l)                  | 117.70±3.69               | 0.001 | 0.001 |
| Thrombocytes $\cdot 10^9$ (cell/l) | 184.90±13.19              | 0.010 | 0.050 |
| ESR (mm/h)                         | 38.10±3.87                | 0.001 | -     |
| Whole protein (g/l)                | 66.76±2.41                | 0.010 | -     |
| Albumin (g/l)                      | 34.36±3.37                | -     | 0.050 |
| Total bilirubin (mmol/l)           | 190.88±28.06              | 0.001 | 0.050 |
| Direct bilirubin (mmol/l)          | 151.30±18.49              | 0.001 | 0.050 |
| PTI (%)                            | 70.07±3.08                | 0.010 | -     |
| APTT (s)                           | 55.47±8.30                | 0.010 | -     |
| AST (mmol/l)                       | 123.01±17.02              | 0.001 | -     |
| Alanine-aminotransferase (mmol/l)  | 49.43±5.85                | 0.001 | -     |
| K (mmol/l)                         | 3.59±0.11                 | -     | -     |
| Na(mmol/l)                         | 130.05±1.40               | 0.001 | 0.050 |
| Ca (mmol/l)                        | 1.57±0.15                 | 0.001 | -     |
| Fibrinogen (g/l)                   | 3.37±0.39                 | -     | -     |
| Alkaline phosphatase (un/l)        | 467.36±38.78              | 0.001 | 0.010 |
| GGTP (un/l)                        | 627.40±23.84              | 0.001 | 0.050 |
| LDH (ME)                           | 482.88±52.18              | 0.001 | 0.010 |
| Creatinine (mcmol/l)               | 0.21±0.06                 | 0.050 | -     |
| Urea (mol/l)                       | 9.60±1.20                 | 0.050 | -     |

### 3. THE BASIC IDEAS FOR TASK IMPLEMENTATION

Analysis of available medical software showed that developers are offered the following types of programs:

1. Programs in the first category are designed to maintain electronic document in a medical facility, the primary purpose of automation – is the task of shifting the doctors to work with electronic medical records. To a large extent, these programs represent an electronic storage of

medical records of patients, with the possibility of fast data processing and information search.

2. Maintenance programs of medical equipment is usually supplied with the devices themselves. The main objective of these programs is to preserve the results of the survey in a universal format for use in other medical systems.
3. Program directories, which are databases for different purposes: Reference drugs, disease guides for therapists general practitioners and specialized expertise.
4. 3D atlases used mainly for educational purposes.
5. Program for the diseases diagnosis.

Last fifth category of programs is one of the smallest in the group of medical software. Most programs are reference information systems for specific diseases. Among the available programs is not found program for screening of hepatorenal syndrome in alcohol abusers.

For the implementation intelligent information system based on a database, comprising a system of interconnected entities have been put forward the following objectives:

1. You need to create managed database, which should be provided for introducing new data, editing data stored.
2. The program should be a server application with a thick client. It can be used both on a single computer or on a local network.
3. The projected database should include several related entities:
  - general patient data;
  - test results;
  - list of medications;
  - list of medical institutions.
4. When filling in the listed entity created by the program must be able to organize the search for the following:
  - name and surname of the patient;
  - after processing of patient data;
  - Date entering the patient base.
5. Software product must process listed in the database of clinical trials results programmatically. In this case the problem of health worker in determining the syndrome will be minimized. The test results should entered and saved them. Everything else will make the program: analyze and process the data, identify the type of syndrome, if it is, compute the control coefficient for inspection and, if necessary, generate the necessary statistical report on patients. All this will help in the short term to diagnose the presence of symptoms and take timely action to treat because detection syndrome is a risk of death.

For realization of goals by selected software products must be nominated by a number of requirements:

- the use of a database located on a server and accessible to other users on the local network;
- create a product to be adapted for the operating system Windows, and Linux;
- database management system must carry large amounts of data storage;
- generated software product should be implemented based on the use of the available software tools.

Let us analyze the existing development tools. Initially, start with the programming language (Table 4).

**Table 4. The comparative characteristic of programming languages.**

| Language  | C# | Delphi | Java | Lazarus |
|---|----|--------|------|---------|
| Parameter   |    |        |      |         |
| free access                                       | -  | -      | +    | +       |
| cross-platform                                    | -  | -      | +    | +       |
| compile the application for each operating system |    |        | -    | +       |
| VM  | -  | -      | +    | -       |
| a wide range of features                          | +  | +      | +    | +       |

Now, consider a database management system – DBMS (Table 5).

**Table 5. The comparative characteristic the DBMS.**

| DBMS                                   | Access | Firebird | MySQL | Oracle |
|--|--------|----------|-------|--------|
| Parameter                              |        |          |       |        |
| free access                            | -      | +        | +     | -      |
| cross-platform                         | -      | +        | +     | +      |
| client-server system                   | -      | +        | +     | +      |
| ability to store large volumes of data | -      | +        | +     | +      |
| small size distribution                | -      | +        | -     | -      |

Based on this analysis of existing software products on the market to achieve this goal will create a desktop-based application on the following technologies:

- Programming language – Java;
- Application Programming Interface (Eng. Application Programming Interface – API) – Swing;
- database management system (DBMS) – Firebird.

Desktop-application will run on a "client-server", in other words, will be created "server application with a thick client."

Concerning the design of the user interface, the software product will be used NimbusLookAndFeel,

proposed by developers Java. Nimbus – a standard design in Swing. All that is necessary for its use is JDK (or JRE). No additional libraries are not required, as all classes are within Java.

#### 4. THE PROGRAM «HEPATORENAL SYNDROMES CREENING»

There are the various programs automating a workplace for the health workers, but computer analogues for diagnostics hepatorenal syndrome isn't developed yet. The revealed theoretical aspects of syndrome definition, significant indices, on which basis it is necessary to define syndrome presence, have been used by engineering of the computer program.

The program «Hepatorenal syndrome screening» is developed on the basis of platform Java SE [7] and database management system Firebird [8] and represents the client-server application.

The software product is developed for data processing optimisation, received as a medical examination result of the patient to reveal at abusers hepatorenal syndrome and definition of its type (I or II type). It possesses the simple and friendly interface that allows any medical worker (to the nurse, the laboratorian, the doctor) to use it in the presence of access to the application.

The program allows:

- to create the patient database, containing the general information, results clinical and biochemical indices of research, data on its hospitalisation, the assigned a medical preparations to a patient for treatment, type hepatorenal syndrome (at its presence);
- to generate reports for statistics about how many patients have I or II type hepatorenal syndrome, reports on the surveyed patients for the certain period.

The user interface workstation health worker in order to conduct screening of hepatorenal syndrome is needed to create a database of patients, detect the presence of the syndrome and the assignment necessary treatment and management of the medical history of these patients. At program startup (double-click the mouse on the file medicalARM.jar) login window appears. To access the application enter a user name and password.

After successful authorization, shows the main window of the application, which consists of three main parts: the top menu, search filter patients and patients list (Fig. 1).

The top menu allows you to exit the program automatically generate different types of reports, edit the list of medications prescribed for the treatment, edit the list of medical institutions, hospitalized patients, edit accounts for access to the application

(add and remove users) to obtain information about the program, including guidance on the use. "Patients filter" allows you to work with an existing database, search by various parameters such as: name, patient name, date of making it to the database, the type of syndrome. The search can be carried out both on one and on several parameters by clicking the "Apply Filter". "Patient List" allows you to view a list of all patients registered in the database, a list of patients that meet the search parameters, and also includes the ability to add a new patient.

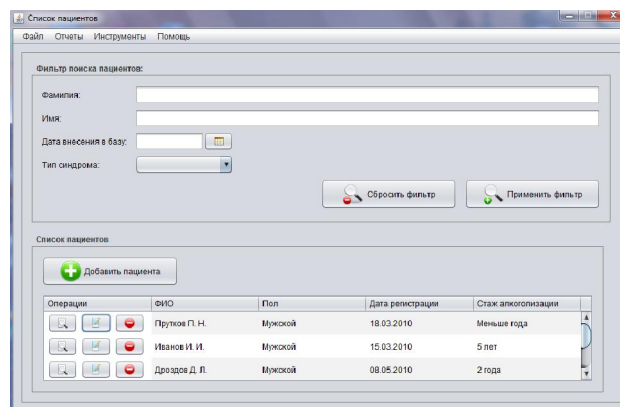


Fig. 1 – The program main window.

For example, a search for the type of syndrome. To do this, select from the drop down list "syndrome type I" and click "Apply Filter". In the lower section displays a list of patients with syndrome of the first type (Fig. 2).

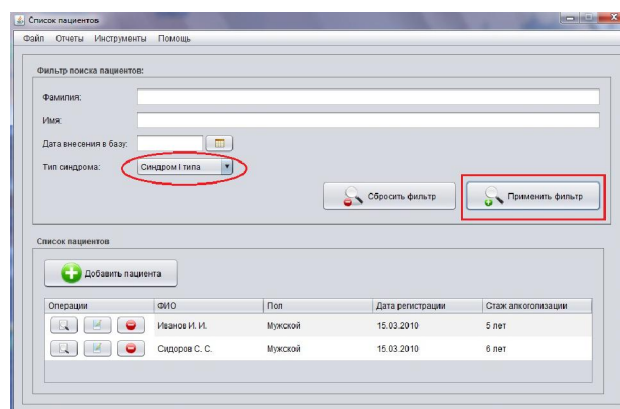


Fig. 2 – Filter usage.

Selecting the exact in the list of patients a particular patient, we can view detailed information about a given patient, edit information about it, or remove the patient from the database by using the corresponding buttons located on the left (Fig. 3). In order to avoid accidental deletion of a patient when you click on the "delete" a warning message stating that the patient will be removed from the database.



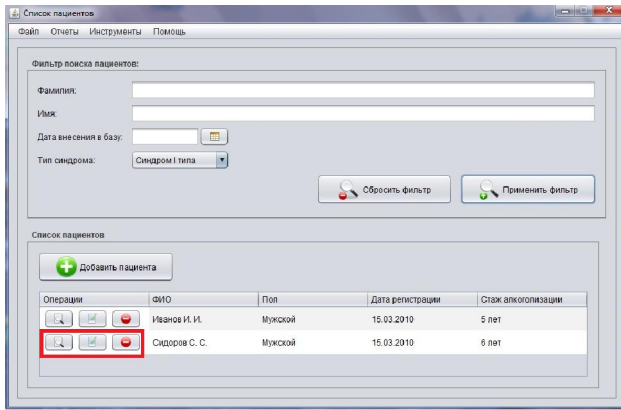


Fig. 3 – Work with patients data.

Furthermore, we can add a new patient to the database. To do this, click in main window, click "Add Patient" and a new form is appear (Fig. 4). Mandatory fields are the following fields: name, surname, patronymic patient, date of birth and the beginning of the abuse of alcohol. After you enter general information about the patient presses the button "Save". The patient will be saved in a database, entering basic data about a patient is inactive block of additional data about the patient, in which you enter the test results, the periods of hospitalization and prescribed medication for treatment.

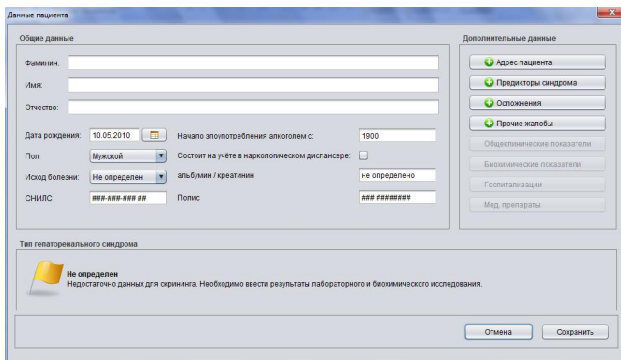


Fig. 4 – Adding the new patient at data base.

They will be active and available to fill only after saving the patient in the database. Type hepatorenal syndrome in this case is defined as sufficient data for screening must enter the results of biochemical and general clinical research. After the patient has been added to the database, we go back to the data of the patient and is able to enter the results of the analyzes (Fig. 5). Enter a general clinical results (Fig. 6).

Then enter the results of biochemical studies (Fig. 7). After entering the results common clinical and biochemical research press "Save" button, the program goes back to the original window, now if you view the data of the patient, it is already in the database to store information about the presence or absence of symptoms. As soon as you save the

program on the basis of the input data determines the diagnosis and calculates the control factor – the ratio of albumin to creatinine (Fig. 8).

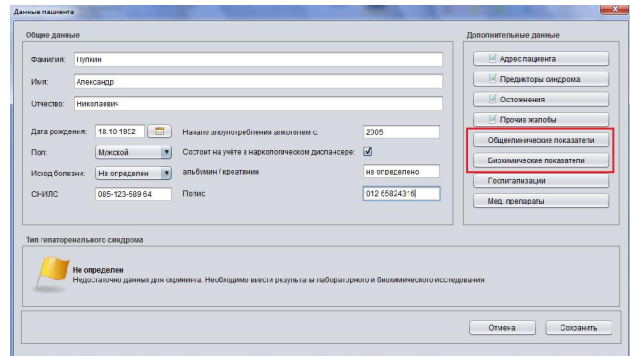


Fig. 5 – Saved in a patient database.

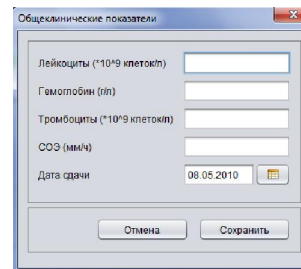


Fig. 6 – Enter the results of routine clinical research.

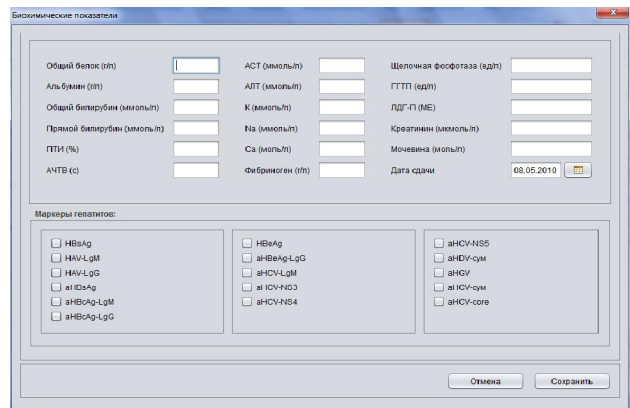


Fig. 7 – Enter the results of biochemical research.

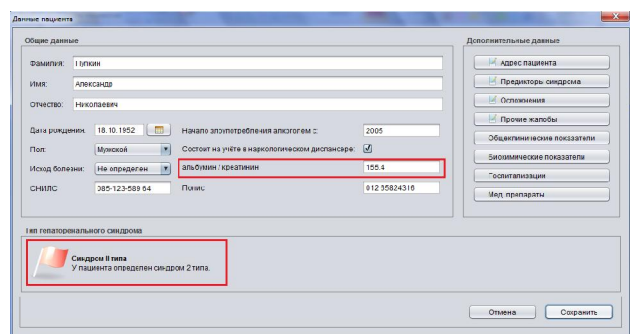


Fig. 8 – Result of determining the syndrome.

In the event that the patient will pass re-analysis, it is also capable of being added to the existing patient in the database, using the "Add results." All

added results will be displayed as a separate line, which at any moment, you can view (Fig. 9).

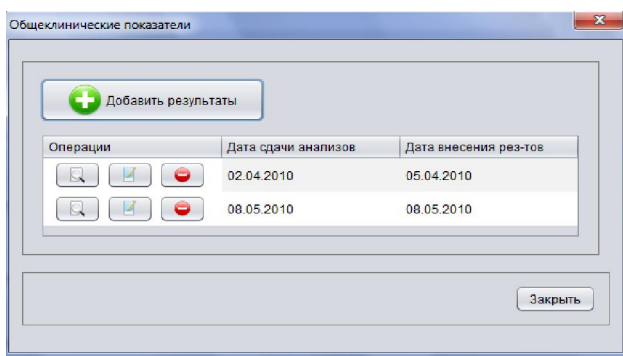


Fig. 9 – Displays in database test results.

And then, the program will again handle the data you entered, and on the basis of recent results to determine the syndrome. When it detects the syndrome in a patient, it should be appropriate treatment. Push the button "Med. drugs." There is a new form (Fig. 10). Push the button "appoint drug" and there is another form of "Appointment of medical drug" (Fig. 11). To select the name of the drug right click "...". The button. medication editor is (Fig. 12), which clicking on "+" button, select the appropriate drug. It will automatically appear in the first box, then fill the dose, date of start and end of the reception, the multiplicity of reception and if necessary any notes. And click "Save."

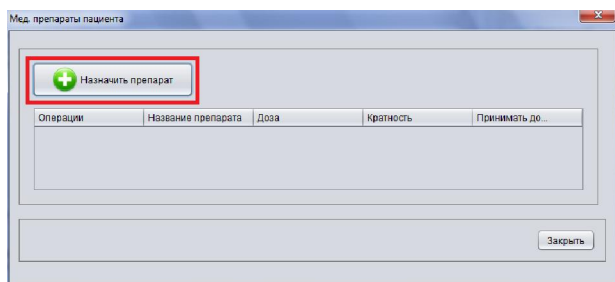


Fig. 10 – Medical drugs.

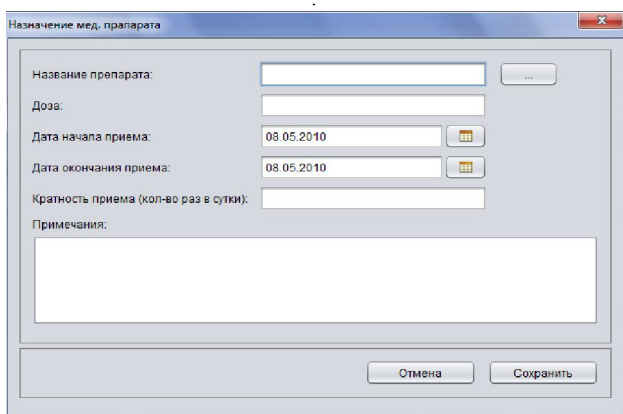


Fig. 11 – Medical drugs appointment.

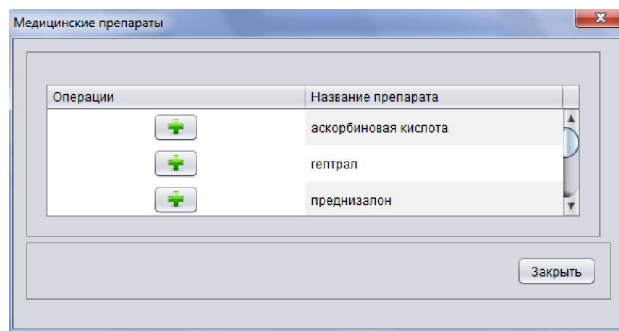


Fig. 12 – Editor medical products.

Analogously entered and other medical drugs, you can type several (Fig. 13). If the patient was hospitalized, all hospital admissions, we can also add to the database. Push in the data about the patient the "Hospitalization" and a new form (Fig. 14).

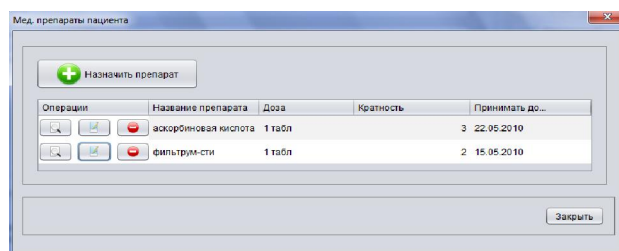


Fig. 13 – List of medical drugs prescribed to patient.

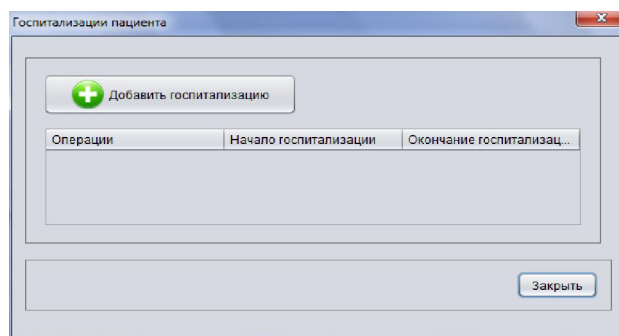


Fig. 14 – Hospitalizations.

Then, similarly as in the case of medical preparations click the 'Add hospitalization.' There is a new form in which we introduce the beginning, the end of hospitalization and place. Place of hospitalization is introduced as a medicine with an editor of medical institutions (Fig. 15). And it is obligatory click the button "Save". If necessary, management reporting and statistics, we can generate and store various types of reports using the top menu tab (Fig. 16).

For example, generate a report, "Patients with the syndrome of the second type." To do this, select the appropriate type of report from the top menu. Before us, a dialog box to save the file (Fig. 17). By default, all reports are saved in a special folder reports,

inside the folder with the software product itself. However, you can choose any way save the file on your hard disk. After selecting the path to the File Name field in specify the file name. All saved files will have the extension txt, which can be viewed by using Notepad.

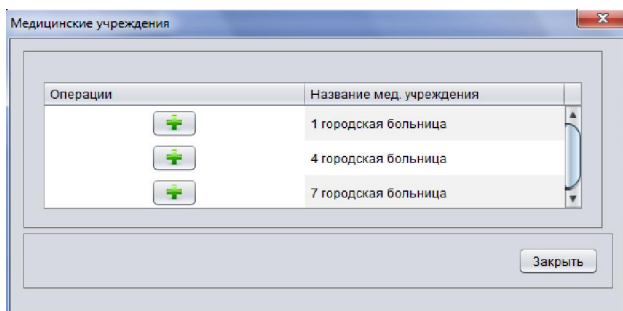


Fig. 15 – Editor of medical institutions.

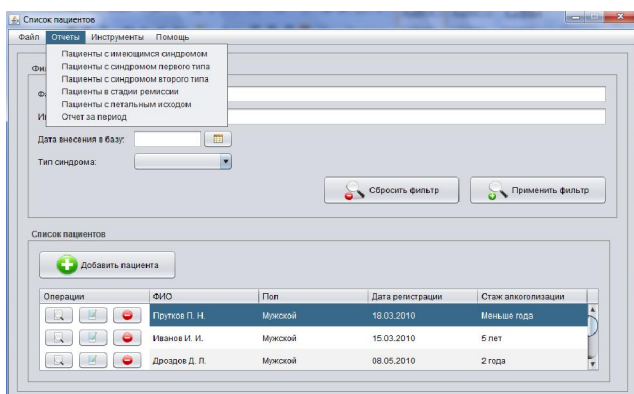


Fig. 16 – Report types.

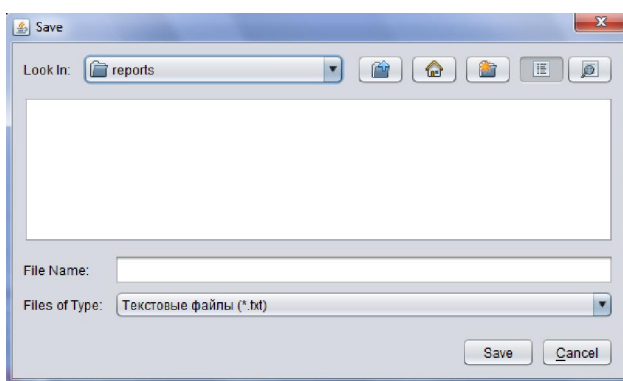


Fig. 17 – The dialog box for saving the report

After pressing the «Save» the message that if we want to see now generated report.

## 5. TESTING RESULTS OF THE STUDY

At the completion of the software product was conducted its testing for the detection and subsequent troubleshooting [5].

Testing included the following items:

1. Testing functional requirements.

Developed product many times progressively elaborated considering insertion adjustments. Therefore, this product fully meets its functional requirements.

2. Testing the user interface.

This application has a friendly interface, the most convenient and intuitive for the user.

3. Testing of individual modules.

Special attention was given to check the correct operation of individual software modules of the product. In particular, the definition of the type of hepatorenal syndrome, report generation, the addition of the patient base, working with editors accounts, medicines and medical facilities.

4. Comprehensive testing.

In addition to individual modules conducted a comprehensive testing of client – server architecture program at a medical facility in Arkhangelsk.

5. Testing rate system boot.

During testing, it was found that the download speed of the system is optimal.

6. Testing boundary conditions.

Testing was performed in the presence of program behavior in determining the boundary condition types syndrome. Upon detection of the syndrome and its type definition is an odd number of significant figures, which do not lead to problems and errors in the data and, ultimately, still based on the results of analyzes will overbalance toward the first or second type.

Testing in the presence of large amounts of information (congestion).

During testing, it was found that for large flows of information the program works without any time delay.

Tests were carried out Arkhangelsk City Clinical Hospital № 1. Data are presented in Table 6.

Table 6. Data Tests Arkhangelsk City Clinical Hospital № 1.

| № | Parameter   | Control group | Experimental group |
|---|---|---------------|--------------------|
| 1 | Patients number   | 46            | 46                 |
| 2 | Patients number with hepatorenal syndrome identified                  | 18            | 21                 |
| 3 | The time spent on entering data into the program (h)                  | 0             | 23                 |
| 4 | Time spent processing the data in one patient (h)                     | 138           | 18,4               |
| 5 | Number of doctors (including specialists)                             | 3 (3)         | 2 (1)              |
| 6 | Level of satisfaction with their work specialists                     | 63%           | 86%                |
| 6 | patients number with detected hepatorenal syndrome while revalidating | 19            | 21                 |

Testing has shown that the time of diagnosis was reduced in comparison with traditional methods at 69 %, with fewer specialists, while job satisfaction of physicians increased by 23 %. Diagnostic accuracy hepatorenal syndrome is not dependent on the method of diagnosis.

## 6. CONCLUSION

Creation of the software product is the important stage in hepatorenal syndrome screening. The developed application will allow without special work even in absence of the doctor-expert to define syndrome presence or absence. Besides, the program will cut time for definition and syndrome revealing by a manual method, the costs connected with inspection.

Free software, crossplatform, sufficient simplicity and reliability are the main advantages of the software product. Program approbation is successfully spent in hospitals of Arkhangelsk. The primary tasks put at the very beginning of work are executed.

Tests were carried out Arkhangelsk City Clinical Hospital № 1. Testing has shown that the time of diagnosis was reduced in comparison with traditional methods at 69 %, with fewer specialists, while job satisfaction of physicians increased by 23 %. Diagnostic accuracy hepatorenal syndrome is not dependent on the method of diagnosis. Testing program showed that the data that gives our program coincide with those of health professionals.

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**Yuriy Kondratenko, Volodymyr Korobko, Oleksiy Korobko, Oleksiy Moskovko. Design of the Fuzzy Control System for the Waste Heat Utilization Plants Driven by the Thermoacoustic Engine, *International Journal of Computing*, Vol. 13, Issue 2, 2014, pp. 88-96.**

The paper addresses the synthesis of fuzzy controllers for computerized control system of the waste heat energy (WHE) utilization plants that operate with a thermoacoustic engine (TAE). Based on the analysis of existing systems, the authors present the main tasks of the synthesized control system, describe its structure and main components. Created system is then tested on the experimental thermoacoustic installation. Using the obtained experimental data, the authors synthesize the mathematical model of the thermoacoustic plant and describe the methodology of its control by the adjustments in resonator length of the thermoacoustic device. Using the suggested approach the authors design a number of conventional discrete and fuzzy controllers and provide the comparative analysis of quality indicators of transient responses of the designed control systems.

**S. P. Malarvizhi, B. Sathiyabhama. Enhanced Reconfigurable Weighted Association Rule Mining for Frequent Patterns of Web Logs, *International Journal of Computing*, Vol. 13, Issue 2, 2014, pp. 97-105.**

Systolic tree structure is a reconfigurable architecture in field-programmable gate arrays which provide performance advantages. It is used for frequent pattern mining operations. High throughput and cost effective performance are the highlights of the systolic tree based reconfigurable architecture. Frequent pattern mining algorithms are used to find frequently occurring item sets in databases. However, space and computational time requirements are very high in frequent pattern mining algorithms. In the proposed system, systolic tree based hardware mechanism is employed with Weighted Association Rule Mining (WARM) for frequent item set extraction process of the Web access logs. Weighted rule mining is to mine the items which are assigned with weights based on user's interest and the importance of the items. In the proposed system, weights are assigned automatically to Web pages that are visited by the users. Hence, systolic tree based rule mining scheme is enhanced for WARM process, which fetches the frequently accessed Web pages with weight values. The dynamic Web page weight assignment scheme uses the page request count and span time values. The proposed system improves the weight estimation process with span time, request count and access sequence details. The user interest based page weight is used to extract the frequent item sets. The proposed system will also improve the mining efficiency on sparse patterns. The goal is to drive the mining focus to those significant relationships involving items with significant weights.

**Ontje Helmich, Michael A. Herzog, Christian Neumann. Seamless and Secure Integration of Social Media, E-Portfolio and Alumni Services into University Information Architecture, *International Journal of Computing*, Vol. 13, Issue 2, 2014, pp. 106-115.**

This document describes the concept and prototype for a lifelong accompanying portal to be used in higher education. Through the use of profiles, good usability and display of concentrated information students should be bound to the portal and university throughout their studies and their life.

The proposed solution to use Elgg as an information portal and social media platform bridges the gap between the closed nature of university IT infrastructure and user-friendly, communication enhancing advancements of state-of-the-art web applications.

**Di Zhao. Fast Solver for Interior Point Method of SVM Training by Parallel GMRES and HSS, *International Journal of Computing*, Vol. 13, Issue 2, 2014, pp. 116-124.**

Support Vector Machine (SVM) is one of the latest statistical models for machine learning. The key problem of SVM training is an optimization problem (mainly Quadratic Programming). Interior Point Method (IPM) is one of mainstream methods to solve Quadratic Programming problem. However, when large-scale dataset is used in IPM-based SVM training, computational complexity happens because of computationally expensive matrix operations. Preconditioner, such as Cholesky factorization (CF), incomplete Cholesky factorization and Kronecker factorization, is an effective approach to decrease time complexity of IPM-based SVM training. In this paper, we reform SVM training into the saddle point problem. By parallel GMRES and recently developed preconditioner Hermitian/Skew-Hermitian Separation (HSS), we develop a fast solver HSS-pGMRES-IPM for the saddle point problem from SVM training. Computational results show that, the fast solver HSS-pGMRES-IPM significantly increases the solution speed for the saddle point problem from SVM training than the conventional solver CF.

**Omar S. Sonbul, Alexander N. Kalashnikov. Determining the Operating Distance of Air Ultrasound Range Finders: Calculations and Experiments, *International Journal of Computing*, Vol. 13, Issue 2, 2014, pp. 125-131.**

Estimating the operating distance of air ultrasound range finders by using the suitably modified radar equation and experimental verification of the developed computational procedure is discussed. It is shown that, despite notable differences between operating conditions of radars and air ultrasonic range finders, the radar equation is applicable to the considered case, and calculations of the relevant terms for this case are presented. The experimental assessment was carried out by evaluating the probability of detection at various distances from the custom built device. The calculated and experimental results seem to agree well despite using a number of values with high degree of uncertainty. The described procedure can be used at the design stage of air ultrasound range finders in order to reduce the number of prototypes before finalizing the design to a single prototype.

**Alexey Lagunov, Darina Lagunova, Irina Berdennikova. Cognitive System of the Hepatorenal Syndrome Screening in Persons with Alcohol Abuse, *International Journal of Computing*, Vol. 13, Issue 2, 2014, pp. 132-140.**

Increase of alcohol consumption is observed in all countries of the world. Over the past 20 years, consumption of alcohol correlated with the level of mortality from liver cirrhosis. Under the hepatorenal syndrome we understand the primary lesion of the liver with subsequent involvement of kidney tissue in the painful process. In order to detect hepatorenal syndrome in medical practice the screening of laboratory markers is used which carried out manually. The use of medical information system can significantly improve the process of disease detection in patients. To the best knowledge of the authors there is no an analogue of medical information system for the screening of hepatorenal syndrome. The analysis of the process of screening of laboratory markers of hepatorenal syndrome allowed to create a client-server intelligent information system based on the Java SE platform using the management database system Firebird. The tests were carried out in Arkhangelsk City Clinical Hospital No. 1. The testing has shown that the time of diagnosis was reduced in comparison with traditional methods to 69% with the use of fewer specialists, while job satisfaction of physicians increased on 23%. The diagnostic accuracy of hepatorenal syndrome doesn't depend on the method of diagnosis. The testing of our software has showed that our results coincide with those of health professionals.

**Юрій Кондратенко, Володимир Коробко, Олексій Коробко, Олексій Московко.** Розробка нечіткої системи управління установкою утилізації вторинних енергоресурсів на основі термоакустичного двигуна, *Міжнародний журнал «Комп'ютинг»*, том. 13, випуск 2, 2014, с. 88-96.

Дана робота присвячена синтезу нечітких контролерів для комп'ютерної системи управління установкою утилізації вторинних енергоресурсів, яка приводиться в дію термоакустичним двигуном (ТАД). На основі аналізу існуючих систем, авторами сформульовані основні завдання синтезованої системи управління, описана її структура та основні компоненти. Розроблена система випробувана на базі експериментальної термоакустичної установки. Використовуючи отримані експериментальні дані, авторами синтезовано математичну модель термоакустичної установки та розроблено метод керування нею шляхом зміни довжини резонатора ТАД. Використовуючи запропонований підхід, авторами створено ряд дискретних і нечітких контролерів та проведено їх порівняльний аналіз, що базується на порівнянні показників якості перехідних процесів проєктованих систем управління.

**S. P. Malarvizhi, B. Sathiyabhama.** Покращена зважена підтримка асоціативних правил для частотних моделей веб журналів, *Міжнародний журнал «Комп'ютинг»*, том. 13, випуск 2, 2014, с. 97-105.

Систолічна деревовидна структура є архітектурою із змінною конфігурацією на базі програмованих логічних матриць, які мають високу продуктивність. Вона використовується для частих операцій добування образів. Висока пропускна здатність і рентабельна продуктивність є основними перевагами систолічної деревовидної структури на основі даної архітектури. Часті алгоритми добування образів використовуються для пошуку компонентів, що часто зустрічаються в базах даних. Тим не менш, вимоги простору та обчислювального часу є досить високими в частих алгоритмах добування образів. У запропонованій системі, систолічне дерево на основі апаратного забезпечення використовується із методологією зваженого асоціативного правила добування (ЗАПД) для отримання елементів, що часто зустрічаються в журналах веб-доступу. Зважені правила добування враховують інтереси користувача і важливість елементів. У запропонованій системі, вагові коефіцієнти автоматично присвоюються веб-сторінкам, які відвідують користувачі. Отже, систолічна деревовидна структура на основі схеми правила добування покращується для ЗАПД процесу, який вибирає часто використовувані веб-сторінки з ваговими коефіцієнтами. Схема присвоєння динамічній веб-сторінці вагового коефіцієнту використовує кількість запитів сторінки та час, на протязі якого ці запити відбувались. Запропонована система покращує визначення вагових коефіцієнтів на основі часових витрат, числа запитів та деталей послідовності доступу. Ваговий коефіцієнт відвідування сторінки використовується для знаходження набору найбільш часто використовуваних елементів. Запропонована система також підвищить ефективність добування рідкісних образів. Метою є здійснення добування образів з урахуванням елементів, що мають високі вагові коефіцієнти.

**Ontje Helmich, Michael A. Herzog, Christian Neumann.** Нескладне та безпечне впровадження послуг SocialMedia, E-Portfolio і Alumni в університетську інформаційну архітектуру, *Міжнародний журнал «Комп'ютинг»*, том. 13, випуск 2, 2014, с. 106-115.

Стаття описує концепцію і прототип довготривалого супровідного порталу, який буде використовуватися в системі вищої освіти. Завдяки використанню профілів, зручному користуванню та представленню необхідної інформації, студенти будуть «прив'язані» до порталу та університету протягом усього їхнього навчання і життя.

Пропозиція використовувати Elgg як інформаційний портал та соціальну медіа-платформу усуває закритий характер університетської IT-інфраструктури та є зручним у користуванні комунікаційним рішенням в найсучасніших веб-додатках.

**Di Zhao.** Швидкий вирішувач для методу внутрішньої точки для навчання машини опорних векторів за допомогою паралельних методів GMRES і HSS, *Міжнародний журнал «Комп'ютинг»*, том. 13, випуск 2, 2014, с. 116-124.

Машина опорних векторів (SVM) є однією з сучасних статистичних моделей для машинного навчання. Ключовою проблемою навчання SVM є задача оптимізації (в основному квадратичного програмування). Метод внутрішньої точки (IPM) є одним з основних методів вирішення задачі квадратичного програмування. Однак, коли в основі IPM-навчання машини опорних векторів

використовується великий набір даних, то обчислювальна складність зростає через складні матричні операції. Попередні умови, розкладання Холецкого (CF), неповне розкладання Холецкого і розкладання Кронекера, є ефективними підходами до зменшення часової складності IPM при навчанні машини опорних векторів. У цій статті навчання SVM зводиться до пошуку сідлової точки. За допомогою паралельних методів GMRES і нещодавно розроблених попередніх умов – ермітових / косоермітових методів розділення (HSS), ми розробили швидкий вирішувач HSS-pGMRES-IPM для проблеми пошуку сідлової точки при навчанні SVM. Результати розрахунків показують, що швидкий вирішувач HSS-pGMRES-IPM дозволяє істотно підвищити швидкість вирішення задачі пошуку сідлової точки при навчанні SVM, ніж звичайне розкладання Холецкого.

**Omar S. Sonbul, Alexander N. Kalashnikov. Визначення відстані дії повітряних ультразвукових далекомірів: розрахунки та експерименти, *Міжнародний журнал «Комп'ютинг»*, том. 13, випуск 2, 2014, с. 125-131.**

Представлено оцінку робочої відстані дії повітряних ультразвукових далекомірів за допомогою відповідним чином модифікованих радіолокаційних розрахунків та експериментальної перевірки розробленої обчислювальної процедури. Показано, що, незважаючи на помітні відмінності між умовами роботи радарів і ультразвукових повітряних далекомірів, рівняння радару у даному випадку є придатним, і представлено розрахунки відповідних величин. Експериментальна оцінка проводилася шляхом оцінки ймовірності визначення різних відстаней індивідуально виготовленим пристроєм. Розрахункові та експериментальні результати збігаються, незважаючи на використання ряду значень з високим ступенем невизначеності. Описана процедура може бути використана на стадії проектування ультразвукових повітряних далекомірів для того, щоб зменшити кількість прототипів до одного ще перед завершенням проектування.

**Олексій Лагунов, Дарина Лагунова, Ірина Берденнікова. Когнітивна система обстеження гепаторенального синдрому в осіб з алкогольною залежністю, *Міжнародний журнал «Комп'ютинг»*, том. 13, випуск 2, 2014, с. 132-140.**

Збільшення споживання алкоголю спостерігається в усіх країнах світу. За останні 20 років споживання алкоголю корелює з рівнем смертності від цирозу печінки. Під гепаторенальним синдромом розуміють первинне ураження печінки з наступним залученням у хворобливий процес ниркової тканини. Для виявлення гепаторенального синдрому в медичній практиці використовують перевірку лабораторних маркерів, яка проводиться вручну. Впровадження медичної інформаційної системи може значно поліпшити процес виявлення захворювання у пацієнтів. Автори не змогли знайти аналог медичної інформаційної системи – обстеження гепаторенального синдрому. На основі аналізу процесу перевірки лабораторних маркерів гепаторенального синдрому створено клієнт-сервер інтелектуальної інформаційної системи на базі платформи Java SE, використовуючи системи управління базами даних Firebird. Випробування проводилися на базі Архангельської міської клінічної лікарні № 1. Тестування показало, що час обстеження скоротився в порівнянні з традиційними методами на 69% при зайнятості меншої кількості фахівців, в той час як задоволеність роботою лікарів збільшилася на 23%. Діагностична точність виявлення гепаторенального синдрому не залежить від методу діагностики. Тестування програми показало, що отримані результати збігаються з результатами спеціалістів у сфері охорони здоров'я.



**Юрий Кондратенко, Владимир Коробко, Алексей Коробко, Алексей Московко.** Разработка нечеткой системы управления установкой утилизации вторичных энергоресурсов на основе термоакустического двигателя, *Международный журнал «Компьютинг»*, том. 13, выпуск 2, с. 88-96.

Данная работа посвящена синтезу нечетких контроллеров для компьютерной системы управления установкой утилизации вторичных энергоресурсов, приводимой в действие термоакустическим двигателем (ТАД). На основе анализа существующих систем, авторами сформулированы основные задачи синтезированной системы управления, описана ее структура и основные компоненты. Разработанная система испытана на базе экспериментальной термоакустической установки. Используя полученные экспериментальные данные, авторами синтезирована математическая модель термоакустической установки и разработан метод управления за счет изменения длины резонатора ТАД. Используя предложенный подход, авторами создан ряд дискретных и нечетких контроллеров и проведен их сравнительный анализ, основанный на сравнении показателей качества переходных процессов проектируемых систем управления.

**S. P. Malarvizhi, B. Sathiyabhama.** Улучшенная взвешенная поддержка ассоциативных правил для частотных моделей веб журналов, *Международный журнал «Компьютинг»*, том. 13, выпуск 2, с. 97-105.

Систолическая древовидная структура является архитектурой с изменяемой конфигурацией на базе программируемых логических матриц, которые имеют высокую производительность. Она используется для частых операций извлечения образов. Высокая пропускная способность и рентабельная производительность являются основными преимуществами систолической древовидной структуры на основе данной архитектуры. Частые алгоритмы извлечения образов используются для поиска компонентов, часто встречаются в базах данных. Тем не менее, требования пространства и вычислительного времени являются достаточно высокими в частых алгоритмах извлечения образов. В предлагаемой системе, систолическое дерево на основе аппаратного обеспечения используется с методологией взвешенного ассоциативного правила добычи (ВАПД) для получения элементов, часто встречающихся в журналах веб-доступа. Взвешенные правила добывания учитывают интересы пользователя и важность элементов. В предлагаемой системе, весовые коэффициенты автоматически присваиваются веб-страницам, которые посещают пользователи. Итак, систолическая древовидная структура на основе схемы правила добывания улучшается для ВАПД процесса, который выбирает часто используемые веб-страницы с весовыми коэффициентами. Схема присвоения динамической веб-странице весового коэффициента использует количество запросов страницы и время, в течение которого эти запросы происходили. Предложенная система улучшает определения весовых коэффициентов на основе временных затрат, числа запросов и деталей последовательности доступа. Весовой коэффициент посещения страницы используется для нахождения набора наиболее часто используемых элементов. Предложенная система также повысит эффективность добычи редких образов. Целью является осуществление добычи образов на основе элементов, имеющих высокие весовые коэффициенты.

**Ontje Helmich, Michael A. Herzog, Christian Neumann.** Несложное и безопасное внедрение услуг SocialMedia, E-Portfolio и Alumni в университетскую информационную архитектуру, *Международный журнал «Компьютинг»*, том. 13, выпуск 2, с. 106-115.

Статья описывает концепцию и прототип длительного сопроводительного портала, который будет использоваться в системе высшего образования. Благодаря использованию профилей, удобному пользованию и представлению необходимой информации, студенты будут «привязаны» к portalу и университета в течение всего их обучения и жизни.

Предложение использовать Elgg как информационный портал и социальную медиа-платформу устраняет закрытый характер университетской ИТ-инфраструктуры и удобен в пользовании коммуникационным решением в современных веб-приложениях.

**Di Zhao.** Быстрый решатель для метода внутренней точки для обучения машины опорных векторов с помощью параллельных методов GMRES и HSS, *Международный журнал «Компьютинг»*, том. 13, выпуск 2, с. 116-124.

Машина опорных векторов (SVM) является одной из современных статистических моделей для машинного обучения. Ключевой проблемой обучения SVM является задача оптимизации (в основном

квадратичного программирования). Метод внутренней точки (ИПМ) является одним из основных методов решения задачи квадратичного программирования. Однако, когда в основе ИПМ-обучение машины опорных векторов используется большой набор данных, то вычислительная сложность возрастает через сложные матричные операции. Предварительные условия, разложение Холецкого (CF), неполное разложение Холецкого и разложения Кронекера, являются эффективными подходами к уменьшению временной сложности ИПМ при обучении машины опорных векторов. В этой статье обучения SVM сводится к поиску седловой точки. С помощью параллельных методов GMRES и недавно разработанных предварительных условий – эрмитовых / косоэрмитовых методов разделения (HSS), мы разработали быстрый решатель HSS-pGMRES-ИПМ для проблемы поиска седловой точки при обучении SVM. Результаты расчетов показывают, что быстрый решатель HSS-pGMRES-ИПМ позволяет существенно повысить скорость решения задачи поиска седловой точки при обучении SVM, чем обычное разложение Холецкого.

**Omar S. Sonbul, Alexander N. Kalashnikov. Определение расстояния действия воздушных ультразвуковых дальномеров: расчеты и эксперименты, *Международный журнал «Компьютинг»*, том. 13, выпуск 2, с. 125-131.**

Представлена оценка рабочего расстояния действия воздушных ультразвуковых дальномеров с помощью соответствующим образом модифицированных радиолокационных расчетов и экспериментальной проверки разработанной вычислительной процедуры. Показано, что, несмотря на заметные различия между условиями работы радаров и ультразвуковых воздушных дальномеров, уравнение радара в данном случае является подходящим, и представлены расчеты соответствующих величин. Экспериментальная оценка проводилась путем оценки вероятности определения дальности на разных расстояниях индивидуально изготовленным устройством. Расчетные и экспериментальные результаты, сходятся, несмотря на использование ряда значений с высокой степенью неопределенности. Описанная процедура может быть использована на стадии проектирования ультразвуковых воздушных дальномеров для того, чтобы уменьшить количество прототипов до одного прототипа еще перед завершением проектирования.

**Алексей Лагунов, Дарина Лагунова, Ирина Берденникова. Когнитивная система обследования гепаторенального синдрома у лиц с алкогольной зависимостью, *Международный журнал «Компьютинг»*, том. 13, выпуск 2, с. 132-140.**

Увеличение потребления алкоголя наблюдается во всех странах мира. За последние 20 лет потребление алкоголя коррелирует с уровнем смертности от цирроза печени. Под гепаторенальный синдромом понимают первичное поражение печени с последующим вовлечением в болезненный процесс почечной ткани. Для выявления гепаторенального синдрома в медицинской практике используют проверку лабораторных маркеров, которая проводится вручную. Внедрение медицинской информационной системы может значительно улучшить процесс выявления заболевания у пациентов. Авторы не смогли найти аналог медицинской информационной системы – обследование гепаторенального синдрома. На основе анализа процесса проверки лабораторных маркеров гепаторенального синдрома создан клиент-сервер интеллектуальной информационной системы на базе платформы Java SE, используя системы управления базами данных Firebird. Испытания проводились на базе Архангельской городской клинической больницы № 1. Тестирование показало, что при обследовании сократился по сравнению с традиционными методами на 69% при занятости меньшего количества специалистов, в то время как удовлетворенность работой врачей увеличилась на 23%. Диагностическая точность выявления гепаторенального синдрома не зависит от метода диагностики. Тестирование программы показало, что полученные результаты совпадают с результатами специалистов в сфере здравоохранения.

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- [4] Chu-Hsing Lin, Jung-Chun Liu and Chun-Wei Liao, Energy analysis of multimedia video decoding on mobile handheld devices, 2007 International Conference on Multimedia and Ubiquitous Engineering, Seoul, Korea (April 26-28, 2007), pp. 120-125.

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- [5] I. M. Martin, M. A. Alves, G. G. Peixoto and M. C. Rezende, Radar cross section measurements and simulations of a model airplane in the X-band, Piers Online, (4) 5 (2009), pp. 377-380, available online on [www.example.com/martin.pdf](http://www.example.com/martin.pdf), accessed June 2010.

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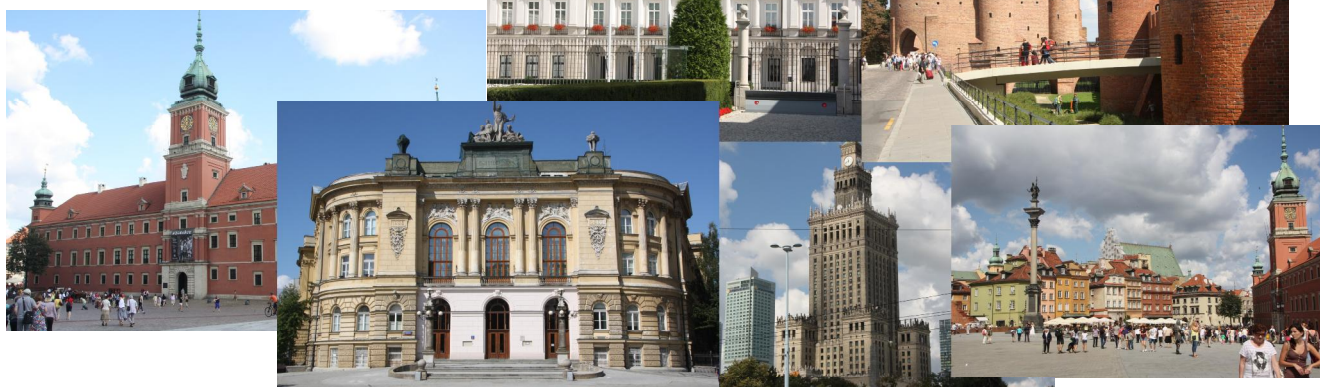
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#### Tentative Streams and Topics

The conference scope includes, but it's not limited to:

1. Special Stream in Wireless Systems
2. Special Stream in Project Management
3. Special Stream in Cyber Security
4. Special Stream in High Performance Computing
5. Special Stream in eLearning Management
6. Special Stream in Advanced Information Technologies in Ecology
7. Special Stream in Intelligent Robotics and Components
8. Advanced Instrumentation and Data Acquisition Systems
9. Advanced Mathematical Methods for Data Acquisition and Computing Systems
10. Artificial Intelligence and Neural Networks for Advanced Data Acquisition and Computing Systems
11. Bio-Informatics
12. Software Tools and Environments
13. Data Analysis and Modeling
14. Embedded Systems
15. Information Computing Systems for Education and Commercial Applications
16. Intelligent Distributed Systems and Remote Control
17. Intelligent Information Systems, Data Mining and Ontology
18. Intelligent Testing and Diagnostics of Computing Systems
19. Internet of Things
20. Pattern Recognition and Digital Image and Signal Processing
21. Virtual Instrumentation Systems

It's our pleasure to invite the interested scientists to organize own Streams.



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