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Conflicts of Interest

The author declares no conflict of interest.

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Arduino Sensor Integrated Drone for Weather Indices: A Prototype for Pre-flight Preparation

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Abstract: Commercial weather stations can effectively collect weather data for a specified area. However, their ground sensors limit the amount of data that can be logged, thus failing to collect precise meteorological data in a local area such as a micro-scale region. This happens because weather conditions at a micro-scale region can vary greatly even with small altitude changes. For now, drone operators must check the local weather conditions to ensure a safe and successful flight. This task is often a part of pre-flight preparations. Since flight conditions (and most important flight safety) are greatly affected by weather, drone operators need a more accurate localized weather map reading for the flight area. In this paper, we present the **A**rduino **S**ensor **I**ntegrated **D**rone (ASID) with a built-in meteorological station that logs the weather conditions in the vertical area where the drone will be deployed. ASID is an autonomous drone-based system that monitors weather conditions for pre-flight preparation. The operation of the ASID system is based on the Arduino microcontroller running automatic flight profiles to record meteorological data such as temperature, barometric pressure, humidity, etc. The Arduino microcontroller also takes photos of the horizon for an objective assessment of the visibility, the base, and the number of clouds.

Keywords: Unmanned Aerial Vehicles; Drones; Arduino; Sensor; Weather data; Flight Level.

Introduction

Local meteorological conditions are usually assessed by a brief look at the sky. However, this is insufficient for optimal flight planning. Factors such as wind speed and temperature may vary with the altitude, and thus must be taken into account in all flights. Existing weather models have difficulty in predicting with accuracy local weather phenomena such as fog, high fog, and thunderstorms, due to insufficient coverage of measurement data in the mid and lower levels of the atmosphere [9]. Pre-flight preparation is required for all flights. One stage of pre-flight preparation is *Weather Briefing* that involves determining forecast and actual weather conditions for the route planned and for selected airfields along the route. En-route weather comprises forecast winds and temperatures at cruising levels along the route together with forecasts of en-route weather conditions, especially cloud conditions, and any associated turbulence and/or icing. This information is depicted on special charts. In an airport, one task of pre-flight preparation is to monitor weather conditions because these can affect aviation. Weather conditions/variables in an airport can be prevailed by capturing special data through sensors and processing these data in a computer ground station. Such data are 1) wind direction and intensity; 2) freezing level; 3) dew point; 4) barometric pressure; 5) cloud base and roof; 6) quantity of clouds; 7) discomfort index; 8) visibility; and 9) temperature. The monitoring of weather data can give vivid and exact information for pre-flight purposes and goes beyond weather stations. An Unmanned Aerial Vehicle (UAV a.k.a. drone) equipped with sensors can measure selected meteorological parameters and its current position. In this sense,

drones can be exploited during the pre-flight preparation process [17].

Nowadays, the development of drone capabilities has disseminated its influence in many domains, such as defense, search and rescue, agriculture, manufacturing, healthcare services [8], vacant parking space detection [13], and environmental surveillance to execute complex industrial functions [1][7]. Mao et al. [9] presented the Smart Arduino Drone that monitors the weather conditions on a rice field, tea farm, maize, or vegetable fields as these crops require different conditions for optimal productivity. Also, drones have been used to investigate microclimate variation at a small scale and from a pedestrian perspective in urban landscapes [14]. Urban landscapes are strongly characterized by a high level of heterogeneity and complex morphology. This characteristic is responsible for the diversification of microclimate conditions even within the same city and not only by comparing urban conditions and rural surroundings.

In this paper, we present an innovative drone-based system specifically designed for monitoring weather conditions at a microclimate scale. The newly developed system is called *Arduino Sensor Integrated Drone* (ASID) and logs weather variables such as temperature, and humidity and captures images of the horizon in different altitudes. The weather data are synchronized to a ground computer station and are displayed to the user through an application programmed.

RELATED WORK

As part of pre-flight preparations, drone operators must check the local weather conditions to ensure a safe and successful flight. While commercial weather stations can effectively collect data for a specified area at the macro-scale, weather conditions in that area at the micro-scale can vary greatly. Since flight conditions can be greatly affected by weather conditions, drone operators need a more accurate localized weather map reading for the area of flight. Maurer et al. [10] proposed the *Weather Box* that creates such a localized map in a network of battery-powered sensor modules to provide drone users with the required information via a website and application. This product allows operators to quickly decide whether the conditions are suitable for a safe drone flight.

Many Radiosonde instruments also measure meteorological parameters such as air pressure, temperature, and humidity [3]. The most famous instruments are the VIZ; Space Data Corp.; Chinese GZZ; Japanese RS2-80; Russian RKZ, MARS, and A-22; and Vaisala RS80, RS 12/15, and RS18/21 radiosondes. These instruments have different error and response characteristics. A Radiosonde instrument is often carried by a free-flying balloon up to a height of about 30 km above sea level (asl). Every 30 secs, the measured values are transmitted to the aerological station using a shortwave transmitter. The measurements are carried out usually twice a day. The spatial resolution of the station's distribution is sparse, usually around 250 km or more in Europe [4].

Few studies consider how meteorological parameters can be sensed from a drone. These studies are mostly covering aspects related only to the wind [12][18]. Also, the drones were initially equipped with a single frequency GPS receiver for measuring the location of the drone. For example, the *Meteodrone* measures the meteorological parameters, wind, and position of a drone. The Meteodrone (www.meteomatics.com) is equipped with sensors that measure temperature, wind speed, wind direction, dew point temperature, relative humidity, and air pressure with a sampling rate of 250 ms [19]. The drone size is 70cm x 70cm and its weight is about 1.5 Kg. The maximum climb rate is 10 m/sec, and the theoretical maximum altitude is 3 km above the ground. The drone has a Beyond Visual Line-Of-Sight (BVLOS) permission issued by the Federal Office of Civil Aviation (FOCA), which means that it can fly within clouds and in fog. The Meteodrone has a water-resistant certificate IP64, and thus, it is also capable of flying in the rain. The main limitation is the severe wind: the drone cannot be operated with wind exceeding 50 km/h.

From another perspective, weather conditions are pertinent to drone (UAV) routing because wind speed and wind direction could agitate the travel speed of the UAV, and the air density, appeased by the temperature in the atmosphere, affect battery performance [2]. The majority of the current state of research has paid less attention to weather factors and ignores the impact of weather on performance [5][6][16]. Existing literature has sporadically considered wind conditions on energy consumption

and the use of that information in planning the missions [11][15]. The studies have assumed constant wind speed and direction and have used linear approximations for energy consumption, giving less focus on the weather [2].

ASID: the Arduino Sensor Integrated Drone

As shown in Fig. 1, The *Arduino Sensor Integrated Drone* (ASID) is a QUAD X-shaped quadcopter controlled by an ArduPilot Mega (APM) microcontroller.

Figure 1. The ASID

ASID flies and records weather data. Then, it sends directly this information to the user (pilot) on a computer system located on the ground. For completing this task, ASID has a build-in meteorological station. ASID has been designed to quickly log the key weather parameters to making a successful pre-flight preparation. It is been built as hands-off, easy to use, and as industry-specific as possible. This smart drone is a big boost to pilots because it can completely transform and revolutionize the aviation industry. An important characteristic of ASID (and of every drone) is the *Thrust/Weight* (T/W) ratio because the higher this ratio is the more agile and fast the drone is. The T/W ratio is calculated as follows:

$$\frac{T}{W} = \frac{Maximum\ Thrust \times Number\ of\ Motors}{Total\ Weight} \qquad (1)$$

If the *Total Weight* increases, the *T/W* ratio decreases, and thus the drone performance is decreased. During the drone flight, the T/W ratio changes depending on the current altitude and temperature. The thrust depends mainly on the density of the air and decreases proportionally as we climb higher. The maximum T/W ratio appears at sea level and with the motors running at maximum intensity. The T/W ratio is decreasing as the drone climbs because the air density decreases. On a usual day (Temperature=15C) at 20,000 feet, the air density is 0.660 Kg/m³, while at sea level, it is 1,225 Kg/m³. If we assume that a drone is a quadcopter and weighs 2 Kgr, the thrust at 20,000 feet should be 3 Kgr. Depending on the day temperature, we can calculate that the required static thrust is 5,586 gr. Therefore, we have 5600/4 (1400) grams distributed in each engine when the drone is a quadcopter. Finally, if we increase the battery capacity (and thus the total weight), the T/W ratio is reduced.

Flight Characteristics

ASID has the following flight characteristics:

- *The maximum flight altitude for ASID is 20,000 feet.* This altitude is close enough to the tropopause (i.e., the area where the weather stops). Thus, ASID does not need to fly higher to log data. At the maximum flight altitude, the T/W ratio becomes 1 and the drone reaches its design limit. Apart from the T/W ratio, the *endurance* of a drone in the maximum reachable altitude is important as there is a possibility that the battery capacity will not be sufficient for the time required to climb there.

- *The wind limit for ASID is 9Bft (or 75km/h).* ASID can fly in winds up to 9 Beaufort. This wind limit is calculated on the ground that with winds above 9 Beaufort, no flights are operated. For a drone to fly with the wind limit, its progressive speed must be greater than or equal to the wind speed. To calculate the progressive speed, we apply the following Equation (2). The calculation is complicated since we have to calculate the thrust loss that exists from the inclination of the fuselage to be able to move.

$$F = 1.225 \frac{\pi(0.0254 \cdot d)^2}{4} \left[\left(RPM_{prop} \cdot 0.0254 \cdot pitch \cdot \frac{1min}{60sec} \right)^2 - \left(RPM_{prop} \cdot 0.0254 \cdot pitch \cdot \frac{1min}{60sec} \right) v_o \right] \left(\frac{d}{3.29546 \cdot pitch} \right)^{1.5}$$

$$(2)$$

- *ASID* can take off with greater wind intensity. However, its landing point will be shifted in the direction of the wind. For example, for a 3-minute flight with winds of 12 Beaufort, ASID will land 2 km away from its take-off point.
- *The maximum climb rate near the ground can reach 120 ft/sec* and decreases as the drone increases its altitude. Near the maximum altitude, the calculated climb rate would be almost 55 ft/s**.** With these climb rates, the drone will need almost 7-8 minutes to reach its maximum altitude. This time is needed to calculate the battery capacity. Theoretically, the maximum ascent speed in ft/s is calculated if we subtract the weight as well as the air resistance in the frame from the maximum thrust. This speed changes during the ascent as the thrust decreases, the weight, and the air resistance decrease. The reduction of the last two is much smaller than the impulse, so the speed decreases during the ascent.
- *ASID is waterproof.* We selected appropriate materials to seal the drone in the rain. DC Brushless Motor motors are waterproof and work even in water. Regarding Electronic Speed Controller (ESC), we selected materials that meet the IP-68 standard and thus can withstand the maximum volume of water that we statistically observe in Greece. The meteorological station is installed in an electrical box that has IP-68 sealing.
- *ASID supports stability* that depends on the correct weight distribution. We selected specific motors so that with half thrust output motors can hold ASID in the air in the HOVER position.
- *ASID supports reliability*: In terms of reliability, the most critical material in construction is the engines. By choosing quality materials we can achieve more than 160 hours of Mean Time Between Failures (MTBF) which translates to about 960 flights without expected failure.
- *A user can create a flight profile that can run automatically.*
- *The meteorological station weighs 200 gr and is installed inside ASID.*

Technical Specifications

ASID has a flight controller, a GPS receiver, speed controllers, a telemetry system, propellers, and a Li-PO battery. The arrangement of 4 motors in our QUAD X—shaped quadcopter is shown in Fig. 2.
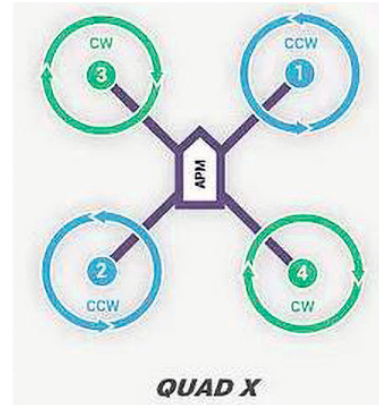

Figure 2. *Arrangement of 4 motors in Quad X*

The Lithium-polymer (Li-PO) battery provides greater energy capacity for the same size than other types of lithium batteries and can be used in applications where weight is a critical feature. The main characteristics of a Li-PO battery are its operating voltage, capacitance, and discharge rate of the voltage. The LiPo battery has a nominal voltage of 3.7 Volts. Increasing the voltage, the efficiency of the drone engines can be improved. A LiPo battery used in drones often has a capacity of 5000 mAh as it provides a good capacity/weight ratio. Such a battery delivers five Amps in 1 hour. The charging rate shows how fast the battery can deliver its energy without being damaged. The charging rate indicator along with the battery capacity allows us to calculate the *maximum load* (*Charging rate X capacity*) we can request without overheating it and thus damaged. For example, a battery with a capacity of 5000 mAh and a charging rate of 50C can give us a load of 250 Amp without overheating.

Electric motors: ASID uses electric motors as they have high torque and small weight. The torque of an electric motor is necessary for the instant change in the engine speed for the drone to be agile. High torque also simplifies the manufacturing of the engine since it does not need transmission gears, which means less weight, and thus a higher

thrust-to-weight ratio. The main characteristics of electric motors are the diameter, the speed per Volt (KV), and the operating voltage. Electric motors are characterized by a four-digit number XXYY that represents their dimensions. The first 2 digits represent their diameter while the last 2 digits represent their height. For example, a 2204 electric motor has a diameter of 22 mm and a height of 04 mm. Speed per Volt (KV) of a motor indicates the number of rounds/per minute with a voltage of 1Volt. This measurement is load-free which means that the actual speed depends on the size of the propeller. KV determines the maximum speed that an engine can achieve. Low KV means that the motor has more torque so more energy per rotation, a motor with high KV will rotate faster but will have less torque. Each manufacturer provides us with the capabilities of each motor depending on the operating voltage as well as the size of the propeller. The flight of the ASID drone is achieved without any kind of rudder since it is based on the asymmetric thrust it creates with the four engines.

The 3DR Radio Telemetry 915 MHz component: Using the ground station (mobile phone or laptop), the flight operator monitors and records all flight parameters by using the radio telemetry component. Using the telemetry component, the pilot checks the drone and sends a new flight plan to be performed. The telemetry system consists of two RF transceivers at 915 MHz or 433 MHz and has a bandwidth of 250Kbs up to 300 Mbps. The 3DR Radio Telemetry 915 MHz component (shown in Fig. 3) contains two transceivers, where one is with a USB plug for connection to a computer or mobile phone via OTG.

Figure 3. The 3DR Radio Telemetry 915 MHz component

The *Flight Controller* (FC) of ASID (shown in Fig. 4) is an Arduino microcontroller that performs all the calculations required for the flights. Sensors are connected to the FC receiver and transmit their sensed weather data. The FC sends the corresponding signals to the Electronic Speed Controller (ESC) that controls the speed of the motors and by using the asymmetric thrust controls it. For the proper FC operation, a constant power supply of 5V is required. Due to the different operating voltage of the Li-Po battery, a special Battery Elimination Circuit (BEC) circuit is used that delivers a constant voltage of 5V DC to the FC.

Figure 4. Flight Controller PixHawk

The *Electronic Speed Controller* (ESC) regulates the speed of an electric motor based on the signals it receives from the FC. ESCs are categorized based on the maximum current Ampere they can provide and the software used. The ESCs are connected to the LiPO battery and to the FC that gives the corresponding signal.

The Arduino central processor board and the ATmega2560 microcontroller: The Arduino central processor board has low power consumption and minimal manufacturing cost. It includes an 8-bit microcontroller (ATmega2560) that has 54 digital inputs and 16 analog inputs. The board has also some extra cards (known as "shields") which offer more features to the microcontroller. These cards can provide additional connectivity to the microcontroller, such as Ethernet network (Ethernet shield), wireless WIFI network, wireless serial communication with Bluetooth Technology (BT Shield), etc. In our project, we used the ARDUINO MEGA 2560 REV3 (shown in Fig. 5). The

ATmega2560 microcontroller is an open-source microprocessor. This means that it can be programmed in Wiring (a variant of the C++ programming language). For the implementation of ASID, we used the functions and sensors of the ArduPilot board to create an automatic navigation system.
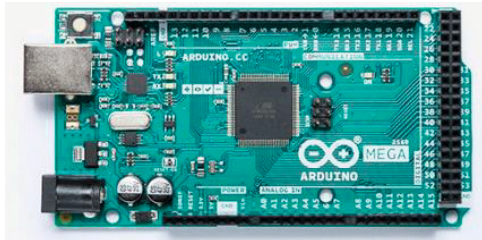

Figure 5. *The ATmega2560 Microcontroller*

Arduino Software: The Arduino has some portals that function as inputs or outputs. The functionality of these portals is managed by writing code in the Arduino IDE programming environment (Arduino 1.8.5 ver. for Windows 10).

THE BUILT-IN WEATHER STATION

Figure 6 shows how the weather station operates.
1. Initially, ASID logs temperature, humidity, and air pressure values on the ground multiple times to accurately calculate the median values of these variables.
2. Then, ASID will take-off to log the same weather variables in the air at a specific height interval.
3. As soon as the ASID system lands, an HTTP fileserver is created to synchronize the logs with the presentation program running on the ground station (laptop).
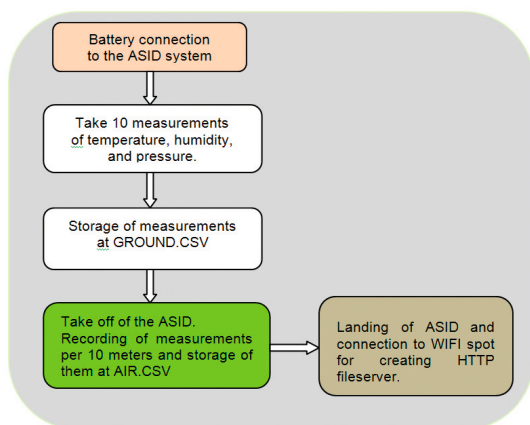

Figure 6. *The operation diagram of ASID*

All the captured data are transmitted to the ground station via a wireless link (2.4 GHz). The display of data on the laptop is obtained using a Java program. Moreover, a camera receives commands from the Flight Controller and takes photos whenever we want. Photos from the camera can either be transferred with a card reader to the laptop or with the use of an Sd air-fi card that through a WIFI connection the data can be synchronized.

The Arduino source code for the operation of the meteorological station was written in Arduino IDE 1.85.

Setup Method: The setup method performs the initialization of all sensors and calculates the Mean Sea Level Pressure that is stored in the variable named SLpressure_HPA. The value of this variable is crucial for the calculation of the rest of the logged variables.

```
1. void setup() {
2. Serial.begin(115200);
3. pinMode(buzz, OUTPUT);
4. SD.begin(chipSelect);
5. delay(2000);
6. bmp280.begin(0x76);
7. rtc.begin();
8. dht.begin();
9. SLpressure_mB = GetMSLP();
10. SLpressure_HPA = SLpressure_mB /
100;
11. }
```

Creating a Flight Profile

We planned a certain flight and created a flight profile using the Mission Planner application (Fig. 7). Mission Planner application transmits (uploads) the data of this flight profile to the FC to execute this profile automatically. The flight profile has the following commands:
1. Take-off and ascent to 10 meters AGL (a height above ground level)
2. Rotate to 90 degrees (East)
3. Capture Image
4. Rotate 180 degrees (South)
5. Capture Image
6. Rotate to 270 degrees (West)
7. Capture Image
8. Rotate 360 degrees (North)
9. Capture Image
10. Rise to 20 meters AGL

These tasks are repeated until the drone climbs to the desired altitude. Then, the drone will continue descending up to 10 meters and after a few seconds, it will land automatically.

Figure 7. *(a) The Mission Planner (points).*

Figure 7. *(b) Mission Planner (commands)*

In Figure 7a, the points are depicted not to be vertical as for the presentation of the drone movements to be more understandable to the reader. The software also allows us to activate the Shutter when we need to capture an image. This signal is transmitted via a special cable between the camera and the FC. Due to the speed of the camera, a delay of 10 ms has been inserted between the changes of course.

The "Aerial Weather Station" Application

We developed an application called "Aerial Weather Station" (shown in Fig. 8). We implemented the Graphical User Interface (GUI) of this application by using Java language with IDE intellijIDEA. The GUI of our application displays the following graphs: (1) Height/temperature graph; (2) Height/humidity graph; (3) Height/pressure graph; (4) Freezing Level; (5) Dew Point; (6) Discomfort Index on the surface; (7) Barometric pressure on the surface; (8) Freezing Level. The main window of the application also includes a button for synchronizing logs as well as for exporting calculations. When the user clicks the SYNC button, the files from the Fileserver are synchronized. Then, the necessary data are processed and displayed in the main window. The time of data collection and data process is also presented.
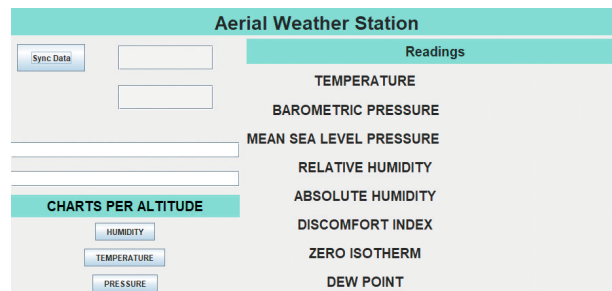

Figure 8. *The Aerial Weather Station application*

Conclusion

The autonomous weather record system provides better weather forecasting and monitoring services in the aviation industry. Shortly, we aim to add new important features in the ASID system such as standalone charging, 360 cameras, lightning sensor, infrared (IR) imaging for fire detection, weather reports on websites the automatic upload of Meteorological Terminal Air Reports (METAR), etc.

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Abbreviations

AGL:	A height Above Ground Level
ASID:	Arduino Sensor Integrated Drone
ESC:	Electronic Speed Control
FC:	Flight Controller
FL:	Flight Level
GPS:	Global Positioning System
GUI:	Graphical User Interface
LiPo:	Lithium Polymer
METAR:	Meteorological Terminal Air Report
MTBF:	Mean time between failures
T/W:	Thrust/Weight ratio
UAV:	Unmanned Aerial Vehicle (a.k.a. drone)

APPENDIX A CAN BE USED ONLY FOR THE REVIEW PROCESS.

APPENDIX A: The source code

```
1. //ΕΙΣΑΓΩΓΗ LIBRARIES//
2. #include "DHT.h"
3. #include < DS3231.h >
4. #include < SD.h >
5. #include < stdlib.h >
6. #include < SPI.h >
7. #include < SD.h >
8. #include < Wire.h >
9. #include "WiFiEsp.h"
10. #include < Adafruit_Sensor.h >
11. #include < Adafruit_BMP280.h >
12. //ΟΡΙΣΜΟΣ PIN//
13. #define DHTPIN 8
14. #define DHTTYPE DHT22
15. Adafruit_BMP280 bmp280;
16. DHT dht(DHTPIN, DHTTYPE);
17. DS3231 rtc(SDA, SCL);
18. WiFiEspServer server(80);
19. const int buzz = 7;
```

```
20. //ΟΡΙΣΜΟΣ ΜΕΤΑΒΛΗΤΩΝ//
21. String readString;
22. const int chipSelect = 53; //PIN SDCARD
23. float temperature_DHT;        // Θερμοκρασία (C)
24. float heat;                   // Δείκτης δυσφορίας
25. float humidity_DHT;           // Υγρασία σε %
26. float altimeter;              //Υψόμετρο
27. float CalAltimeter;           // Διορθωμένο υψόμετρο με βάση την MSLP
28. float SLpressure_HPA;         // MSLP σε hPa
29. float pressure;               // Βαρομετρική πίεση σε Pa
30. float pressure_HPA;           // Βαρομετρική πίεση σε hPa
31. float PressureCorrection = 0.995; // Μεταβλητή διόρθωσης βαρομετρικής πίεσης
32. float PressureCorrected;      // Διορθωμένη βαρομετρική πίεση
33. float SLpressure_mB;          // Βαρομετρική Επιφανείας
34. int Interval = 5;             // Υψομετρικό διάστημα καταγραφής δεδομένων στο air.csv
35. int run = 0;                  // Μεταβλητή για το αν έχει γίνει log στο ground.csv
36. int listenint = 0;           // Μεταβλητή για το αν είναι έτοιμος ο fileserver
37. int ELEVATION = 45;                  //Υψόμετρο που βρίσκομαστε για υπολογισμό της MSLP
38. char ssid[] = "diktio";       // όνομα SSID wifi hotspot
39. char pass[] = "2610333918";        // κωδικός wifi
40. int status = WL_IDLE_STATUS; // Κατάσταση σύνδεσης Esp8266
41. //0.Μέθοδος δημιουργίας ήχου
42. void buzzer(int time) {
43.     tone(buzz, 1000);        // Send 1KHz sound signal...
44.     delay(time);            // ...for 1 sec
45.     noTone(buzz);           // Stop sound...
46.   }
47. //1.Μέθοδος Δημιουργίας Http Fileserver//
48. void MakeServer() {
49.     Serial1.begin(115200);
50.     WiFi.init( & Serial1);
51.     while (status != WL_CONNECTED) {
52.             Serial.print("Προσπάθεια για σύνδεση στο WPA SSID: ");
53.             Serial.println(ssid);
54.             status = WiFi.begin(ssid, pass);
55. }
56.     Serial.println("Επιτυχής Σύνδεση");
57.     printWifiStatus();
58.     server.begin();
59.     listenint = 1;
60.     }
61. //2.Μέθοδος HTTP send του ground.csv//
62. void DownloadGround() {
63.     WiFiEspClient client = server.available();
64.     client.println("HTTP/1.1 200 OK");
65.     client.println("Content-Type: text/csv");
66.     client.println("Content-Disposition: attachment; filename=\"ground.csv\"");
67.     client.println("Connection: close");
68.     client.println();
69.     File myFile = SD.open("ground.csv");
70.     if (myFile) {
71.             Serial.println("file opened"); //send new page
72.             byte clientBuf[1760];
73.             int clientCount = 0;
74.     while (myFile.available()) {
75.             clientBuf[clientCount] = myFile.read();
76.             clientCount++;
77.             if (clientCount > 1759) {
78.                     client.write(clientBuf, 1760);
79.             clientCount = 0;
80.             }
81.     }
82.     if (clientCount > 0) client.write(clientBuf, clientCount);
83.     myFile.close();
84.     client.stop();
85.     readString = "";
86.     Serial.println("Removing air.csv...");
87.     SD.remove("air.csv");
88.     Serial.println("Removing ground.csv...");
89.     SD.remove("ground.csv");
90.     }
```

```
91.    }
92. //3.Μέθοδος HTTP send του air.csv//
93. void DownloadAir() {
94.    WiFiEspClient client = server.available();
95.    client.println("HTTP/1.1 200 OK");
96.    client.println("Content-Type: text/csv");
97.    client.println("Content-Disposition: attachment; filename=\"air.csv\"");
98.    client.println("Connection: close");
99.    client.println();
100.           File myFile = SD.open("air.csv");
101.           if (myFile) {
102.                   Serial.println("file opened");
103.                   byte clientBuf[1760];
104.                   int clientCount = 0;
105.                   while (myFile.available()) {
106.                           clientBuf[clientCount] = myFile.read();
107.                           clientCount++;
108.                           if (clientCount > 1759) {
109.                                   client.write(clientBuf, 1760);
110.                                   clientCount = 0;
111.                           }
112.                   }
113.           if (clientCount > 0) client.write(clientBuf, clientCount);
114.           myFile.close();
115.           client.stop();
116.           readString = "";
117.           delay(5000);
118.           client.stop();
119.           return;
120.           }
121.    }
122. //4.Μέθοδος αναμονής του HTTP fileserver για πελάτη//
123. void listen() {
124.    WiFiEspClient client = server.available();
125.           if (client) {
126.                   Serial.println("New client");
127.                   boolean currentLineIsBlank = true;
128.                   while (client.connected()) {
129.                           if (client.available()) {
130.                                   char c = client.read();
131.                                   readString += c;
132.                                   if (c == '\n') {
133.                                     Serial.println(readString.indexOf("air"));
134.                                     Serial.println(readString.indexOf("ground"));
135.                                     if (readString.indexOf("air") > 5)  DownloadAir();
136.                                    else DownloadGround();
137.                                   }
138.                           }
139.                   }
140.       }
141.    }
142. //5.Μέθοδος εκτύπωσης στοιχείων σύνδεσης//
143. void printWifiStatus() {
144.    Serial.print("SSID: ");
145.    Serial.println(WiFi.SSID());
146.    IPAddress ip = WiFi.localIP();
147.    Serial.print("IP Address: ");
148.    Serial.println(ip);
149.    Serial.println();
150.    Serial.print("To see this page in action, open a browser to http://");
151.    Serial.println(ip);
152.    Serial.println();
153. }
154. //6.Μέθοδος υπολογισμού της MSLP//
155. float GetMSLP() {
156.    pressure = bmp280.readPressure();
157.    PressureCorrected = pressure * PressureCorrection;
158.    float SLpressure_mB = (((PressureCorrected * 100.0) / pow((1 - ((float)(ELEVATION)) / 44330), 5.255)) /
100.0);
159.    return SLpressure_mB;
160. }
```

```
161. //7.Μέθοδος καταγραφής δεδομένων στο air.csv//
162. void LogAir() {
163.    humidity_DHT = dht.readHumidity();
164.    temperature_DHT = dht.readTemperature();
165.    heat = dht.computeHeatIndex(temperature_DHT, humidity_DHT, false);
166.    pressure = bmp280.readPressure();
167.    PressureCorrected = pressure * PressureCorrection;
168.    pressure_HPA = PressureCorrected / 100;
169.    SLpressure_HPA = SLpressure_mB / 100;
170.    altimeter = bmp280.readAltitude(SLpressure_mB);
171.    CalAltimeter = (SLpressure_HPA - pressure_HPA) / 0.12;
172.    File dataFile = SD.open("air.csv", FILE_WRITE);
173.    if (dataFile) {
174.            dataFile.print(rtc.getDateStr()); //Log Date
175.            dataFile.print(","); //Next Column
176.            dataFile.print(rtc.getTimeStr()); //Log Time
177.            dataFile.print(","); //Next collumn
178.            dataFile.print(temperature_DHT, 1);
179.            dataFile.print(",");
180.            dataFile.print(humidity_DHT, 1);
181.            dataFile.print(",");
182.            dataFile.print(heat, 1);
183.            dataFile.print(",");
184.            dataFile.print(pressure_HPA, 2);
185.            dataFile.print(",");
186.            dataFile.print(CalAltimeter, 2);
187.            dataFile.print(",");
188.            dataFile.println();
189.            dataFile.close();
190.    } else Serial.println("Αποτυχία εγγραφής");
191. }
192. //8.Μέθοδος καταγραφής δεδομένων στο ground.csv//
193. void LogGround() {
194.    humidity_DHT = dht.readHumidity();
195.    temperature_DHT = dht.readTemperature();
196.    heat = dht.computeHeatIndex(temperature_DHT, humidity_DHT, false);
197.    pressure = bmp280.readPressure();
198.    PressureCorrected = pressure * PressureCorrection;
199.    pressure_HPA = PressureCorrected / 100;
200.    SLpressure_HPA = SLpressure_mB / 100;
201.    altimeter = bmp280.readAltitude(SLpressure_mB);
202.    CalAltimeter = (SLpressure_HPA - pressure_HPA) / 0.12;
203.    File dataFile = SD.open("ground.csv", FILE_WRITE);
204.    if (dataFile) {
205.            dataFile.print(rtc.getDateStr()); //Log Date
206.            dataFile.print(","); //Next Column
207.            dataFile.print(rtc.getTimeStr()); //Log Time
208.            dataFile.print(","); //Next collumn
209.            dataFile.print(temperature_DHT, 1);
210.            dataFile.print(",");
211.            dataFile.print(humidity_DHT, 1);
212.            dataFile.print(",");
213.            dataFile.print(heat, 1);
214.            dataFile.print(",");
215.            dataFile.print(pressure_HPA, 2);
216.            dataFile.print(",");
217.            dataFile.print(CalAltimeter, 2);
218.            dataFile.print(",");
219.            dataFile.println();
220.            dataFile.close();
221.    } else Serial.println("Αποτυχία εγγραφής");
222. }
223. //9.Αρχικοποίηση των Sensor//
224. void setup() {
225.    Serial.begin(115200);
226.    pinMode(buzz, OUTPUT);
227.    SD.begin(chipSelect);
228.    delay(2000);
229.    bmp280.begin(0x76);
230.    rtc.begin();
231.    dht.begin();
```

```
232.    SLpressure_mB = GetMSLP();
233.    SLpressure_HPA = SLpressure_mB / 100;
234.  }
235.  //10.Main Loop//
236.  void loop() {
237.    if (run == 0) {
238.            for (int i = 0; i <= 5; i++) {
239.                    Serial.println("Log Ground");
240.                    buzzer(500);
241.                    LogGround();
242.                    delay(3000);
243.                    if (i == 5) {
244.                            run = 1;
245.                    }
246.            }
247.    } else {
248.            if (CalAltimeter > Interval) {
249.                    Serial.println("Log Air");
250.                    Serial.println(Interval); //buzzer(2000);
251.                    LogAir();
252.                    Interval = Interval + 5;
253.                    delay(3000);
254.            }
255.    }
256.  if (run == 1 && Interval > 35 && listenint == 0) {
257.    MakeServer();
258.    buzzer(5000);
259.    listenint = 1;
260.    }
261.  if (run == 1 && Interval > 35 && listenint == 1) {
262.            listen();
263.    }
264. }
```

About the authors

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For citation

Impact of Pointing Errors on the Performances of Double Rician FSO Channels

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Abstract: In this paper we will propose new analytically traceable probability density function (PDF) model for free space optics (FSO) turbulence, obtained as a generalization of double Ricean turbulence model, that encompasses both large-scale and small-scale turbulence eddy effects along by taking into account performance decreasing influence of misalignment introduced through boresight pointing error model. Consequently, after delivering the closed-form expressions for the newly introduced double FSO model, we obtain the analytical expressions for the bit error rate (BER) performance for the Double Rician distribution affected by misalignment. Numerical results will show the impact of system parameters on FSO link performance and we will provide full performance analysis. © 2021.

Keywords: free space optics (FSO), atmospheric turbulence, pointing error, bit error rate (BER).

Introduction

Providing the tractable probability density function (pdf) to describe atmospheric turbulence is important in order to study the performance characteristics of a free space optics (FSO) transmission system [1]-[6]. Over the last decades, a number of statistical models have been proposed for different degrees of turbulence severity. However, in addition to the scintillation effect, misalignment between transmission point and reception point due to building wobble causes oscillation of the FSO beam and, thus, pointing errors that restrict the performance of atmospheric FSO links, so the impact of pointing error (jitter) was widely investigated in literature. Recently, a new and generalized statistical model, called double Rician distribution, was used to model the the irradiance fluctuations of an unbounded optical wavefront propagating through a homogeneous, isotropic channel [7], [8], [9]. Double Rician distribution was demonstrated to have the advantage of unifying most of the proposed statistical models delivering, additionally, an excellent settlement with measured characteristics of plane wave and spherical wave propagation for a wide range of observed turbulence conditions (weak, moderate, strong). Here, such a model is upgraded by encompassing the harmful influence of pointing error losses that occur due to misalignment. In such esteem, familiar effects of aperture size, beam width and jitter variance are brought into consideration. In this work, we are introducing a novel general turbulence model, named as Double-Rician, for representing broad range of irradiance fluctuations. The parameters of the presented model pdf are connected straightly to the atmospheric parameters. Based on the Rytov approach which is commonly used in scintilation theories, we observe the synthesized turbulence as the product of smal-scale and large-scale turbulences, both analytically modeled by the Rician distribution model, and further derive closed-form expressions for their pdf and cumulative density (cdf) functions expressed through Meijer's G-function. Further, such a model is completed by by encompassing the harmful influence of pointing error losses that occur

due to misalignment. In this regard, prominent up-shots of aperture size, beam width and variance of jitter are taken into consideration. Consequently, after introducing the closed-form expressions for the synthesized composite distribution of scintillation and pointing errors, we obtain the closed-form ex-pressions for the BER performance of an IM/DD for the Double-Rician distribution affected by misalignment, exposuring the impairment in performance of pointing errors in atmospheric FSO links. Numerical results show the impact of misalignment on link performance.

ATMOSPHERIC DOUBLE-RICEAN MODEL

Let us here introduce closed form of new Double-Rician model as the product of two types of fluctuations. The optical turbulence channel can be modeled as the modified Rician distribution, where both the amplitude and phase of the optical signal fluctuate. The intensity fading h_j, j = 1, 2, induced by optical atmospheric turbulence can be statistically described by:

$$f_{h1}(h_1) = \frac{1+K_1}{\overline{h_1}} \exp\left(-K_1 - \frac{(1+K_1)h_1}{\overline{h_1}}\right) \times I_0\left(2\sqrt{\frac{h_1(1+K_1)K_1}{\overline{h_1}}}\right) \qquad (1)$$

$$f_{h2}(h_2) = \frac{1+K_2}{\overline{h_2}} \exp\left(-K_2 - \frac{(1+K_2)h_2}{\overline{h_2}}\right) \times I_0\left(2\sqrt{\frac{h_2(1+K_2)K_2}{\overline{h_2}}}\right) \qquad (2)$$

where $\overline{h_j}$, j = 1, 2, is the mean value of the turbulence intensity, K_j is reciprocal of the contrast parameter and $I_0(x)$ is the firstkind modified Bessel function of order zero. $\overline{hj}$ and K_j can be expressed as [10],[11]:

$$K_j = \left(\frac{\overline{\alpha}_{rj}^2 + \sigma_{rj}^2 + \sigma_{ij}^2}{\sqrt{\overline{\alpha}_{rj}^4 + 2\overline{\alpha}_{rj}^2\left(\sigma_{ij}^2 - \sigma_{rj}^2\right) - \left(\sigma_{ij}^2 - \sigma_{rj}^2\right)^2}} - 1\right)^{-1}, \quad (3)$$

$$\overline{h_j} = \overline{\alpha}_{rj}^2 + \sigma_{rj}^2 + \sigma_{ij}^2, \quad j = 1,2; \quad (4)$$

where $\overline{\alpha}_{rj}$, denote the mean values of real part of the effective turbulences coefficients, while σ_{rj}^2 and σ_{ij}^2 denote the variances of the real and imaginary parts of the effective turbulences coefficients, respectively:

$$\sigma_{rj}^2 = \frac{1 + \exp\left(-2\sigma_{\varphi j}^2\right) - 2\exp\left(-\sigma_{xj}^2 - \sigma_{\varphi j}^2\right)}{2N}$$

$$\overline{\alpha}_{rj} = exp\left(-\frac{\sigma_{xj}^2 + \sigma_{\varphi j}^2}{2}\right)$$

$$\sigma_{ij}^2 = \frac{1 - \exp\left(-2\sigma_{\varphi j}^2\right)}{2N}, \qquad j = 1,2; \qquad (5)$$

with $\sigma_{\varphi j}^2$ and σ_{xj}^2 denoting the variances of amplitude fluctuations and phase variations respectively, while N representing the number of statistically independent cells in the receiver aperture (RA), defined as:

$$N = \left(1.09(r_0/D)^2 \gamma\left(6/5, 1.08\,(D/r_0)^{\frac{5}{3}}\right)\right)^{-1}, \qquad (6)$$

where D denotes the aperture diameter, r_0 denotes the wavefront coherence diameter and $\gamma(a, x)$ stands for the lower incomplete Gamma function. The log-normal amplitude variances $\sigma_{\varphi j}^2$ are related to a

scintillation index (SI), $\sigma_{\beta j}^2 = exp(4\sigma_{\varphi j}^2) - 1$, while the Gaussian phase variances σ_{xj}^2 are defined as $\sigma_{xj}^2 = C_J \left(\frac{D}{r0}\right)^{5/3}$, where C_J is determined by the number (J) of Zernike terms corrected by active modal compensation. As a result, the intensity fading of the optical signals over the modified Rician channels are determined by both the amplitude scintillation and phase aberration.

According to Rytov principle [2], [5] the resulting irradiance of the received optical wave can be represented through a product of two types of fluctuations, i.e. $h_a - h_1 h_2$, appearing from both large and small scale turbulence eddies, respectively. It is supposed that h_1, h_2 are mutually independent random processes and, hence, the second moment of the irradiance is expressed as :

$$E\langle h_a^2 \rangle = \langle h_1^2 \rangle \langle h_2^2 \rangle = \left(1 + \sigma_{h1}^2\right)\left(1 + \sigma_{h2}^2\right), \qquad (7)$$

where σ_{h1}^2 and σ_{h2}^2 are normalized variances of $h1$ and $h2$, respectively. Without loss of generality, we suppose $E\langle h_a \rangle = 1$ or analogously $E\langle h_1 \rangle = 1$ and $E\langle h_2 \rangle = 1$. Then the scintillation index can be expressed as:

$$\sigma_{ha}^2 = \frac{E\langle h_a^2 \rangle}{E\langle h_a \rangle^2} - 1 = \left(1 + \sigma_{h1}^2\right)\left(1 + \sigma_{h2}^2\right) - 1. \qquad (8)$$

Let us suppose that both type of scale of the irradiance fluctuations are conducted by the Rician distribution, i.e. h_1, h_2 and poses the pdfs of (1) and (2) with parameters K_1, $\overline{h_1}$ and K_2, $\overline{h_2}$, respectively. Then, based on the method proposed in [5], the pdf of h_a can be written as:

$$f_{h_a}(h_a) = \sum_{p=0}^{\infty} \sum_{q=0}^{\infty} \frac{2(1+K_1)^{\frac{p+q+2}{2}}(1+K_2)^{\frac{p+q+2}{2}}K_1^p K_2^q}{\overline{h_1}^{\frac{p+q+2}{2}} \overline{h_2}^{\frac{p+q+2}{2}} \Gamma(p+1)\Gamma(q+1)p!q!} h_a^{\frac{p+q}{2}}$$
$$\exp(-K_1)\exp(-K_2) K_{p-q}\left(2\sqrt{\frac{(1+K_1)(1+K_2)h_a}{\overline{h_1}\overline{h_2}}}\right) \qquad (9)$$

where $K_v(x)$ is v^{th}-order modified Bessel function of the second kind [12, Eq. 8.432].

MISALIGNMENT FADING MODEL

The pointing errors arise as a result of the misalignment between the transmission point and reception point. Weak earthquakes, thermal expansion and powerful wind cause buildings to oscillate which results in the vibrations of the optical beam. In order to describe the effects of pointing errors, we start from the model proposed in [13]. This model assumes a Gaussian spatial intensity profile of beam waist w_z on the receiver plane and a circular aperture of radius a. Both vertical and horizontal oscillations are modeled by mutually independent identical Gaussian distributions, so the radial displacement r at the receiver detector can be expressed by Rayleigh distribution with the jitter variance σ_s^2. The PDF of h_p can be expressed as [13], [14]:

$$f_{hp}\left(h_p\right) = \frac{g^2}{A_0^{g^2}} h_p^{g^2-1}, 0 \leq h_p \leq A_0, \qquad (10)$$

where $g = \omega_{zeq}/2\sigma_s$ is the ratio between the equivalent beam radius at the receiver and the pointing error

displacement standard deviation (jitter) at the receiver and $\omega_{zeq}^2 = \frac{\omega_z^2 \sqrt{\pi}\, \mathrm{erf}(v)}{2v \exp(-v^2)}, v = \sqrt{\pi}a/2\sqrt{\omega_z}, A_0 = [\mathrm{erf}(v)]^2$, where $erf(\,)$ is the error function [12], (8.250.1).

COMPOSITE CHANNEL MODEL STATISTICS

Here, we deliver a composite statistical model of a stochastic FSO channel by taking into account both scintillation inducted by turbulence and pointing errors inducted by misalignment. Therefore, the unconditional pdf, $f_h(h)$, for the channel state, h, is obtained by calculating the product of the two pdfs presented above in [14]:

$$f_h(h) = \int f_{h|h_a}(h|h_a) f_{h_a}(h_a)\, dh_a \qquad (11)$$

where $f_{(h|ha)}(h|h_a)$ is the conditional probability given a turbulence state, h_a, and it is expressed as:

$$f_{h|h_a}(h|h_a) = \frac{1}{hp}\, f h_p \left(\frac{h}{hp}\right), \quad 0 < h \leq A_0 h_a \qquad (12)$$

Substituting expression (12) in (13) we get the expression for PDF in the form of:

$$f_h(h) = \sum_{p=0}^{\infty} \sum_{q=0}^{\infty} \frac{(1+K_1)(1+K_2)K_1^p K_2^q \exp(-K_1) \exp(-K_2)}{\overline{h}_1\, \overline{h}_2 A_0 \Gamma(p+1)\Gamma(q+1)p!q!}$$
$$g^2 G_{1,3}^{3,0}\left(\frac{(1+K_1)(1+K_2)}{\overline{h}_1\, \overline{h}_2 A_0} h \,\middle|\, \begin{matrix} g^2 \\ g^2-1, p, q \end{matrix}\right) \qquad (13)$$

where $G_{1,3}^{2,1}(x)$ denotes Meijer G function, given with [15, Eq. (07.34.02.0001.01)], Eq. (07.34.21.0085.01), [15, Eq. (07.34.17.0011.01)].

AVERAGE BER

In this section, we capitalize on presented analysis by delivering the procedure for obtaining the closed-form expressions for the BER of the Double Rice pdf in the presence of pointing errors, when IM/DD link using OOK signaling has been considered. Mainly in practice, signal-to-noise ratio (SNR) at the reception is limited by shot noise, that arises by background light and could be much stronger than the power of the desired signal. Similarly, it can be limited by thermal noise that arises from electronic components that follow the photodetector. Because of that, noise is usually modeled to high accuracy as Additive white Gaussian noise (AWGN) that is statistically independent of the desired signal. Presence of AWGN, may lead to the occurrence of reception errors when determining the values of actual transmitted symbols is made. The overall probability of error, $P_b(e)$ can be determined by calculating following weighted sum:

$$P_b(e) = p_0 p(e|0) + p_1 p(e|1), \qquad (14)$$

where p_0 denotes the transmission probability of a binary symbol "0" and p_1 denotes the transmission probability of a binary symbol "1", as pointed out in [16]. On another note, $p(e|0)$ and $p(e|1)$ denote the conditional bit error probabilities when the transmitted bit is "0" and when the transmitted bit is "1", respectively. It is assumed that either symbol (binary "0" or binary "1") are equally possible to be transmitted, i.e., $p_0 = p_1 = 1/2$. Assuming that $p(e|0) = p(e|1)$, it is easy to show that the conditional BER can be expressed as:
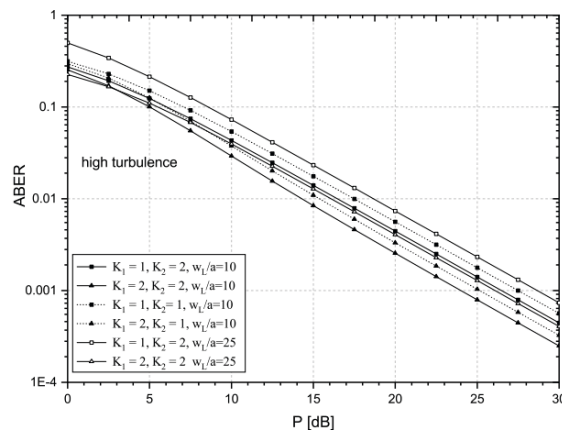
$$P_b(e|h)p(e|0,h) = p(e|1,h) = Q\left(\frac{PR_h}{\sigma_N}\right), \qquad (15)$$

where P denotes the average power of optical signal, while R denoting the responsivity and σ_N^2 standing for the AWGN variance, while $Q(x)$ represents the Gaussian Q function. ABER. Now, $P_b(e)$, can be obtained by averaging $P_b(e|h)$ over $f_h(h)$:

$$P_b(e) = \int_0^\infty P_b(e|h)f_h(h)dh. \qquad (16)$$

After substituting (13) into (16), and by using [15, Eq. (07.34.21.0013.01)], the ABER is derived in a closed-form expression as:

$$P_b(e) = \sum_{p=0}^\infty \sum_{q=0}^\infty \frac{2^{p+q-2}K_1^p K_2^q \exp(-K_1)\exp(-K_2)A_0^2}{\pi\sqrt{\pi}\Gamma(p+1)\Gamma(q+1)p!\,q!}$$
$$\times G_{2,6}^{7,4}\left(\frac{8PRh_1^{-2}h_2^{-2}A_0^2}{(1+K_1)^2(1+K_2)^2\sigma_N}\,\middle|\,\begin{matrix}\frac{1-g^2}{2},\frac{-g^2}{2},\frac{-p}{2},\frac{1-p}{2},\frac{-q}{2},\frac{1-q}{2},1\\0,\frac{1}{2},\frac{-g^2}{2},\frac{1-g^2}{2}\end{matrix}\right), \qquad (17)$$

Fig. 1. ABER for the double Rician pointing error channel model for different values of the normalized optical beam radius
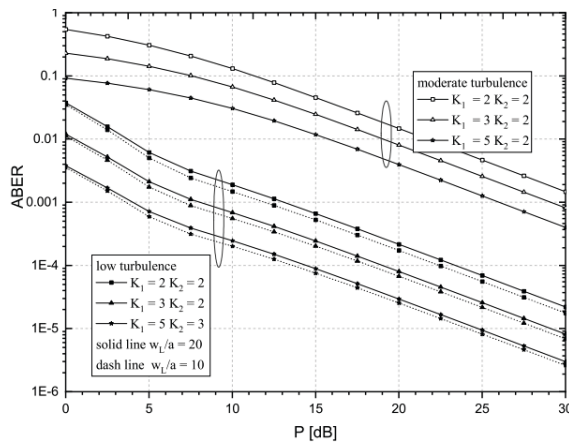
Fig. 2. ABER for the double Rician pointing error channel model for different values of the atmospheric conditions

NUMERICAL RESULTS AND DISCUSSIONS

For the numerical calculation, the FSO system was observed at the wavelength $\lambda = 1550 \, nm$ and at the distance between transmitter and receiver $L = 1 \, km$. Three types of atmospheric turbulence were considered: weak, moderate and strong, with indexes of reflection $C_n = 6 * 10^{-15} m^{-2/3}$, $C_n = 2 * 10^{-14} m^{-2/3}$, and $C_n = 1.2 * 10^{-13} \, m^{-2/3}$, respectively. Total received signal power is $P = 1$, while detector responsivity $R = 1 \, [A/W]$ and noise variance is $\sigma_N = 10^{-7} [A/Hz]$. The radius of a circular detector aperture $a = 0.05 \, m$, optical beam radius at distance L from transmitter $\omega_L = 0.5 \, m$, pointing error displacement standard deviation (jitter) at the receiver $\sigma_s = 0.2m$ are considered.

In Fig. 1 and Fig. 2 are shown ABER behavior of double Ricean channel model, with applied OOK modulation scheme as a function of the average optical power at the transmission P, for different values of the normalized optical beam radius ω_L at distance L from transmitter. Since optical beam radius ω_L depends on the distance L from the transmitter, it is clear that higher values of this parameter greatly affect the deterioration of ABER, as well as the system performance. As expected, for stronger turbulence and lower values of the K factor, the higher ABER values are obtained. In both the atmospheric turbulence and the pointing error model, the ABER decreases significantly faster for higher values of the K factor then for those lower ones.

CONCLUSIONS

Double Rician scintillation channel model was demonstrated to have the asset of encompassing most of the proposed channel models derived until now in the literature in a closed-form expression, while delivering, additionally, an excellent settlement with measured characteristics of plane wave and spherical wave propagation for a wide range of observed turbulence conditions (weak, moderate, strong). Here, this model has been upgrading by incorporating the harmful effects of pointing error losses due to misalignment. In this regard, prominent effects of aperture size, beam width and variance of jitter are taken into consideration. In this work we have presented the analytical closed form representations for the PDF of the irradiance at the receiver, as well as of instantaneous SNR for the newly introduced double Rician model in the presence of atmospheric turbulence and pointing error are derived. Finally, we obtain closed-form expressions for the BER characteristics of an IM/DD for the Double-Rician distribution affected by misalignment.

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FOR CITATION

Implementation of User Authentication System in Smart Hospitals Useful in the Age of the Covid-19 Pandemic

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Abstract: The security system for authentication and user records in a smart hospital is part of an integrated security system consisting of various authentication devices. The security system should be adapted to different characteristics of users, their user processes, but also to periods when the possibility of infection is increased due to a virus pandemic and contamination during multiple touches of different persons on authentication devices. The use of gloves and a medical face mask during a pandemic limits biometric scanning of fingerprints and facial images. During a virus pandemic, some authentication devices have limitations that need to be considered when creating an integrated security system that will have the purpose of securing doctors, staff, patients, information, and things in a smart hospital. In this paper, the parameters on the basis of which it is possible to design an optimally integrated security system are recommended.

Keywords: smart hospital, access control, user authentication, virus pandemic.

Introduction

Part of the smart hospital's integrated security system is the access control system. Due to the different characteristics of smart hospital users in relation to users of other types of smart buildings, it is necessary to create a customized user interface that should enable the interaction of specific types of users with the security system of the smart hospital. Users of smart hospitals, unlike users of other smart buildings, differ in psycho-physical characteristics and user processes that they perform on a daily basis. The system should enable the recording of doctors, other hospital staff, patients and visitors. Due to the large number of patients, but also visitors who become part of the smart hospital system every day, it is necessary to design a specific user interface with which different types of users will be able to easily register in the access control system. Each type of user interface has its advantages and disadvantages. In a time of virus pandemic, authentication devices such as biometric fingerprint scanners are a potential source of disease transmission due to contamination from

touch by different users. These devices pose a potential risk of transmitting the infection. The deposition of dirt from a finger that touches the surface of authentication devices or a biometric fingerprint scanner can contaminate the surface of the device [1]. It is potentially possible for a smart hospital user to become infected with viruses that can be found on the surface of authentication devices [2]. These authentication models increase the possibility of the user becoming infected with viruses [3]. The essence of this paper is a set of parameters on the basis of which different designs of authentication and identification devices are proposed, which should be adapted to all specific users of smart hospitals and their user processes. The design and implementation of several different authentication and identification devices enables the smart hospital: records of all present users of the smart hospital, reporting of incidents in the building with facilitated identification of the responsible person, control of user movement in smart hospital departments. This system is able to control the optimal number of doctors in individual depart-

ments. With adequate software, the system could control the maximum number of visitors per ward, then, it could activate an alarm, in case the optimal number of doctors in the wards is reduced. This paper is conceived as follows: Chapter 2 of this paper presents an overview of previous research and available literature. Chapter 3 describes the problem of authentication and identification in smart hospitals. Chapter 4 describes the proposed parameters for the implementation of the smart hospital user authentication system. Chapter 5 describes the implementation process. Chapter 6 contains the conclusion of the paper.

LITERATURE REVIEW

Initially, smart buildings referred only to buildings that had a system for optimizing energy consumption. In the early 1980s, a smart building could manage systems such as lighting, air conditioning, and electricity consumption. Today's smart buildings are multifunctional systems that use the available technology of various sensors and automation systems. The systems and technologies used in today's smart building are [14]:

- Sensors - a network of sensors installed inside the building provides various information about the user's location and accordingly allows automatic control of systems such as: system for switching electrical devices on and off, switching heating on and off. An important segment in smart buildings is security. Therefore, it is necessary to ensure the security of systems in a smart building and protect them from attacks, especially the user access control system (access control), which consists of security cameras, ID devices and motion detectors. Sensors and face recognition cameras are used to identify a person in smart buildings. Unauthorized access is considered the greatest danger in a smart building.
- The access control system assigns different access rights to different users. Some functions (e.g. lighting control or air conditioning) can be assigned to all users, but some users (children, visitors) can be restricted to certain functions. The process of registration and identification of users who log in to the system should be as simple as possible, but se-

cure enough. A good solution to this problem is biometric fingerprint protection [14], but this solution is not optimal for different types of smart hospital users.

Accurate patient and visitor identification is of great importance for hospital safety [15]. It can be found in the literature that the health industry is increasingly accepting new technologies [16]. Organizations want to improve the treatment phase and make patient care easier. Hunderdon Healthcare has simplified the registration of patients, because they decided to apply iris biometrics. All users were well informed about the benefits of new technologies and there was no opposition when using this technology [3]. ImPrivata company proposes the identification of smart hospital users using PalmVein biometrics (palm blood biometrics). In this case, the patients bring their hand closer to the palm reader and the scanner recognizes the pattern of veins on the palm on the basis of which it identifies the user. This simple scanning procedure improves patient identification: It reduces errors in patient identification and reduces the possibility of infection, as there is no palm contact on the device. Palm recognition is one of the most accurate and appropriate methods of patient identification [17]. Different technologies are available for implementation in a smart hospital.

PROBLEM OF AUTHENTICATION AND IDENTIFICATION OF SMART HOSPITAL USERS

Due to the large number of users who enter smart hospitals on a daily basis, it is necessary to implement a system of records and access control. The record system should allow only authorized persons to move through the hospital. It is a great challenge to create special ID devices that will be financially optimized, and at the same time efficient enough for different types of smart hospital users. User records should be made in front of each hospital ward, hospital room or any other room. Upon entering the building, an unauthorized person must register in order to obtain an authorization to move. The identification and authentication system is performed on an ID device that needs to be optimally designed with regard to the type of

ID technology. When designing ID devices for the needs of user records in smart hospitals, it is necessary to focus on understanding the diversity of users. There are several types of users that need to be registered. Each type of user has its own work processes and its own psychophysical characteristics, for that reason the recording system must be harmonized with several parameters. The implementation of unnecessarily expensive or inefficient identification technology should be avoided. Therefore, it is necessary to design several variants of the ID device that will enable fast and efficient identification of all types of users.

For the purposes of implementing a record keeping system, it is necessary to design financially optimized devices. The paper proposes to take into account the parameters on the characteristics of user types shown in Table 1 and their user processes for the implementation of optimized devices. An integrated system for user identification and authentication (access control) should enable:

- Records of all present smart hospital users
- Reporting an incident with facilitated identification
- Control of user movement in smart hospital wards
- Control of the optimal number of doctors in certain departments
- Control of the maximum number of visitors per department
- Activation of the alarm if the number of doctors in the hospital wards is reduced,
- Parking control, etc.

PROPOSED PARAMETERS FOR IMPLEMENTATION OF AUTHENTICATION DEVICES

The parameters that affect the development of the optimal system for user authentication are presented in four groups:
- Characteristics and processes of hospital users
- Available technologies from which it is necessary to choose the optimal ones
- ID device layout by hospital premises
- User registration and identification process.

Characteristic processes of hospital users

It is necessary to implement ID devices for identification and authentication application that would be adapted to all users of the smart hospital and their user processes [5]. The design of the ID device should meet the psychophysical needs of the user and enable a simple process of user registration and identification. Table 1 lists the characteristics of the smart hospital user process that affect the authentication and identification process.

Table 1 – Characteristic processes of hospital users

User type	Characteristic processes of users
Medical staff	A fast system is needed to identify the entrance to operating rooms and hospital rooms. Work in gloves and a special medical suit.
Other staff	A fast identification system is needed in front of operating rooms and hospital rooms. Work with dirty hands, with which they cannot be registered with a PIN number.
Patients	Due to reduced psychophysical abilities, the range of proposed ID technologies, such as remembering a PIN number or carrying an ID token, has been reduced.
Visitors	The area of movement is the corridors from the entrance to the building to the hospital room where the patient the visitor wants to visit is accommodated. There are many visitors in the hospital and cheap ID technology is needed.

List of available ID technologies

A list of proposed ID technologies with advantages and disadvantages depending on the user processes in the hospital can be found in Table 2. [6] [7]. Various identification and authentication technologies are available: Biometrics, PIN number, RFID chips, barcodes. Each of these technologies has certain advantages and disadvantages. For example: RFID cards can be lost or forgotten, PIN numbers can be used without authorization, biometric systems must be adapted to the psychophysical characteristics of the user. Due to health disorders, patients cannot use any biometric system. It is impossible to expect elderly patients to remember PIN numbers. The voice-based biometric system cannot be used by patients who have a problem with sore throat.

Barcode technology requires optical visibility [6]. Unlike barcodes, the RFID system actively broadcasts data, eliminating the need for manual reading. This advantage significantly improves customer service [8]. RFID systems have a shorter scan time than

Table 2 – Characteristics of ID technologies

Characteristics of various ID technologies				
1D barcode	**2D barcode**	**RFID**	**PalmVein biometrics**	**PIN**
Requires optical visibility	Requires optical visibility	Readable even though it is not in sight	There is no transmission of the infection, because the user has no contact with the device.	4-digit number easy to remember.
Unauthorized copying is possible	Unauthorized copying is possible	RFID distance from the scanner - a few centimeters.	It is used where a higher level of hygiene is needed.	Adequate for older and younger population
Low production costs.	Easy to make, low production costs.	It can also be used in aggressive environments.	Identification is not affected by skin moisture	Cheap technology.

barcode systems. RFID is an automated solution that makes the process of identification and data collection more efficient [7].

Technology selection by user types:

a. Doctors - Emergency medical intervention in the surgical department requires rapid identification on all identification devices. An effective way of identification is for the doctor to have an RFID wristband, which will enable him to quickly identify himself by placing his hand near the scanner with a few tens of centimeters. It is possible for doctors to identify with surgical gloves, because even then, a thin RFID bracelet can be identified. The problem with RFID is the high cost of tags [14], however, the model assumption in this paper is that tags will be used exclusively by physicians and other hospital staff, which in a complete implementation will not represent a major investment. For these reasons, RFID technology was chosen for the needs of this model for the needs of doctors.

b. Other hospital staff - hospital staff need to have a fast and efficient identification system due to frequent visits to other wards, rooms or corridors. It would be inefficient if the user had to stay in front of the ID device for a long time to enter a PIN number or identify himself with Palm biometrics. The registration process would be difficult while the user is wearing hospital gloves or has dirty hands. For these reasons, RFID technology was chosen for the needs of this model for the needs of hospital staff.

c. Patients - It is impossible to expect the patient to carry an RFID device with him. For the needs of patient records, a biometric technology was chosen - PalmVein, whose advantages are: a high level of security, simplicity of the identification process and reduced transmission of infectious diseases [17].

d. Visitors - the most represented users of the smart hospital are visitors. Cheap identification PIN technology was chosen for the needs of visitor records. They need access to only one hospital ward in the hospital, and that is the ward where the patient they are visiting is lying. The visitor has the possibility to move only to one hospital room, so it is enough that the system assigns a certain PIN number to enter only one hospital room. Table 3 shows the optimal technologies by user types.

Table 3 – optimal ID technologies by user types

Users	Chosen technology
Medical staff	RFID bracelet
Other staff	RFID bracelet
Patients	PalmVein biometrics
Visitors	PIN number

Spatial units in the hospital

The data in Table 4 shows the technology IDs to be implemented on sites. The "+" symbol defines the user and the ID technology that is necessary to be installed in the ID device at a specific location in the hospital. The sign "-" defines that a certain ID technology is not required in a certain location. Each variant of the ID device will have optimal ID technology depending on the needs of a particular location. With such an approach, the implementation cost will be optimized.

Table 4 – ID device variants for user identification

Spatial unit	Doctors (RDIF)	Other staff (RFID)	Patients (PalmVein)	Visitors (PIN)	ID device variant
Registration	+	+	+	+	A
Hospital parking lot	+	+	+	-	B
Passageways	+	+	+	+	A
Waiting room	+	+	+	+	A
Registration unit	+	+	+	+	A
Spec. department	+	+	+	-	B
Cafeteria for employees	+	+	+	+	C
Warehouses	+	+	-	-	C
Apartments	+	+	+	+	A
Rooms	+	+	+	+	A
Technical rooms	+	+	+	-	B
Medical premises	+	+	-	-	C

The data in Table 4 show that it is necessary to design three variants of ID device for a specific smart hospital. Each of the devices will have selected identification technologies.

User identification and authentication process

The process of entering an unauthorized person in the hospital begins with the process of user registration. After registration, the system user accesses the ID of the device on which they need to authorize. In accordance with the successful authorization, they will receive a permit to enter the department. The system recognizes three operational processes and these are: User Registration, Successful Authorization and Failed Authorization. After registration, an unauthorized person becomes a user of the hospital and after that the security system will allow the user to move through the smart hospital after successful identification on ID devices. The list of locations in front of which the registration and identification system should be implemented can be found in Table 4. User registration - Figure 1 shows the process of registration of unknown persons. The user approaches the system administrator who inserts the smart card into the card reader. The administrator processes the data from the ID card and registers the user. The admission department

in the hospital enters in the database a permit for categorization of an unauthorized person in the category (patient, visitor).
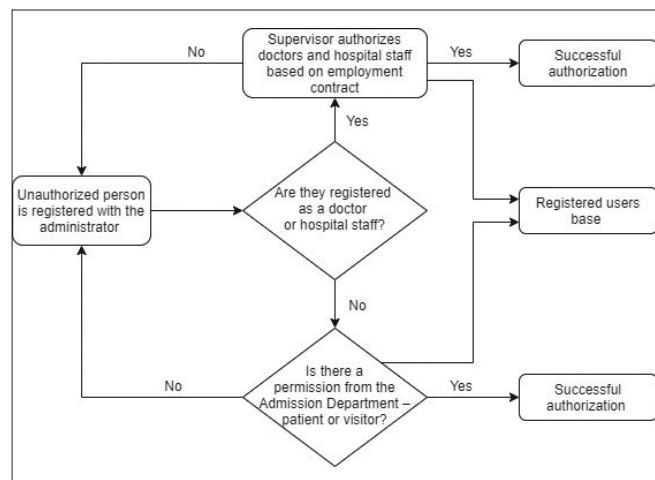
Figure 1 – User registration

The movement of the authorized user through the wards of the smart hospital is enabled by identification on the ID device. Upon successful authorization, the system will allow access to the department. Successful user identification - Figure 2 shows the successful identification process. After successful identification, the system provides access and the user is authorized to enter. The user accesses the ID device, uses one of the offered ID technologies and, depending on the authorization rules, the ID device

allows access to the department by opening the electronic lock.
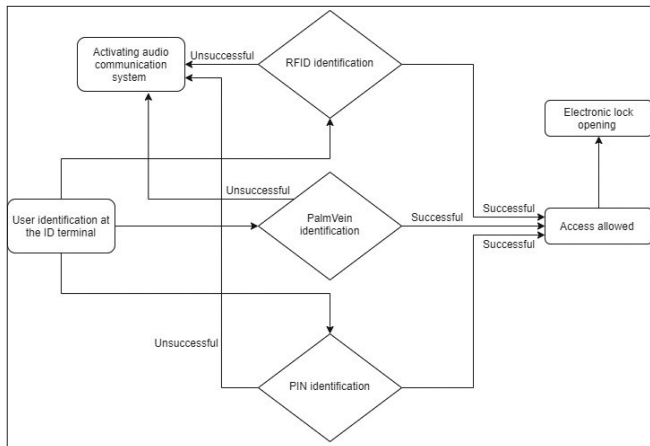
Figure 2 – Successful identification process

Failed user identification - Figure 3 shows the failed identification process. The user tries to identify himself, but the system does not recognize the user. In that case, an audio device is turned on, through which the system directs the user about the direction of movement through the hospital.
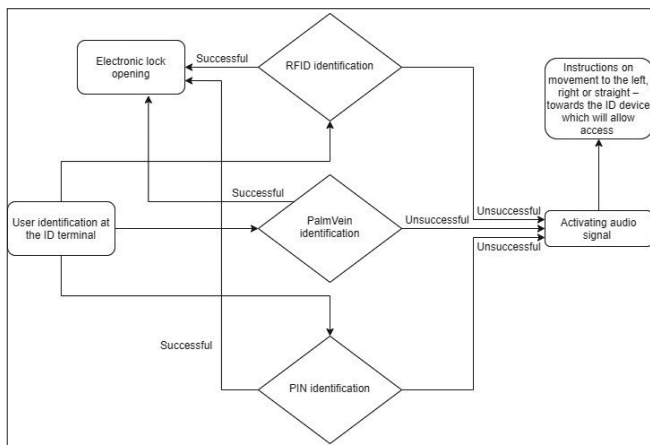
Figure 3 – Failed identification process

IMPLEMENTATION

The implementation of a user record system requires prior categorization of users and user processes that will determine the optimal ID technology. Implementation planning implies that security objectives are well defined [5]. The data analysis shown in Table 4 will determine the required ID de-

vice types. If a good estimate is not made in terms of the total number of ID devices, the system may not be able to provide the required level of security. Examples of parameters are defined on the basis of a general hospital. Analyzing the parameters from Chapter 4 of this paper, three variants of identification and authentication (ID) devices are proposed. Their implementation achieves optimized costs. Below are the processes that will run on each of the three designed interfaces.

ID device variant A - enables identification of all users:

Figure 4 shows a variant of the ID device that allows the identification of the Physician and Hospital staff to perform the process of visiting the patient, entering the operating rooms and other medical rooms. This variant of the ID device allows patients to identify themselves for the process of entering hallways, waiting rooms and rooms. Also, this variant of the device enables the identification of the visitor in the room where the patient is accommodated.
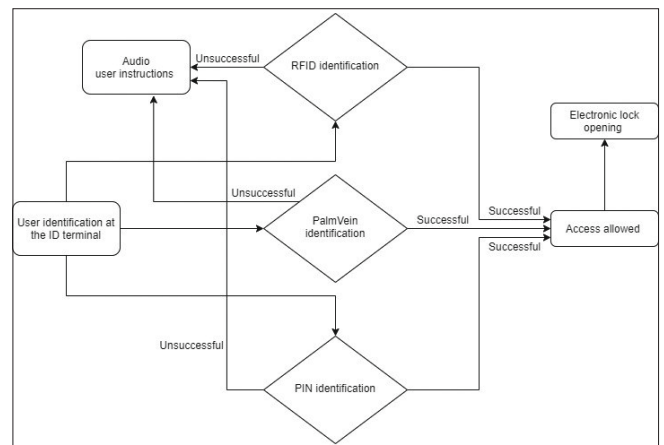
Figure 4. Identification processes on an ID device – Variant A

ID device variant B - enables identification of doctors, staff and patients:

Figure 5 shows a variant of the ID device that allows the identification of the Physician and Hospital staff for the processes of visiting the patient, entering the operating rooms and other medical rooms. This variant of the ID device allows patients to identify themselves for the process of entering hallways

and rooms. This device will be implemented in front of a location that visitors do not enter.
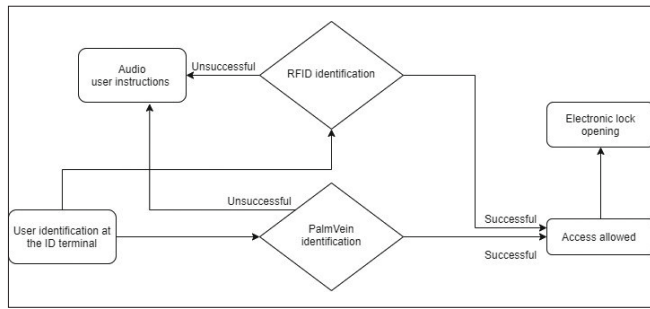
Figure 5. *Identification processes on an ID device – Variant B*

ID device variant C - enables identification of doctors and hospital staff:

This variant of the device is the cheapest to implement and enables the process of identification of doctors and hospital staff. It enables RFID identification and that is enough for their user processes: going to visit the patient, entering the operating rooms and other doctor's rooms.
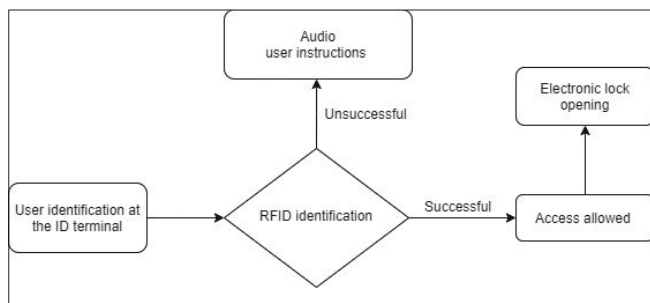
Figure 6. *Idetification processes on an ID device – Variant C*

All hospital users are registered on these three variants of the ID device. For the implementation of the user record system in hospitals, the design of the ID device is shown in Figure 7 with three interface variants arranged in the locations defined in Table 4. The selected interface must be in accordance with the user characteristics. It is necessary to test the security, effectiveness and functionality of the recording system and in that way it is possible to reach the optimal interface design. Figure 7 shows the proposed three interface models to be used in the user record system. Each of them needs to pass the use phase test. Redesign may be required during testing.

ID devices in Figures 8 - 10 are proposed. The ID devices meet the HCI interfaces defined in this paper. For the variant variant, the proposed model is from the manufacturer Dehicon [12], [13].

CONCLUSION

The presented system for user authentication in a smart hospital is adapted to different characteristics of users, their user processes, but also to periods when the possibility of infection is increased, such as the period due to a virus pandemic. The proposed set of parameters of this system enables the development of a specific system for user authentication in smart hospitals and helps in the development of different variants of the device with respect to different authentication interfaces. The innovative interface model for authentication and user access control presented in the paper is applicable in the era of a pandemic of a virus like Covid-19. The implementation process keeps track of the required HCI (human-computer interface) components depending on the users who are authorized to access a particular hospital room. Such an approach will enable the optimization of implementation costs. Us-
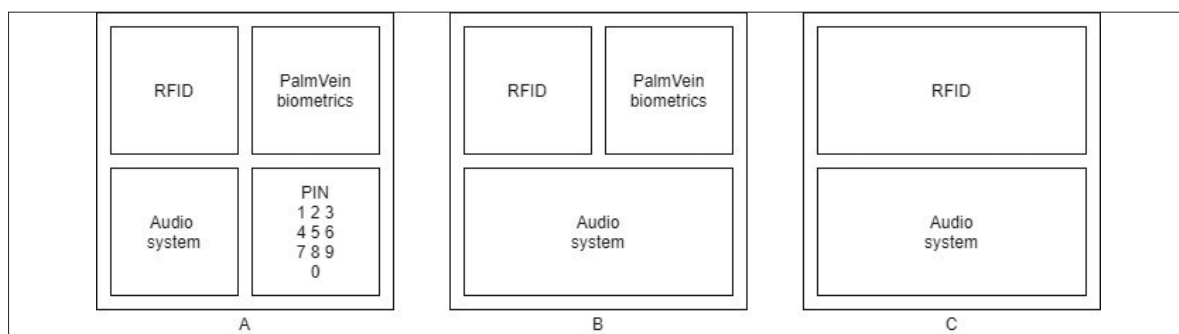
Figure 7. *Three variants of ID device: a) variant A, b) variant B, and c) variant C*

Figure 8.
ID device - variant A

Figure 9.
ID device - variant B
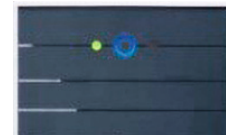
Figure 10.
ID device - variant C

ing additional software support, the functions of the user record system can be expanded with a detailed record of smart hospital users present, such as controlling the optimal number of doctors in a particular hospital ward at a given time, but it is also possible to control the maximum number of visitors per ward. In short, by choosing an adequate software component, the possibilities of control in the field of smart hospital security are expanded.

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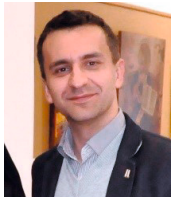
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Making Decisions in Monitoring by Using Decision-Making Method, Knowledge Bases and New it Solutions

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Abstract: In this paper we deal with decision-making processes in monitoring with the use of new technological solutions. This is an area where decision-makers in monitoring face a large number of different challenges and need appropriate specific knowledge. We give an example of a method for making complex decisions. Here we propose the application of the semantic web and knowledge bases that can provide decision-makers with a quick access to the necessary knowledge in the decision-making process. To update some of the knowledge we will use the Protégé editor, an open source platform. Our goal is not to update all the necessary knowledge needed by those who make decisions in monitoring, but only to propose a new concept to their faster fullfilment and more efficient use.

Keywords: monitoring, decision-making, knowledge base, efficient use of knowledge, methods, facilitation, business intelligence.

Introduction

Monitoring consists of continuous observations of certain activities carried out under a particular program or project, as well as report/reports accordingly. It is a process of continuous collection of information on all aspects of a particular project. The task of monitoring is to check the progress of project activities. In essence, it is a set of systematic and purposeful observations. Monitoring provides very important feedback to project donors/funders, as well as to project implementers and beneficiaries. Monitoring serves financiers to respond in a timely manner if something proves to jeopardize the desired result of the project; reporting to management benefits in the decision-making process to improve the performance of project activities; while through monitoring the final users we are tring to provide the desired level of quality of the outcome of the project to which they are entitled.

A project is a set of activities (investments) whose goal is to solve a certain problem(s) in a predicted time frame and a defined space/location. Investments include: time, money, human and material resources. Achieving the set goal, i.e. goals implies that the project will go through several clearly defined and specified phases.

Monitoring should be carried out by all individuals and institutions that have an interest in the project itself (i.e. participants). In order for the project to be implemented effectively, the persons involved in planning and implementation should plan each of the phases in advance and predict their course in as much detail as possible.

The ultimate philosophy of project implementation in the EU goes so far that the ultimate goal is no longer the successful implementation of projects as such, but ultimately "criticism" is directed to the course of the implementation process, or answering the question - how much is the process implementation selected and implemented in the most optimal way? This thinking is based on the desire to better understand the entire implementation process, more than the implementation itself, and to analyze the use, management and "maintenance/correction" of the same. Thus, the question "how well do we reach the desired goal?" makes it clear that according to the EU PCM methodology, the application of the phrase "goal justifies the means" has no place.

Monitoring is important both for the planning/ design phase of the project and for the implementation phase itself. Monitoring could be allegorically compared to recreational skiing. It is like when we ski, and we look ahead to stay in the desired direction, not deviating from the trail, and possibly avoid various obstacles, bumps and other things that could happen to us on the trail [9].

Decisions are a common part in monitoring, and they strongly influence the final outcome of project implementation and depend on the position of the decision-maker. Understanding the decision-making process can help avoid bad decisions and stimulate good ones. However, there are many factors that influence decisions, and not every one of them is known, nor the ways in which they are related. At the same time, decision-making processes, due to their complexity, are approached from different points of view, even within a certain science.

If we look at decision-making as such, during monitoring, we can see that it includes the management of a higher number of related components, such as the dynamics of project implementation, unexpected events, resource allocation, reprogramming of activities and the like. The uncertainty associated with each of these components, as well as the changing relationships that exist between them, in terms of time and space, form the very core of project management complexity. Clarifying each of these complex components is essential to responding effectively to unforeseen situations and examining how useful alternative strategies are in decision-making. However, it is very difficult to predict the consequences of such complex behavior, because they often occur within a dynamic context.

Good leadership, competent and trained to make the right decisions is essential if management wants to achieve top results and improve productivity. Monitoring, especially in the field of construction projects, is by nature a multidisciplinary area, where the successful implementation of projects requires the commitment of all parties, including monitoring, designers, contractors, investors, supervisory authorities and institutions. All of them must initiate requests, cooperate with each other, consider and understand everyday problems, as well as make decisions to solve them.

Monitoring benefits from the employment of individuals who possess developed interpersonal skills that facilitate the process of collaboration with a multitude of different stakeholders at different levels. The use and even the abuse of these skills during the implementation of projects can positively, but also negatively affect the final outcome.

The term "monitor" is a person who is responsible for monitoring the implementation of the project. It represents a person-expert who has many years of experience in monitoring the implementation of projects and who is familiar with legal regulations an, procedures for the implementation of the project, who has many years of expert experience in construction projects (discussed in this paper) and number of other characteristscs that give him the opportunity to identify all obstacles and complications that may arise in the implementation of the project.

The key associate of the monitor is the "project manager", a person who is responsible for project management and refers to project leaders, but is also used in the broadest possible sense, without a generally accepted definition due to the uniqueness of each project and system for its implementation.

In order to be able to observe a different approach to monitoring and implemention of the new ideas in faster acquisition of knowledge in the decision-making process, we will introduce some more terms that we need here. These are primarily the semantic web and knowledge bases.

The concept of the Semantic Web was introduced by Tim Berners Lee (2001) as a clear structure for the content of a Web page. It arose as a need to more efficiently find certain information and knowledge. It is based on the idea of information on the web making readable to the machine. Instead of documents linked by hyperlinks, it should use interconnected data (information) that have a specified structure and meaning [10].

For having the idea of the Semantic Web to be able to operate, computers would have to have access to collections of information. It must provide rules for reasoning about data, and enable the presentation of data and information.

In this paper, we use the Protégé editor [11], an open source platform for knowledge update that allows knowledge to be read and stored. Protégé editor provides a rich set of modeling structures and

activities that support the creation, visualization and manipulation of data and information represented in different formats.

What is often overlooked is that modern processes from monitoring in construction and construction works requires knowledge of complex financial issues and demands interpersonal skills as well, which means that monitors know all activities such as tender documents, price analysis, price control, construction contracting works, planning of works, etc. Unlike from the managerial position e.g. in sales, monitors have to deal with a large number of different tasks and processes for each construction project.

The key contributor to the project monitor is the project manager, as he not only oversees all actors in the project implementation, but he also makes decisions about their engagement and must provide: purpose, direction and motivation to both contractors and subcontractors who work for them, who do not necessarily have the same or similar structure of their organization and working processes.

Each discipline requires from its managers to perform similar duties, although the true nature of these duties depends on the project. For example, a designer or engineer typically manages processes related to the design and construction of specialized facilities or structures. In the construction industry, although some of the responsibilities are duplicated, given the category of work, each of the managerial positions deals with different participants in terms of supporting the construction project and the goals of the construction organization. Therefore, managers must possess specialized interpersonal and leadership skills, especially when it comes to decision-making in various managerial positions. Solving problems and making appropriate decisions is an interpersonal process. Behavior during the decision-making process is directly related to the achievements of the individual on each construction project, as well as the achievements during his career in performing the assigned tasks.

The quality of decision-making within activities and success of monitoring depends to a large extent on those who make decisions, what skills and abilities they possess, what their management style is, and what techniques and methods they use in decision-making [1]. Therefore, it is not only the application of appropriate techniques and methods in decision-making that is important, but also the professional skills, education and experience that monitors have.

All individuals, involved in the implementation of a construction project, are exposed to situations where a decision must be made. Their decision-making process involves many aspects and is influenced by several connections and factors. Here will be presented, the decision-making process with using the semantic web and knowledge bases, so that the necessary knowledge can be obtained faster and the decision-making process itself can be better understood.

Using the Protégé editor, an open source platform, we will update only some basic knowledge related to the decision-making process: decisions are part of everyday life and affect the lives of individuals (help to avoid bad decisions; stimulate good ones).

Some factors that influence decisions in monitoring are: labor productivity; unexpected events; resource allocation and reprogramming of activities (uncertainty associated with each of the components; variable connections that exist between them (time, space).

Good leadership: is competent; trained to make the right decisions; supervises associates; provides purpose, direction and motivation; must possess leadership skills; ensures the success of monitoring, is of appropriate education and appropriate experience (Figures 1 and 1a).
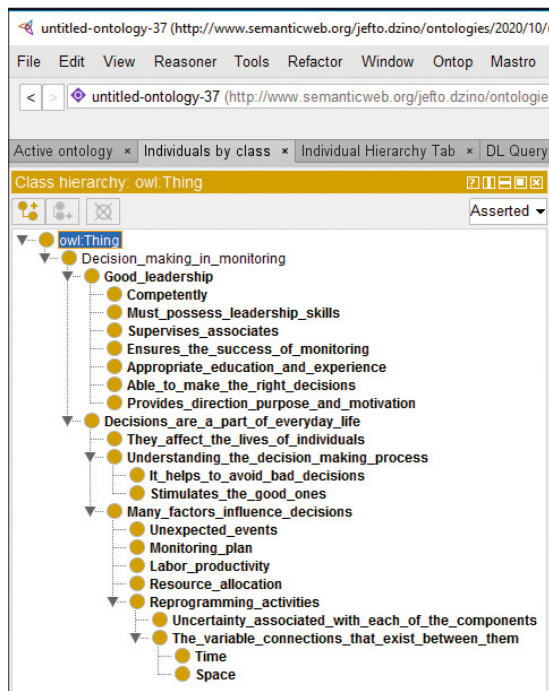
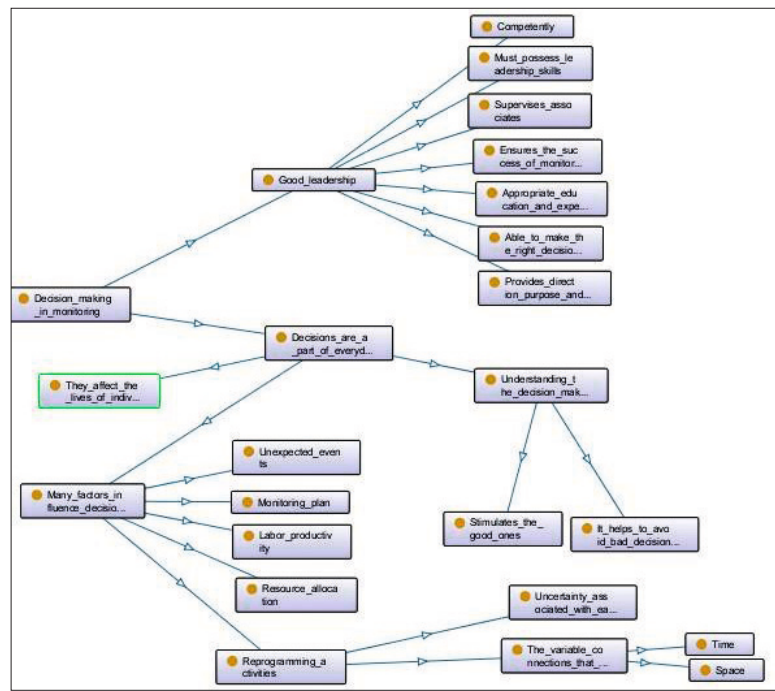*Figure 1. Basic concepts related to the decision-making process*

Figure 1a. OntoGraf - Basic concepts related to the decision-making process

DECISION-MAKING IN MONITORING

In monitoring, decisions are made every day, both small, everyday decisions, and those related to the project implementation strategy. There are many significant factors that influence decision-making, and they can be seen as the final outcome of the process, apropos the choice between different options [6]. The decision-making process can be viewed as a unity of the following phases: the "before-decision" phase, the "decision-making" phase and the "after-decision" phase.

In the decision-making process in monitoring, the main goal is to implement the project without any other alternatives existing. There are two basic approaches in the decision-making process, the goal-oriented approach and the procedure-oriented approach [8]. A goal-oriented approach implies the possibility of predicting the outcome, and a procedure-oriented approach is one in which the process is in the center of attention.

According to Turban, (2011) there are several stages in the decision-making process [9]:

Information gathering phase: The information gathering phase is a process in which the decision-maker examines reality, in order to identify and define the problem. The decision-maker searches for conditions that require a particular decision.

Design phase: This phase refers to attempts to find, develop and analyze all possible courses of action for the rest of the process. The design phase implies creativity, which means that decision-makers are looking for alternative solutions, which they then analyze in more detail.

Election phase: In the election phase, a real decision has already been made and a certain course of action is being followed. The decision-maker compares the best solutions available and then chooses the best ones.

Implementation phase: In the final phase, the decision implementation phase, the selected solution is applied.

One should always have in mind that after realization, this process does not stop. Continuous monitoring of the decision-making process in monitoring is crucial, in order to achieve the best results and ensure the implementation of the project.

Using the Protégé editor, we will update the basic terms related to the decision-making stages. Stages in the decision-making process: Gathering information - (decision-maker examines reality, searches for conditions); Design phase - (finding and analyzing possible courses of action); Selection phase - (a real
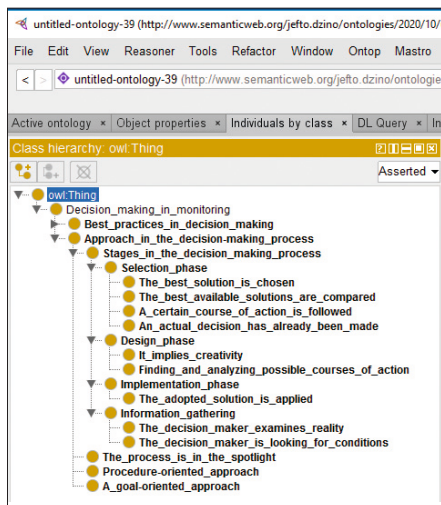
Figure 2. Decision-making phases
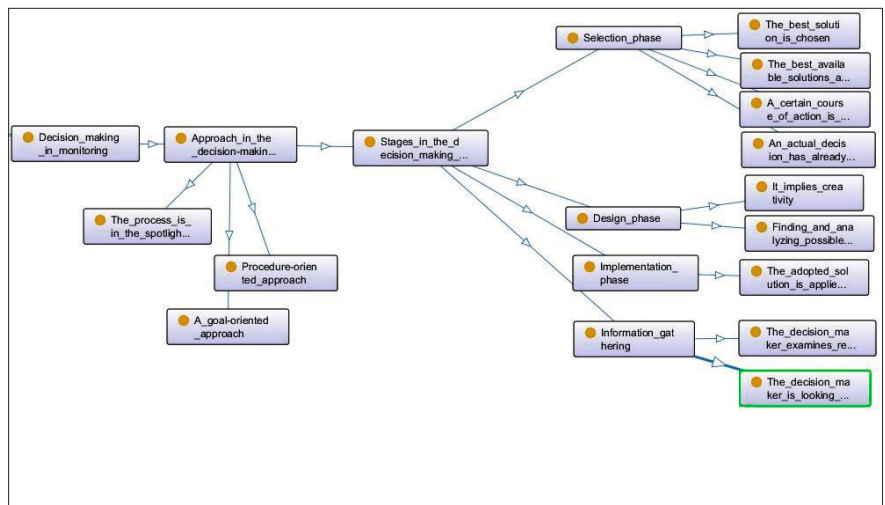
Figure 2a. OntoGraf - Phases of decision-making

decision has already been made, a certain course of action is followed, the best available solutions are compared, the best solution is chosen); Implementation phase - (the adopted solution is applied), (Figures 2 and 2a).

BEST PRACTICES IN DECISION-MAKING

Often monitors rely on common managerial approaches that work well in some conditions but not in others [5]. Why do these approaches fail, even when logic says they should prevail? The answer lies in the basic premise of organizational theory and practice: that a certain level of predictability and order exists in the world. This assumption, based on Newton's science that forms the basis of scientific management, encourages simplifications that are useful in regulated circumstances. Circumstances change, however, as they become more complex, simplifications may fail.

Monitors in their decision-making can encounter: simple situations, complicated situations, complex situations and chaotic situations.

Simple situations: The domain of good practice

Simple situations are characterized by stability and a clear cause-and-effect relationship that any monitor can easily spot. The right answer is often obvious and indisputable. In this area, the decisions are undisputed because all parties share the understanding. Simple situations, properly evaluated, require direct management and supervision. Here,

monitors recognize, categorize, and respond. They assess the facts of the situation, categorize them and then base their response on established practice.

Since both project monitors and implementers have access to the information necessary to deal with the situation in this area, the command and control style for establishing parameters works best. Recommendations are specific, decisions can be easily delegated, and roles can be automated. Exhaustive communication between the monitor and the project implementer is usually not required, as there is rarely disagreement about what needs to be done.

Complicated situations: The domain of experts

Complicated situations, unlike simple ones, can contain more correct answers, although there is a clear connection between cause and effect, not everyone can see it. While monitors in a simple situation must recognize, categorize and respond to the situation, monitors in a complicated situation must recognize, analyze and respond. This approach is not easy and often requires expertise. Making decisions in complicated areas can often be time consuming, and there is always hesitation - a lot of time from finding the right answer to making a decision. When the right answer is unattainable and when the decision must be based on incomplete data, the situation is more complex than complicated.

Complex situation: Occurrence domain

Most situations and decisions in project implementation are complex, due to some major change - bad weather conditions, bad quarter, changes in monitoring, changes in project implementation procedures, etc. which represent unpredictability. In this area, only in retrospect can one understand why things are unfolding in a certain way. Instructional patterns, however, can arise if the monitor performs experiments that certainly fail. Therefore, instead of trying to impose a course of action, the monitor must patiently allow the way forward to be shown. They must first examine, then see, and then answer.

Chaotic situations: The domain of quick reaction

In chaotic situations, looking for the right answer would be pointless: The connection between cause and effect is impossible to determine, because they are constantly changing and there are no suitable patterns - just turbulence. This is an area of inaccessibility.

Business schools and organizations prepare managers to operate in regulated domains (simple and complicated), but the monitor usually has to rely on its natural abilities when operating in a disordered environment (complex or chaotic). When faced with greater complexity today, however, intuition, intellect and charisma are no longer enough. Monitors need resources and approaches to monitor projects through lesser known waters. In the complex en-

vironment of today's business world, monitors are often asked to act contrary to their instincts. They will have to know when to share power, and when to keep it to themselves, when to turn to the wisdom of the group, and when to consult on their own. A deep understanding of the situation, the ability to accept complexity and paradox, and the will to flexibly change the managerial style, will be necessary for monitors who want to allow things to unfold at a time when uncertainty is growing.

Using the Protégé editor, an open source platform, we will update only some basic knowledge related to best practices in decision-making: Simple situations - the domain of good practice (characterized by stability and clear connections (monitors recognize, categorize, respond)). Complicated situations - the domain of experts (clear link between cause and effect; Monitors see, analyze and respond -) (requires expertise, requires a lot of time), Complex situation - the domain of occurrence (the monitor must examine, see and answer); Chaotic situations - the domain of rapid response (the relationship between cause and effect is difficult to determine (deep understanding of the situation, ability to accept complexity, ability to accept paradox, willingness to change managerial style)), (Figures 3 and 3a).
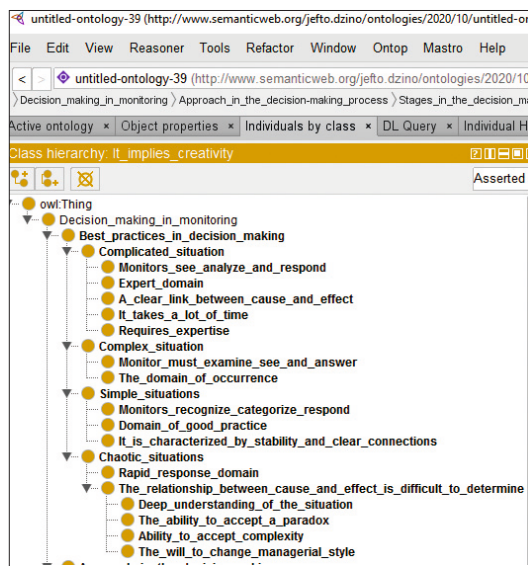
Figure 3. *Best practices in decision-making*
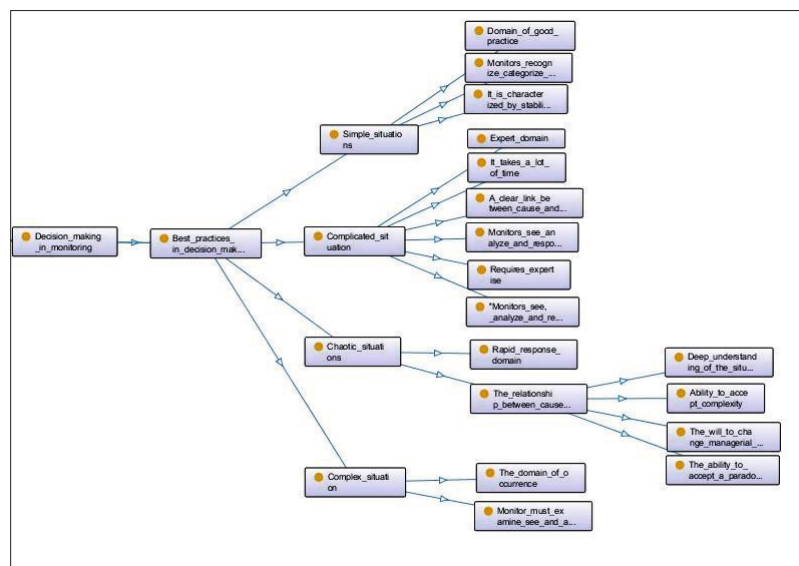
Figure 3a. *OntoGraf - Best practices in decision-making*

Nowadays, the time of modern business, modern way of doing business, those who make decisions need new technological solutions to quickly get the necessary knowledge. Quality monitors must have the appropriate knowledge, skills and experience in the field of construction management. This is necessary because the decisions that are made are of different complexity in different areas.

In modern business conditions, monitors must find the best way that means project implementation, harmonization of profitability levels, meeting the needs of investors, efficient use of resources, and key elements of progress and responsibility. A good knowledge base can certainly help them in this.

DIGITAL DATA EXPLOSION

Digitization ensures that huge amounts of data are easily accessed. Data on suppliers, deadlines, subcontractors, occupancy of construction machinery, their efficiency and many others can be obtained almost in real time. Most construction companies are ready to share all types of information with monitors, project managers, subcontractors and suppliers online.

Almost since the invention, IT systems have helped automate the process. Now monitoring has a practical way to standardize the processes they have perfected and sell them to others. Any process that is the best, but not crucial to the competitive advantage of monitoring, can be turned into a profitable business. Cloud computing makes such capabilities more accessible, as it allows easy software distribution, simplified software version control, and the like [7].

Lately, information technologies have been deviating from their traditional role of automation and reducing business and process management costs. IT will continue with this function but will increasingly provide new business opportunities. The faster they progress, the more opportunities open up [2].

Technical and analytical progress in the analysis of large amounts of data is crucial for the development of business intelligence. By processing, storing and transmitting data at extremely low prices - digitization has the capacity to change almost every form of human labor. Digitization and analysis of large amounts of data will open up new possibilities, and this will lead to new challenges. Remote

teams are available, and the traditional hierarchical structure is disappearing and transforming into an increasingly flexible, internal and networked structure.

Well-established business models based on digitalization and processing of large amounts of data, aim to optimize existing processes, and increase the efficiency of monitoring and thus the construction and quality of products and services. Digitization reduces transaction costs for information gathering, communication, and control activities.

Using the Protégé editor, we will update the basic concepts related to what digitization provides, which are: a large amount of data; easy access to data; getting data in real-time; analysis of large amount of data; opening up new opportunities and reducing transaction costs.
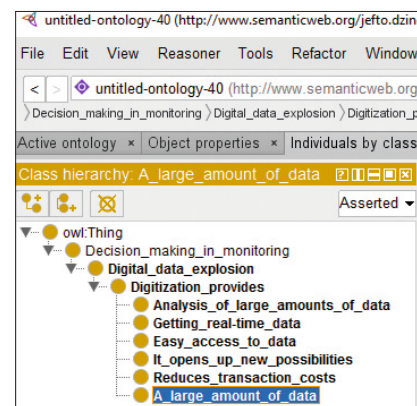
Figure 4. Digitization

METHOD FOR DECISION-MAKING

During the work, unforeseen circumstances can jeopardize the implementation, and decision-making is a key factor in the implementation of projects. How to choose the right decision and how to act is a question that we all ask ourselves, this comes to the fore especially when a decision, which needs to be made, includes several participants and is neither easy nor simple to make. In circumstances when the implementation of the project is in question, it is necessary to gather all actors and choose a decision.

We can say that making a decision seems simple, because in everyday life we make a number of decisions, but in complex decisions we need to consult, to explore, to consider several solutions that can be made as a decision, to choose one solution - a decision, to discuss the same and to consult whether it

is correct and then say that we have chosen is the right decision.

In practice, making a decision is one initial step, followed by the responsibility of who will implement it, which is also a challenge, because by making a decision we have done nothing if we do not have a person in charge of it.

What is a challenge in making decisions is that they do not just stay on paper or in the air, we have a decision, we have a person who is in charge of that decision, but it is necessary to implement that decision in practice, so we need a person who is in charge to implement it. In practice, for decisions that are not complex and it is related to just one person, but for complex decisions these may be different people.

Guided by these facts, our recommendation is to use the facilitation [4] and method called "final decision" that we have created for these needs in these cases.

The French writer Antoine de Saint-Exupery [12] said, "Force (the enemies) to build a castle together and you will turn them into brothers."

The purpose of the "final decision" method is to reach a solution to the problem, how to implement the solution and take responsibility in the implementation plan to ensure the implementation of the solution. The method uses external experts for help - people who are recognized experts for a given problem. The complexity of the method is reflected in the fact that it not only provides a solution, but also brings a way to implement the solution in oreder to ensure the implementation of the solution.

For the purpose of preparation, the topic-problem should be clearly defined. Experts prepare lectures-case studies in accordance with the topic-problem. All participants in the meeting should be introduced to the topic, forward all professional literature and available documents.

MODE OF OPERATION

Preparation: After scheduling a meeting or workshop, facilitators collect material (expert and scientific literature as well as available documents) from experts, contractors and the participants themselves in order to prepare and send it to all participants.

This is a very important and responsible job that needs to be done as best as possible.

The facilitators, in consultation with the participants, determine the time required for the materials to be read and for the participants to be prepared until the beginning of the workshop.

The exchange of materials between the participants is desirable - it should be stimulated.

In preparation, participants are divided into groups of 3 to 8 members.

For the purpose of the process of the method to be presented, suppose that we wil work in three groups.

The method consists of three working parts:
1. The first part refers to decision-making - solution
2. The second part refers to the manner of implementation of the decision-solution
3. The third part refers to taking over responsibility for the implementation of the decision-solution
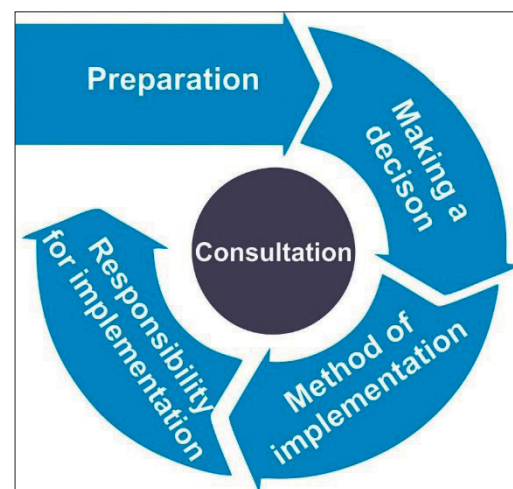
Figure 5. Flow of the method

PROCESS OF THE METHOD

Part I - Adoption of the final decision

1. Adoption of principles - total duration 45 minutes
   a. Explanation of the mode of operation
   b. Work in groups - lasting 20 minutes
   c. Group presentations - a total of 15 minutes (e.g. if we have three: 3x5)
   d. Adoption of the principle - lasting 10 minutes

2. Expert opinion on the topic-problem - total duration of 45 minutes
   a. Introduction to the problem - lasting 10 minutes

b. Explain the problem - in 10 minutes

c. Best practices - lasting 10 minutes

d. Questions - lasting 15 minutes

3. Discussion - total duration 45 minutes

a. Work in groups - lasting 20 minutes

b. Presentation of the solution - lasting 15 (3x5) minutes

c. Adoption of possible solutions in three to 10 minutes

4. Expert opinion on solutions - total duration 45 minutes

a. Expert presentation - for a total duration of 15 (e.g. if we have three 3x5) minutes

b. Questions - lasting 10 minutes

c. Work in groups - lasting 10 minutes

5. Adoption of the decision - solution - for 10 minutes (the method that can be used here is voting or by everyone writing their name on the stick and sticking to the solution they consider the best)

Part II - How to implement the final decision - solution

1. Way of implementation of the final decision - solution - total duration 75 minutes

a. Work in groups - lasting 20 minutes

b. Presentations - lasting 15 minutes

c. Expert opinions - lasting 10 minutes

d. Questions-discussion - lasting 10 minutes

e. Adoption of the final plan - lasting 10 minutes

f. Deadlines - lasting 10 minutes

Part III - Taking responsibility - total duration 15 minutes

a. Taking responsibility - 15 minutes

CONCLUSION

The success of project implementation is significantly influenced by decision-makers, what skills and abilities they have, what is their management style, what techniques and methods they use in decision-making. It is not only the technique in decision-making that is important, but also the professional opportunities and experience that managers have, and especially their education.

Good leadership is essential if monitoring is to achieve quality project implementation. Monitoring in the field of construction projects is by nature a multidisciplinary field, where successful project implementation requires the engagement of everyone, including monitors, project managers, designers, contractors, designers, users and institutions. All of them must initiate requests and cooperate with each other.

As complex decision-making is a challenge, here is a method with precisely stated processes that
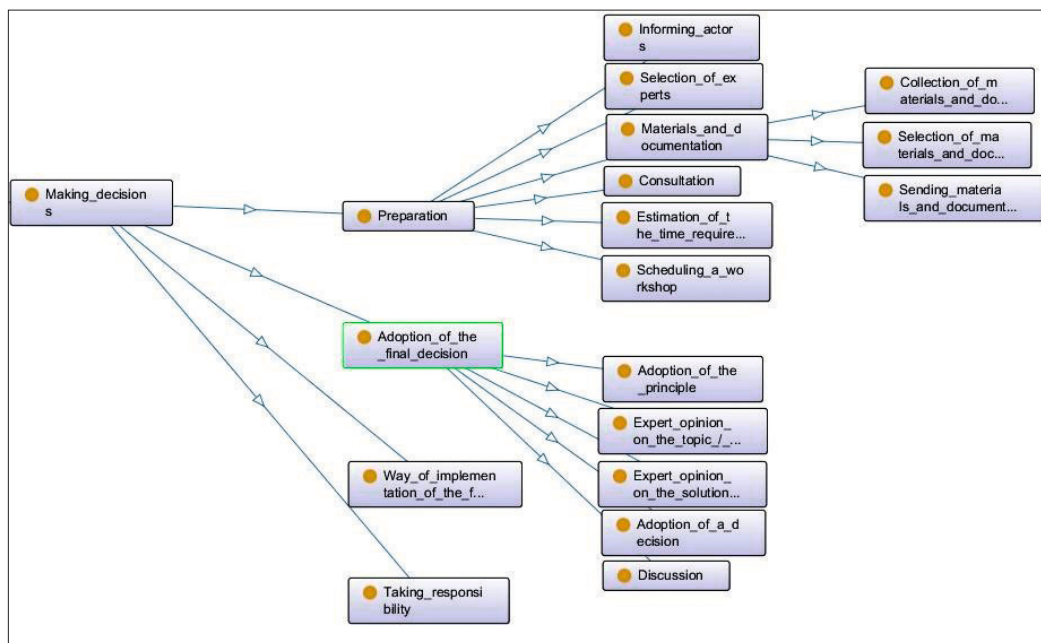
Figure 6. OntoGraf - final decision method

can be used in making such decisions. Modern processes of monitoring construction projects include complex issues and demanding interpersonal skills, which means that monitors are engaged in activities such as monitoring the progress of project implementation, price bidding, price control, tenders, project planning, etc. Project managers have to deal with a multitude of tasks and processes for each construction project or completely different types of projects. They must possess specialized interpersonal and leadership skills, especially when it comes to decision-making in various managerial positions.

There are several important factors that influence decision-making, and the decision can be seen as the final outcome of the process, i.e. the choice between different options. Lack of information is usually considered an important constraint for decision-maker, along with constraints on decision-maker in terms of attention, memory, understanding and communication. Within these limitations, the basic assumption remains that the decision-maker strives to be rational.

The information available to decision-makers contributes to their ability to understand whether they are for or against a decision, to measure the usefulness, and to assess the possibility of an outcome. Quality information increases a decision-maker's ability to make good decisions.

Business intelligence significantly improves the business decision-making process, as it can provide knowledge to the decision-maker. Knowledge is more valuable than data and information because it is closer to action and can be used to make more correct decisions. Intelligence represents knowledge about the environment and serves as a basis for making quality decisions. Business intelligence directs attention to spotting important directions and patterns as well as the connection between project implementation and its environment. Therefore, it can be said that business intelligence is active knowledge about the application of information content.

The application of business intelligence significantly improves the business decision-making process, because its use makes knowledge more valuable than data and information. Intelligence represents knowledge about the environment and serves as a basis for making quality decisions. Business

intelligence directs attention to spotting important directions and patterns as well as the connection between project implementation and its environment. Therefore, we are of the opinion that business intelligence is active knowledge about the application of information content. Business intelligence includes a series of activities, guided by the specific information needs of those in charge of decision-making, with the goal of achieving a competitive advantage. Through business intelligence processes, monitoring can collect, analyze, store and share accurate and useful information, necessary for monitoring and decision-making. The paper is part of research and solutions for the purpose of using information and knowledge from databases and for the purpose of decision-making.

Here we have shown how the decision-making process in monitoring can be carried out using knowledge bases and the semantic web. Decision-makers can also use a specially created method when making complex decisions. Those who make decisions face different challenges and it is necessary for them to be able to get the necessary knowledge quickly, and knowledge bases can help them in that.

The purpose is to propose a new approach in the use of knowledge to those who make decisions in monitoring, with the aim of making decisions easier, faster and more efficient.

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FOR CITATION

FOUR-LAYERED STRUCTURE OF E-GOVERNMENT SYSTEMS

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Abstract: The structure of the e-government systems plays a vital role for provision of quality of e-services offered. These systems are quite complex deploying the most advanced technologies and developed and rich countries minimised this complexity with centralised systems. However, the less developed and countries with limited financial support are creating distributed and decentralised systems trying to keep the pace with more developed in provision of e-government services. The common identifier for both types of the systems is four-layered structure, which provides quality of service provision. This paper discusses the four-layered structure of e-government systems on cases of Estonia, Serbia and Bosnia and Herzegovina. The four-layered structure was found as the quality solution for distributed and decentralised e-government systems.

Keywords: e-government, quality, structure, four-layer, X-tee, X-road.

INTRODUCTION

Information systems have a number of functions (data collection, processing, storage and distribution), so in relation to them and their application in business systems, information systems can appear in the form [1][2]: **a) Centralized information systems** that involve processing and storing data and information on a central computer (Mainframe); **b) Decentralized information systems** - as opposed to centralized - logically centralized (each doing its job or function independently of each other), and decentralized in a physical sense (in different locations or departments), where each unit has its own database managed by maintains, and **c)Distributed information systems** - created as a combination of the two mentioned above, combining their best characteristics (e.g. use of a central database)

There are examples of partially or completely centralized e-government systems, such as examples in Estonia, Bahrain, Singapore, India, Korea, Sweden, etc. These are countries that have invested significant funds in the infrastructure of these systems and educating the population to use the e-services they provide through these systems. However, many less rich and less developed countries, such Bosnia and Herzegovina, have electronic public administration systems (e-government) usually in the form of complex and distributed systems with centralized management and organization. For such countries, the development of the centralised e-government is less likely due to the lack of investment funds. Therefore, the system emerges gradually and without a systematic approach causing different problems, leading to the lack of the quality in provision of services. Depending on the capabilities and financial capacity, the units of the public administration system are developing their systems with different speed, quality and with engagement of different contractors. There is no single system for managing the functional units of the system (as is the case with centralized systems), so we can assume that these systems are physically decentralized because only one part is connected to a central local computer network (for example, ministries in the Governmental building), while the other part of the public administration system is decentralized (physically separate and remote, such as local governments or some agencies) and distributed (because each of these units has its own data processing and its own database that

it maintains). This means that these systems are very complex for managing and achieving a higher level of services automation by the public administration system, which is one of the main objectives of the e-government introduction. In other words, the quality of services provided by e-government will be strongly related to the effectiveness of the system architecture. According to the International Telecommunication Union, the quality of services depends equally on network performance and non-network performance [3]. In this respect, we can say that the layered architecture is seen as a part of non-network performance and, as such, influences the quality of the whole e-government system, including the quality of services provided.

The recent study [4] analysed 28 different architectures observed in more than 100 papers discussing it. This paper analysed primary architecture characteristics and building blocks (related to standards, technologies, and recommendation and not as the elements of the architecture) not paying attention to the layer structure of the analysed architectures. From the other hand, Helali at all [5] define seven architecture types concerning mainly developed countries, excluding Jordanian type as developing country.

Analysing and comparing existing architecture of e-government systems, less developed countries can prevent quality problems with introduction of proposed four-layered architecture by Ebrahim and Irani [6]. Although this solution is not fully replacing centralised e-government solutions in respect of accomplishing interoperability, it will significantly minimise lack of interoperability and will provide user experience of seamless functioning. The intention of this paper is to point on use of four-layered architecture as a temporary and transition solution for achievement of full functional e-government.

METHODS AND MATERIALS

Talking about e-government architecture, we primarily consider defined standards, infrastructure components, applications (software), technologies, business models that we try to regulate facilitated interaction between users and public administration systems, but also increase public administration productivity. The introduction and organization of the e-government system itself is a very complex,

time and financially demanding undertaking that cannot be realized "overnight" but requires a systematic and informed approach that will minimize the initial costs of introducing e-government. These costs can be very high, depending on the state of infrastructure in public administration institutions, but it is very important in such a strategic approach to pay attention to the architecture of such a system. There are several studies from the early 21st century that have discussed the architecture or components of e-government [7] [8][9][10]. Each of these studies gives its own view of the organization of e-government systems and each of them has its advantages and disadvantages., The study of Ebrahim and Iran from 2005 on four-layer architecture [6] was used as the most comprehensive. Also, already mentioned papers by Baheer and Helali [4] [5] provided significant variety of solutions explaining the architecture, which were considered in structuring and writing of this paper.

To establish e-government with quality and with as few problems as possible, as well as to understand other factors that condition quality establishment, it is necessary to study and accept the generally accepted and most common structural model of e-government based on four-layer architecture. This model of the architecture of the public administration system is the most frequently discussed model by the scientific community [6]. The described architecture is conceived as a hierarchical one which seeks to integrate technologies to provide unhindered flow of information and data, as well as quality communication and customer service. The authors propose a four-layer architecture, as shown on Figure 2, consisting of:

- Access layer
- E-government layer
- E-business layer
- Infrastructure layer

Logical layers are merely a way of organizing e-government system from the software development point of view. Typical layers include Presentation, Business and Data – the same as the traditional 3-tier model in software engineering theory and practice. Analysing different sources of information for this paper, we have observed that there is a need of clarification of the term „layered architec-

ture". Namely, the software engineering literature recognises terms „layer" and „tier" in respect of the architecture. In this paper, we shall use term „layer", which explains the logic of the organisation of the architecture. These layers might run on different computers or in different processes on a single computer or even in a single process on a single computer. This is important to notice as we are here dealing with the decentralised systems. Therefore, we are discussing a way of organizing a system into a set of layers defined by specific function(s).

From the other hand, „tiers" are not in focus of this paper as they deal with the physical location of the implementation of the tools and devices. Therefore, for the purpose of this paper we consider layers more important as the systems in focus of this paper are classified as highly complex, distributed and decentralised. Physical tiers, however, are only important if looking where the specific code runs. In other words, the tiers are places where layers are deployed and where layers run. In other words, tiers are the physical deployment of layers.

Efforts of e-government are to enable centralization and achieve cohesion of public administration services that are available to users. Therefore, the integration of e-government is seen as a critical success factor for achieving a higher and more mature level of e-government development [11] [12]. One of the most important factors preventing this integration is the lack of interoperability of the e-government system architecture caused by the inflexibility of inherited IT resources and systems, as well as the inherited business processes that make up the e-government system. [13]

As early as 1998, the Estonian Government initiated a strategic approach to addressing the efficiency of public administration. Thus, already in 2000, a pilot implementation of networking of institutions appeared by connecting three databases and their exchange using XML-RPC (XML Remote Procedure Call) standard protocol. Estonia has simply used existing technologies and applied them in a new way in the context of state governance. The outcome of this new application of existing technologies in 2001 was named X-Road [14] [15]. After that, additional improvements were made and new items were added, and as of 2018, X-Road has been renamed X-tee, which includes the entire collabora-

tion system, while X-Road only implies the technology underlying X-tee.

An example of a solution in the direction of centralization of public administration e-services is given in Figure 4, which shows the possible centralized logical architecture of the electronic public administration system from the study according to Starčević [16]. Centralization has been established through the e-government backbone and the central portal, as well as a resource dictionary that supports the integrity of the system's functioning. Users can access the services through the central portal, or directly through the information system of the competent first instance body in charge of working with users.

Both of studied cases are following four-layered structure as in the work of Ebrahim and Irani.

RESULTS AND DISSCUSSION

Further is the discussion of the four-layered structure by Ebrahim and Irani [6], as well as examples of e-government structures of Estonia, Serbia and Bosnia and Herzegovina.

Access layer

At the top of the architecture proposed by Ebrahim and Irani is an **access layer** whose main task is to be an intermediary layer between the end-user and the e-government system. This layer describes who can use publicly open administration e-services, but also shows the channels for access to the services. The model dates from 2005 the model shows communication channels existing at the time. Of course, the model should not be understood as finite and immutable, and therefore the number of channels depends on the available technologies and solutions.

Also, it is important to mention that the access layer covers communication channels that work in both "online" and "offline" mode, which, again, seeks to emphasize the constant availability of e-government. The essence is that this layer exists to enable communication between the user and the system, thus representing a kind of interface to the system.

A two-way arrow at the figure 2 indicates two-way communication of the access layer with the e-government layer enabling different communication models (G2B, G2C, C2G, C2B, etc.). This is very in case of "more mature" public administration systems in which various e-services are provided including the

transaction services. What is an important feature of this layer is that this layer is the simplest in the whole architecture because it is managed by users of e-government services.

E-government layer

The **e-government portal** is a key element of this architecture. It is a place of single access to e-government services (Single sign-on portal) that facilitates improved access to services. The role of this layer is to integrate data and information from several data repositories, from different agencies and public administration institutions that is typical for distributed systems. Integrating data from different databases is invaluable for both users and creators of public administration services, because in this way it is possible to solve a certain problem or provide a certain service with a significantly smaller number of steps for the user. As represented by the scheme, this unique portal consists of a series of elements (sites and applications) through which the user can interact with the unit or public administration that provides selected service. Complexity is reflected in the structure of the portal and the number of links between the elements and the portal. The functionality of the portal, as a single point of access, depends mostly on quality of communication thorough these links. Single sign on portal enables savings in terms of costs associated with the provision of public administration services, raises the quality-of-service delivery, but also facilitates the work of units or institutions of public administration that no longer have to suffer the pressure of physical presence of clients in the service area.

As the most important element of the portal is, from users' point of view, the construction of the portal user interface. The user interface of such a complex system must meet the highest standards in terms of functionality and especially the visibility of the functionalities and services it offered. It is very important that the user finds and use the requested information or service in the easiest possible way, with minimal number of clicks thus reducing the overall occupancy of resources on both sides (the client and the server).

Between the access layer and the e-government layer is also duplex communication enabling exchange of communication and information in real-time or delayed communication. This also shows that the e-government layer behaves as the presentation layer of the e-government system.

An example of such a e-government portal is the portal of the European Union (http://www.europa.eu) or the European Commission (https://ec.europa.eu) which serve as a starting point for further use of services offered by these institutions to users, such as European Funding and Tender portal (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home) presented in Figure 1. This is the only and the starting point for applying to available funds,
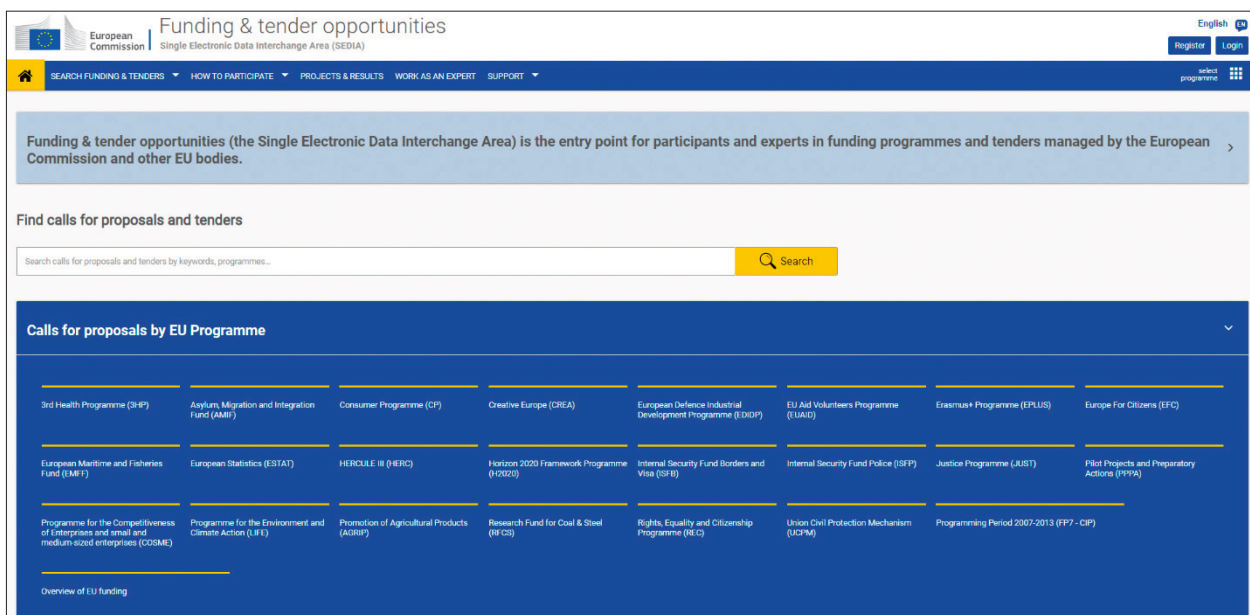
Figure 1. Example of the single-sign-on portal of the European Commission's funding

from where the portal leads you to different parts of the system related to the competitions, applications, payments and other necessary functionalities.

E-business layer

Despite the complexity of such a system, the real problem solving is enabled using applications, catalogues, and other elements of the public administration **e-business system**. This layer aims to ensure automatic, high-quality, and real-time feasible communication between the various subsystems that make up a single system of public administration. This is a key layer of G2G communication, including G2E and E2G (communication of employees with public administration institutions) since this layer is maintained by engagement of employees in public administration themselves. In this way, employees are enabling quality exchange of data and simplification of work processes, including automation of certain business processes. In essence, this layer enables the true connection of the elements of the public administration system into one functional unit.

The following applications stand out as the most important:

- **Document Management System** - enabling uniform and quality document management within the system;
- **Customer Relationship Management -** to monitor users and organize business processes according to customer needs;
- The **Enterprise Resource Planning** – enabling monitoring of business in the system as well as integration of information flow through the system (including modules such as financial module, human resources module, etc .);
- **Web Service Applications** – enabling the use of e-business applications in a web environment (most often on the principle of "search" and "answers" (Request and Reply), "search" (Search), etc .);
- The **Enterprise Application Integration (EAI)** – enabling the integration of intra- and inter-organizational systems reducing development and integration costs;
- The **Electronic Data Interchange** - for the transfer of structural data and services using standardized messages between computer applications;

- The system of **collaborative tools (Groupware)** - enabling cooperation, sharing and organization of information for a particular group of people with the aim of facilitating different tasks.

A two-way communication between the layers of e-government and e-business indicates cooperation and interaction between these layers, and thus complements one of the previous views on duplex (two-way) communication both within the system and with users (in this case civil servants working in e-government system).

Infrastructure layer

Agreed standards and applied best practices, as well as communication protocols between systems that communicate with each other, represent a significant component of the infrastructure layer in addition to hardware as the foundation of quality public administration system infrastructure. **The infrastructure layer** technologies aim to support and unify the operations of the information system and related e-business applications using the necessary standards and protocols in network access, such as:

- A **Local Area Network (LAN)** - computer network connecting computing devices and enabling the exchange of data within a narrow environment such as a company, a building, or a department, etc .;
- **Servers** are specialized computer machines enabling the operation of applications and databases that "run" on them, including the servers enabling the communication via the Internet, intranet and external communication channels;
- The **Internet** - a key medium for wide use of public administration services facilitating exchange of data or connection with users;
- **Intranet** - enabling connection, communication and sharing of resources to employees of one institution in a secure way using web-based technologies and protocols;
- An **extranet** - a controlled private network, accessible to those who are not employed but with prior authorization and assignment of access credentials and can be seen as an "extension" of the intranet to key business associates.
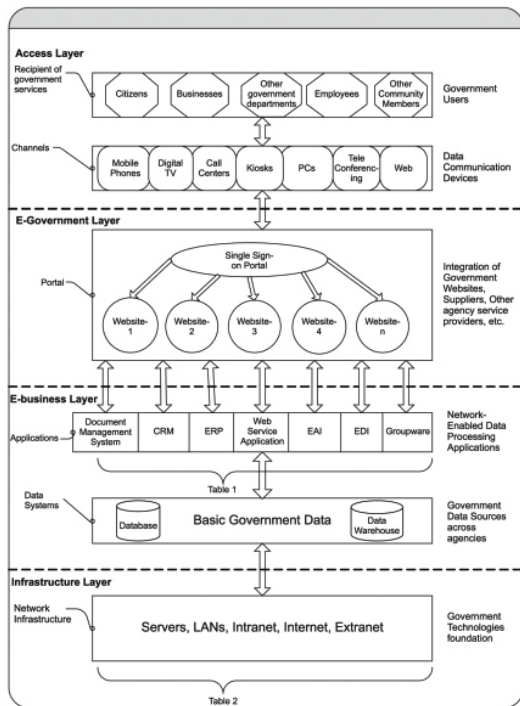
Figure 2. The four-layer model of Ebrahim and Irani [6]

Estonian model

At the core of Estonia's success is the visionary approach to the use of modern and up-to-date technologies in daily work of the public administration. Back in 1996, the Estonian government started a national project to establish a national broadband network infrastructure called "Eebone" at the end of 1998. This network connects state and local levels of government and is centrally funded, and every

public institution has the right (not the obligation) to use Eebone for free, while clients only pay for access to the network [17].

Most state and local government institutions use EEbone based on the X-tee (initially called X-Road), which is essentially a national "middleware" that provides unified access to all government databases that uses web services as support technology, and allows easy access to data in government registries without compromising the security of flows and with minimal impact on existing systems. X-tee was initially developed as an environment that facilitates the query formulation of networked databases in a standardized manner. The architecture of this complex system is given in Figure 3 showing this central "backbone" of the system based on the Internet, in part related to the central management of this system, as well as repositories provided by security servers to private sector.

The architecture of X-tee enables distributed, secure, unified web services based on a framework for inter-institutional data exchange. Distribution is reflected in the fact that X-tee does not centralize data and does not change ownership of the data. The databases and registers are not centralized and the data is managed by the same institution that created it. Each institution is responsible for the quality of the data and can determine which other institution will have access to the data. X-tee does not limit the way registries and institutions will implement their information systems - all platforms and host-
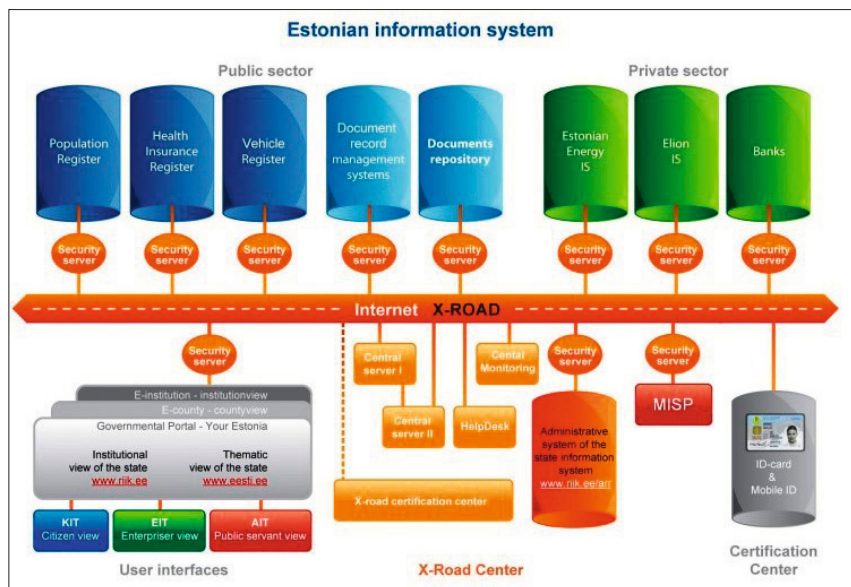
Figure 3. Estonian model of e-government infrastructure called X-tee (former X-Road)

ing models are supported, including cloud-based setups, allowing for system heterogeneity.

The basic elements of trusted infrastructures in the e-Estonia system structured in four-layer logic are:

1. Access layer
   - Electronic identification card (eID),
   - PKI infrastructure,
2. E-government layer
   - Personalized portals for citizens (KIT), industry (EIT) and administration (AIT),
3. E-business layer
   - Secure layer for X-tee data exchange,
   - Document Exchange Center,
4. Infrastructure layer
   - EEbone Broadband Network,
   - Register of registers with service catalogs,
   - Data addressing infrastructure, and
   - Spatial information infrastructure.

The Estonian model can be said to be based on *Service Oriented Architecture* (SOA). This type of architecture is typically concerned with building independent business solutions based on services as building blocks. Services, as software units, are combined into the desired business processes and services can have a lifespan, i.e. they can be easily withdrawn from use, which is an advantage in business process modelling, which achieves scalability and flexibility of the business as a whole. The basic characteristics of this architecture are tolerance to the diversity of employed technologies and platforms, easier transfer and sharing of services, as well as increased reliability in distributed systems.

Centralized e-government systems on the European continent are becoming a general trend, as is the case with Estonia. Each state authorizes one or more ministries to carry out the process of centralization of e-government, which enables the creation of an organized, integrated and functional environment for providing services to citizens from one place (one-stop-shop). The application of a centralized digital system of public administration, according to a study by the European Commission from 2014, would lead to significant annual savings in the work of public administration, with additional economic effects of such business for the immediate environment. The study estimates that applying digital strategies in public administration at the level of the 28 EU member states would save approximately € 10 billion a year, implying a significant number of transactions [18].

Serbian model

The Serbian model in the direction of centralization of public administration e-services is given in Figure 4, which shows the possible centralized logical architecture of the electronic public administration system from the study according to Starčević [16]. Centralization has been established through the e-government backbone (e-government bus) and the central portal, as well as a resource dictionary that supports the integrity of the system's functioning. Users can access the services through the central portal, or directly through the information system of the competent first instance body in charge of working with users as shown in Figure 4.

The basic elements of trusted infrastructures in the Serbian system structured in four-layer logic are:

1. Access layer
   - Users,
2. E-government layer
   - Central portal,
3. E-business layer
   - Information system units,
4. Infrastructure layer
   - e-government bus,
   - Dictionary of e-government resources
   - e-payment, and
   - e-security

Bosnia and Herzegovina model

Bosnia and Herzegovina (B&H) is an example of a decentralised and distributed system. The public administration system itself is divided (decentralized) into several basic levels of government:

- state (competence of the Council of Ministers of B&H),
- entity (entity governments),
- cantonal (cantonal governments) in the Federation of B&H, ie local self-government institutions in the Republic of Srpska (city and municipal authorities), and
- Brčko District (District Government) as a separate administrative unit.

Each of these levels of government is independent in terms of organizing and equipping the pub-
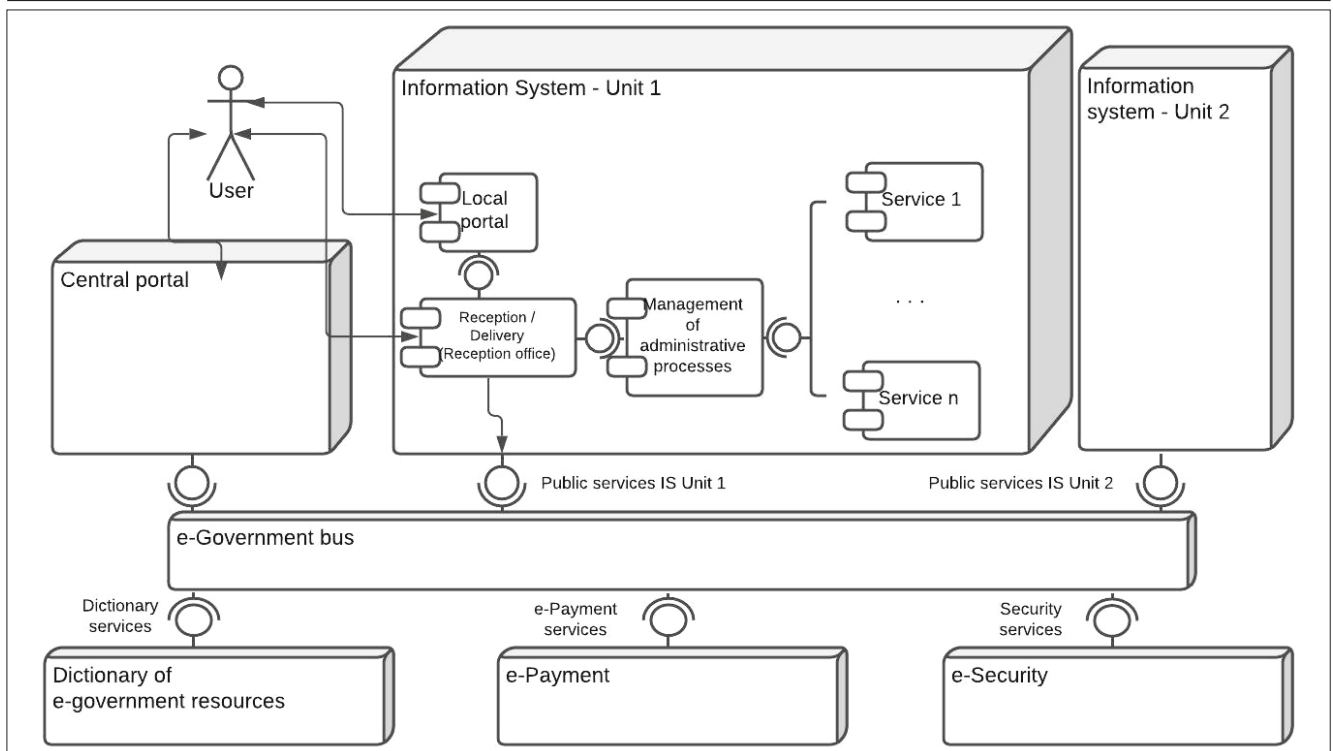
Figure 4 *Example of the proposed Serbian model for e-government architecture (from [16])*

lic administration system in its domain. Therefore, the establishment of a centralized system as such is not even defined by the B&H Constitution. However, when we talk about centralization, this is possible at individual, lower levels of government and in accordance with their competencies and powers.

To meet the requirements of the project and ensure that the interests of stakeholders are met, the proposed architecture is shown in Figure 5. This architecture takes into account all the advantages of a four-layer architecture that integrates the management system in a quality way to meet user needs.
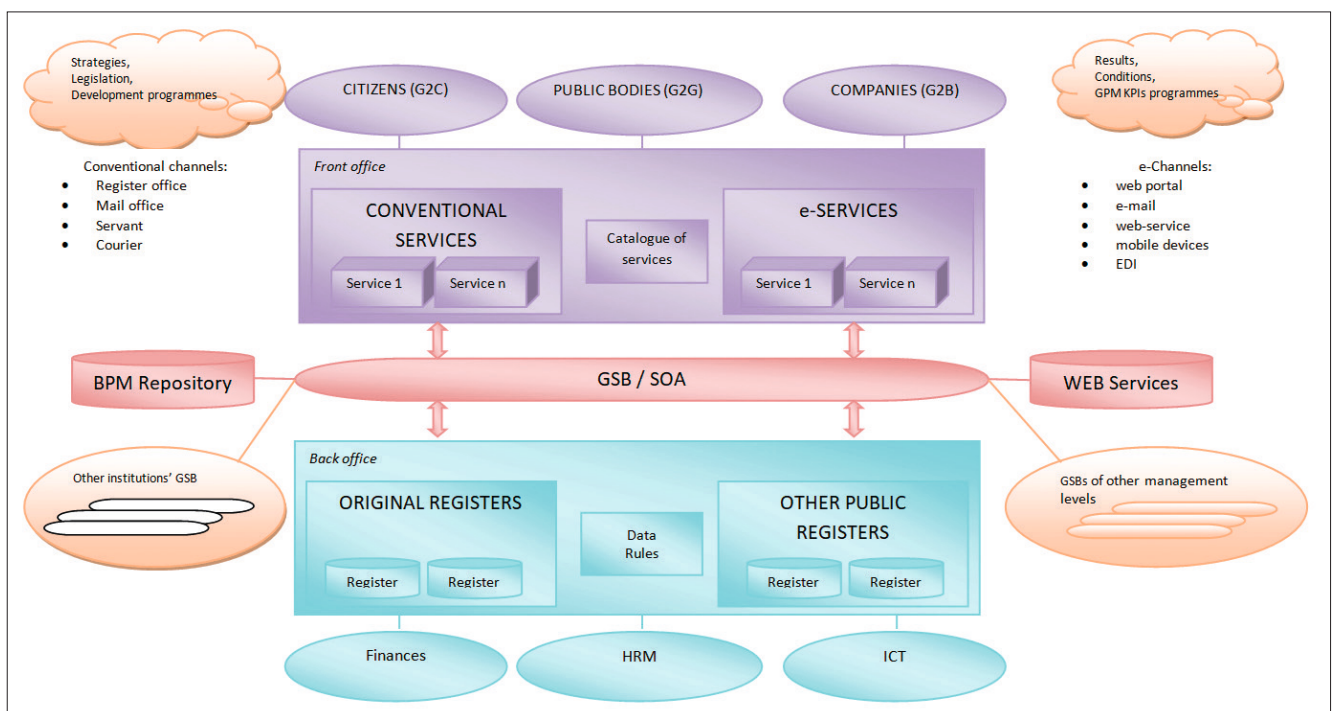
Figure 5. *Example of proposed Bosnia and Herzegovina's model [19]*

Thus, the presentation layer is singled out as special and connected to all public administration services offered, which are divided into two categories: conventional services and e-services, depending on the communication channel. This model proposes the establishment of the so-called Government Service Bus, which is the counterpart of the Estonian X-tee, and which would be based on a service-oriented architecture. This would enable flexibility and scalability of the system because it would be based on the services offered by the public administration system and thus could "orchestrate" business processes and adapt to user needs.

The Public Administration Reform Fund in B&H financed the project "Development and establishment of an interoperability framework and standards for data exchange" which created the document "Guidelines and standards for system architecture and application development" [19] The project and document was implemented by Infodom d.o.o. from Zagreb (Croatia), which in the mentioned document proposed a solution for the architecture of the system, which was based on positive experiences from Germany and the application of SAGA [20] standards. This standard defines a multi-layered architecture on three or four levels, depending on whether the presentation layer is separated from the e-business layer, i.e. from business logic, and where, in fact, the user represents a special layer.

The basic elements of trusted infrastructures in the B&H system structured in four-layer logic are:

1. Access layer
   - Citizens (G2C),
   - Public bodies and municipalities (G2G),
   - Companies (G2B),
2. E-government layer
   - Front office with conventional and e-services,
3. E-business layer
   - Finances,
   - HRM (Human Resource Management),
   - ICT (Information-Communication Technologies),
   - Web services,
4. Infrastructure layer
   - government service bus,
   - service buses of individual institutions,
   - source registers,

- other public registers,
- BPM (Business process modelling) repository.

CONCLUSION

The aim of this paper was to explain the four-layered structure of e-government systems and to propose it as a quality solution for distributed and decentralised systems. We provided insight in three models: one from the country with very advanced e-government system (centralised, Estonia), one from the developing country (centralised, Serbia) and one from the country with strongly decentralised system (Bosnia and Herzegovina). The advantage of the four-layered structure lies in its universality for implementation, as it was proven by these three systems with quite different advancement in implementation of e-government and governance. It is proven that this structure is feasible even for low-income countries with highly decentralised system of governance, such as Bosnia and Herzegovina.

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Software Application Development Using Container Technology

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Abstract: The paper will give an example and an overview of how we can set up and maintain web applications using a Docker. We will define what Docker is, what containers are and how to use them. Developers often find themselves in a situation where their program works properly on a computer in the laboratory environment in which the application was developed, but after installing the program on the production server, the program does not work as expected. In such circumstances, it is difficult for a programmer to determine why a program is not working. Docker solves this problem by placing applications and virtual containers that run on the same operating system.

Keywords: Docker, Devops,Virtual machine, Container technology.

Introduction – Problems of operation development

Since the beginnings of programming and software application development, developers have created programs and applications in one place and installed them to run in another place. Preparing the work environment has often been a problem in implementation.

Developers often find themselves in a situation where their program works properly on a computer in the laboratory environment in which the application was developed, but after installing the program on the production server, the program does not work as expected. In such circumstances, it is difficult for a programmer to determine why a program is not working. There can be several reasons for that and it is very difficult to detect these malfunctions.

This type of problem is costly, frustrating, and often disrupts interpersonal relationships between system administrators and developers.

Today, there are several technologies that are trying to solve this problem. The traditional way of solving is based on the use of virtual machines, using cloned environments and "snapshots". A new and improved way is to use containerization technologies (in our case Docker containers).

Docker – a different approach to virtual machines

One of Docker's common misunderstandings is its comparison to a virtual machine, which seems to do something similar, but is, in fact, significantly different. [1]

Virtual machines solve the same problem, but in a different way. Virtual machines are virtual instances of a complete operating system, Windows or Linux. If we are developing a web application on a Linux virtual instance, we can run that application anywhere to run that same instance of Linux.

This approach has been successful for years. However, there is one problem - if we want to service and deploy a single web application, we need to run a complete virtual operating system. It is quite expensive, especially if we have multiple applications running.

Docker solves this problem by placing applications and virtual containers that run on the same operating system. Each container contains the com-

plete code, all the libraries and all the dependencies that are necessary for the application to run. [2]

This approach saves us large amounts of disk space, time, processing power and significantly reduces complexity.

Why Docker?

Many reputable companies use Docker for their web applications.

The main advantages of using Docker are the following:
- Docker allows us to have many more individual applications on the same number of servers than with other technologies.
- It makes application development encapsulated, ready to use. Everything is delivered in containers.
- Also, it makes the whole process of managing and installing applications on servers much easier and more secure. We can modify the application, send a new image to the repository, and instantly launch that application from any location.

When we put all this together, we can have a very attractive product that will make maintenance work easier for both developers and system administrators. [3]

Placing applications in Docker using Docker containers

The basic steps of developing and placing a web application in a container using Docker are as follows:
- Installing Docker on the physical or virtual environment we will be using
- Setting up the registry on the Docker Hub
- Creating your own Docker image
- Setting up "docked" environments
- Setting up the application

Docker installation

Docker allows us to easily run our applications anywhere, but the places where those applications run must have Docker installed.

There are three main Docker releases:
- Docker Enterprise Edition (Docker EE)
- Docker Comunity Edition (Docker CE)
- Docker Cloud
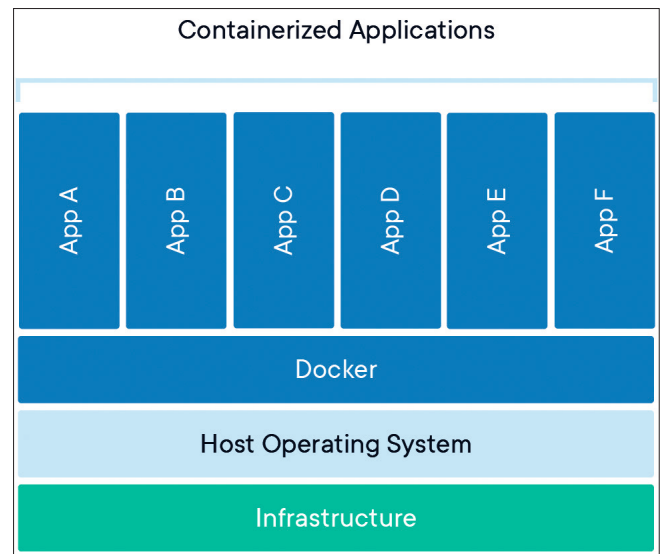
Figure 1: *Illustrative presentation of container technology*
https://www.docker.com/resources/what-container

At the moment, Docker can be installed on Windows, Linux and MacOS environments, as well as on cloud service providers such as Amazon AWS and Microsoft Azure.

In our example, we will use Linux CentOS 8.

Before starting the installation, it is necessary to remove all old versions of Docker called docker or docker-engine. [4]

We will perform the installation by adding an official repository, so that we have the option of automatically upgrading and patching Docker.

If it is a server that doesn't already have a Docker repository, we need to add them.

Preparing the Docker repository:
```
$ sudo dnf install -y dnf-utils
$ sudo dnf config-manager \
 --add-repo \
  https://download.docker.com/linux/
centos/docker-ce.repo
```

Docker Engine installation:
```
$ sudo dnf install docker-ce docker-
ce-cli containerd.io
```

If we have not used Docker repositories before, the installation will ask us to accept the GPG - Gnu Privacy Guard key, of the repository, which we must do if we want to continue the installation.

After a successful installation, we start Docker as follows:

```
$ systemctl start docker.service
```

Setting up the registry on the Docker Hub

In order to easily distribute applications, we need to have a place to share them.

The Docker Hub is like a GitHub Docker container. On it we can find thousands of applications and examples of how to use them.

To set up our own private or public repository and to start setting up our applications, we need to go to the Docker Hub website.

We can use the Docker Hub to set up and download changes to our application in different locations. There are also tools we can use to automate this.

To access the Docker Hub panel, we must log in using our user account. If we don't have it, we need to create an account on the Docker Hub. After creating an account, we log in to the Docker Hub panel, from where we can create a public or private repository.

Once we have created the repository, we can proceed with the next steps.

It is important to note that there is a paid Docker Hub option, which provides more functionality and resources than the free one, which we will use in this example. For these purposes, the free option is more than enough. [5]

SETTING UP DOCKED ENVIRONMENTS

The next step is to prepare the Docker environment to execute the application. We will do this using the command line and several different tools.

These environments are responsible for setting up and running the container. There are several other, interesting things we can do, such as running multiple instances of our application and using a load balancer to send traffic to different versions.

Making Docker images and containers

Docker containers are created from a Docker figure. In order for our application to be distributed to different servers, we need to create a Docker image. We can do this using the Docker file.

The Docker file (we will use the official title Dockerfile below), usually contains 3 to 30 lines of text that represent the commands necessary to create Docker figures.

There are many ways to create a Dockerfile, but before that we need to get acquainted with the best practice, before we make it.

For example, we will take a simple application, node-bulletin-board, which is used as an example of how to create and run Docker figures. [5]

The first step is to download the necessary files:

```
$ curl -LO https://github.com/dock-
ersamples/node-bulletin-board/ar-
chive/master.zip
```

We unpack the compressed archive:

```
$ unzip master.zip
```

We change the current working directory to the directory created by unpacking the archive:

```
$ cd node-bulletin-board-master/bul-
letin-board-app
```

We can look at the contents of the new directory:

```
[root@localhost docker]# cd node-bulletin-board-master/bulletin-board-app
[root@localhost bulletin-board-app]# ls -la
total 36
drwxr-xr-x. 4 root root  187 Oct 27 16:53 .
drwxr-xr-x. 3 root root   65 Oct 27 16:53 ..
-rw-r--r--. 1 root root 1239 Oct 27 16:53 app.js
drwxr-xr-x. 2 root root   53 Oct 27 16:53 backend
-rw-r--r--. 1 root root  127 Oct 27 16:53 Dockerfile
drwxr-xr-x. 3 root root   23 Oct 27 16:53 fonts
-rw-r--r--. 1 root root   22 Oct 27 16:53 .gitignore
-rw-r--r--. 1 root root 1826 Oct 27 16:53 index.html
-rw-r--r--. 1 root root 1131 Oct 27 16:53 LICENSE
-rw-r--r--. 1 root root  572 Oct 27 16:53 package.json
-rw-r--r--. 1 root root  888 Oct 27 16:53 readme.md
-rw-r--r--. 1 root root 1071 Oct 27 16:53 server.js
-rw-r--r--. 1 root root 1227 Oct 27 16:53 site.css
[root@localhost bulletin-board-app]#
```

Figure 2: Application directory content

We can see a Dockerfile that contains parameters to create. When we open Dockerfile, we see its contents in the image below:

```
root@localhost:~/docker/node-bulletin-board-master/bulletin-board-app

FROM node:current-slim

WORKDIR /usr/src/app
COPY package.json .
RUN npm install

EXPOSE 8080
CMD [ "npm", "start" ]

COPY . .
~
```

***Figure 3:** Dockerfile content*

In order, we see lines that give instructions on which command to execute:
- FROM: which figures will be used as the basis
- WORKDIR: define the working directory, all commands will be executed in it

- COPY: copy local files to the container
- RUN: run the command during container creation
- CMD: run the command after starting the container
- EXPOSE: publish container ports to be available outside the Docker network

We will continue to create containers. The command with which we create and test the image is:
```
$ docker build --tag bulletin-
board:1.0 .
```

For the command to be successful, we must be in the directory where the Dockerfile is located or manually specify the path.

```
[root@localhost bulletin-board-app]# docker build --tag bulletinboard:1.0 .
Sending build context to Docker daemon  45.57kB
Step 1/7 : FROM node:current-slim
current-slim: Pulling from library/node
e50c3c9ef5a2: Pull complete
7d035f3b6068: Pull complete
1758a95126e3: Pull complete
d39676814e5a: Pull complete
e7aa22215d06: Pull complete
Digest: sha256:7bf36131ed121f8113794e83a665bdf5d81cdf77c07672a6c1620fd71675bc8c
Status: Downloaded newer image for node:current-slim
 ---> 9ac9e9f30b2c
Step 2/7 : WORKDIR /usr/src/app
 ---> Running in cedce0f45eef
Removing intermediate container cedce0f45eef
 ---> c4651e1f5f91
Step 3/7 : COPY package.json .
 ---> 2fa6e2dff9fc
Step 4/7 : RUN npm install
 ---> Running in ca76e1773fbe

added 91 packages, and audited 91 packages in 5s

found 0 vulnerabilities
npm notice
npm notice New minor version of npm available! 7.0.15 -> 7.1.2
npm notice Changelog: <https://github.com/npm/cli/releases/tag/v7.1.2>
npm notice Run `npm install -g npm@7.1.2` to update!
npm notice
Removing intermediate container ca76e1773fbe
 ---> 505c2bc02700
Step 5/7 : EXPOSE 8080
 ---> Running in 8c9e140ff596
Removing intermediate container 8c9e140ff596
 ---> 5bef16d20584
Step 6/7 : CMD [ "npm", "start" ]
 ---> Running in a990f175e277
Removing intermediate container a990f175e277
 ---> e4449d1902d8
Step 7/7 : COPY . .
 ---> 0451f4b23265
Successfully built 0451f4b23265
Successfully tagged bulletinboard:1.0
[root@localhost bulletin-board-app]#
```

***Figure 4:** Creating a Docker image*

By command $ `docker images` we can view the containers available in the local environment:

```
[root@localhost bulletin-board-app]# docker images
REPOSITORY         TAG             IMAGE ID          CREATED           SIZE
bulletinboard      1.0             0451f4b23265      4 minutes ago     177MB
node               current-slim    9ac9e9f30b2c      2 days ago        160MB
[root@localhost bulletin-board-app]#
```

Figure 5: Display of available figures on a Docker host

Once we have the image created, we can proceed to create the container with the command:
```
$ docker run --publish 8000:8080 --detach --name bb bulletinboard:1.0
```

We can access the application at the address of the server and port that we entered in EXPOSE conf
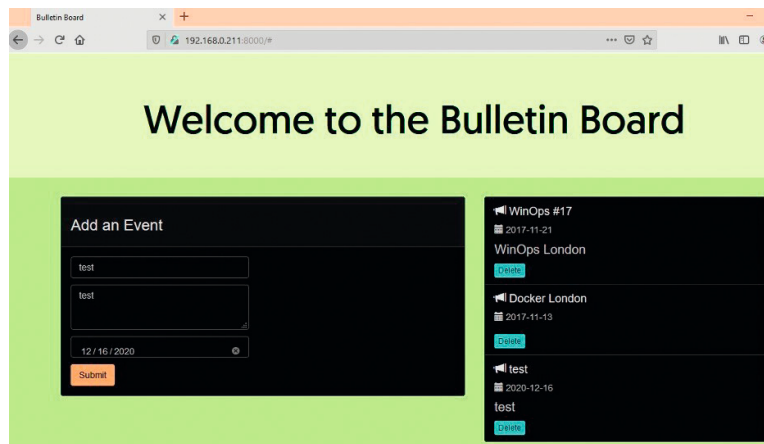
Figure 6: Application launched from Docker container

Image publishing on Docker Hub

We create a bulletinboard repository on our Docker hub.

By command
```
$ docker tag bulletinboard:1.0
kojo1984/bulletinboard:1.0
```
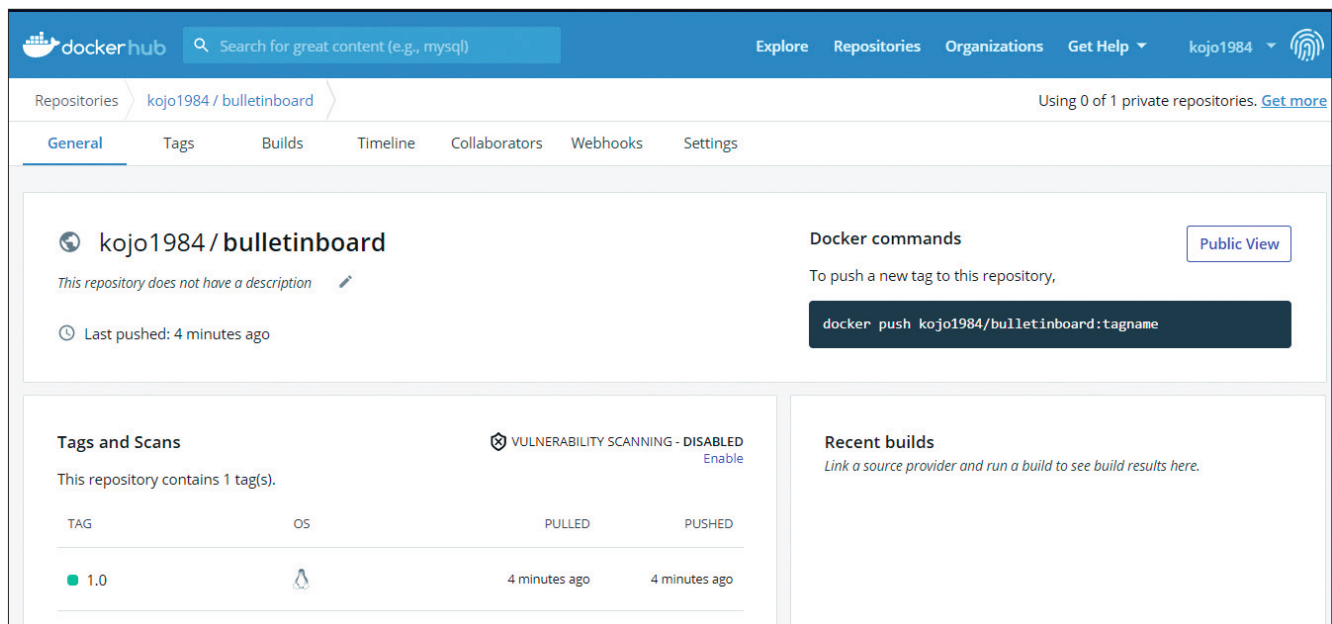

Figure 7: Image tagging and copying on Docker Hub

We tag the image, preparing it for copying to the Docker hub.
By command

```
$ docker push kojo1984/bulletinboard:1.0
```

We copy the image to the repository

Figure 8: Image display on Docker Hub - we can see the published image on Docker Hub

Once we have published and made the image available on the Docker Hub, we can run it anywhere. If we try to run the image on a system that does not have an image, Docker will automatically try to download it from the Docker Hub. By using the figure in this way, we no longer need to install additional software and libraries on the system on which the application will run, it is enough to have Docker installed.

It is a good practice to stick Dockerfile together with the source code of the application, so that the changes and versions in the file and the application are at the same level. [6]

CONCLUSION

Docker is a very popular technology nowadays, and with good reason. In this paper, we have seen only a fraction of what can be done with container technology (in our case with Docker).

With the proper use of container technology, in addition to saving us money, it will save us time, resources, make work easier and make applications more accessible.

We have presented the basic process of how to run a containerized application on a server. The same procedure is applied anywhere, from local server, to virtual machine and cloud environment.

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FOR CITATION

THE QUALITY OF SOFTWARE METRICS

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Abstract: This paper discusses the definition, types, characteristic and construction of software metrics in the field of software development. Finally, an overview is given regarding the use of a software tool in software development in relation to software metrics in the field of banking.

Keywords: software engineering, software metrics, SEI, CISQ, ISO/IEC, banking.

INTRODUCTION

Nowadays, the discipline of software engineering is well-represented in practice as well as a scientific theory. The reason for this is the extensive use of software and, consequently, the need to develop the respective software. Despite the mass production of software, there is a lack of quality assurance of software and the process of its development. For the monitoring, control and prediction of the characteristics of software product, software metrics are often used [7] [8] [15]. Therefore, in this paper, in the context of software engineering, we define terms software quality and software metrics.

According to ISO organization [10], quality is defined towards object and speaks of the degree how inherent characteristics of the object fulfill required set of demands on it. The object represents any entity that can be seen or conceived, and its inherent characteristics are properties that exist in the object or its associated items. In the context of software engineering, the definition of quality of software as product quality, as well of software development as a quality development process can be applied.

This paper [16] shows that some software metric tools interpret and implement the definitions of software metrics in different ways. Therefore, any metric should be precisely defined prior to each application thereof. More specifically, the metric itself must be of good quality to have a product with high-quality software within itself. The metric must be defined first abstractly, second textually and with mathematical formulas and equations; and then, in the next step, in the form of algorithms and pseudo-code.

SOFTWARE QUALITY ASSURANCE

Among others, there are two important organizations in the world dealing with the concept of software quality and metrics:

1) CISQ (The Consortium for IT Software Quality), jointly organized by the Software Engineering Institute (SEI) at Carnegie Mellon University and the Object Management Group (OMG), and

2) ISO/IEC and their standard „ISO/IEC 9126 Software engineering — Product quality" and its successor ISO/IEC 25010:2011.

The last organization is more important and better known, therefore we will deal with their standards. The name of the standard is ISO/IEC 9126 Software engineering — Product quality. It was an international standard for the evaluation of software quality. The new standard with the same subject is ISO/IEC 25010:2011. The main goal of the ISO/IEC standard is to addresses some of the known human tendencies that can negatively affect at the delivery and perception of software development project. Therefore, the standard tries to develop a common understanding of the project's priorities, objectives

and goals. After clarifying, agreeing on the project priorities and subsequently converting abstract priorities to measurable values follow. The standard is divided into four parts:

- quality model (with name 9126-1),
- external metrics (9126-2),
- internal metrics (9126-3), and
- quality in use metrics (9126-4).[11][12][13][14]

The quality model presented in the first item of the standard, classifies software quality in a structured set of characteristics:

- Functionality, "a set of attributes that bear on the existence of a set of functions and their specified properties" (suitability, accuracy, interoperability, security, and functionality compliance).
- Reliability, "a set of attributes that bear on the capability of software to maintain its level of performance under stated conditions for a stated period of time" (maturity, fault tolerance, recoverability, reliability compliance).
- Usability, "a set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users" (understandability, learnability, operability, attractiveness, usability compliance).
- Efficiency, "a set of attributes that bear on the relationship between the level of performance of the software and the amount of resources used, under stated conditions" (time behaviour, resource utilization, efficiency compliance).
- Maintainability, "a set of attributes that bear on the effort needed to make specified modifications" (analyzability, changeability, stability, testability, maintainability compliance).
- Portability, "a set of attributes that bear on the ability of software to be transferred from one environment to another" (adaptability, installability, co-existence, replaceability, portability compliance).[11]

Each sub-characteristic (e.g. suitability) is further divided into attributes. An attribute is an entity which can be measured in the software product and links to software metrics.

SOFTWARE METRICS

In order to ensure quality of software it is necessary to measure multiple parameters. This should be done by defining software metrics, i.e. the type of measurement that is related to a software system, process or a related document. It is necessary to make a selection of parameters which will be measured and provide testing software products using the strategy of the necessary approaches to validation testing. All this is needed to get a software product that meets the requirements of customers, developed in accordance with the specification and which is free of errors.

In reference [9], we have given the first serious definition of software metrics (in fact, the definition defines quality metric, which shows a significant connection between metrics and quality):

(1) A quantitative measure of the degree to which an item possesses a given quality attribute.

(2) A function whose inputs are software data and whose output is a single numerical value that can be interpreted as the degree to which the software possesses a given quality attribute.

A similar definition of software metrics, like this in item (2), is given in reference [19].

As output metric gives statistical/numerical value and it can be the lowest value in a given time interval, the highest in the interval, and the average value of the interval. In addition, metric can be given as an absolute or percentage value. Together with metrics, we may present other statistical indicators such statistical distributions, correlation, benchmarking, trends, graphs of various types.

CLASSIFICATION OF METRICS

Software metrics can be classified in several ways depending on the criteria. According to the criteria of the software system state is divided into static and dynamic metrics. Thus, the dynamic measurement metrics collected over running software (sometimes called external metrics). Static metrics are collected through measures made by the system representation and which do not rely on software execution (internal metrics).

Management side of all metrics can be divided into control metrics and prediction metrics. Control metrics is used by management in order to control the processes related to software, examples of the

required work and the use of disk space. Control metrics can provide information about the quality of the process and the quality of the product itself. Prediction metrics extent attributes of the software product to predict the future of software quality.

In reference [1], we have given taxonomy framework with candidate metrics, which is summarized in Table 1.

Table 1. *Types group of software metrics, constructed from [1]*

Types group:	Group of metrics:
Target types	Product metrics
	Process metrics
	Hybrid metrics
Structure types	Elementary metrics
	Composite metrics
Obtainment criterion types	Objective metrics
	Subjective metrics

The same has been given more types of metrics including: design, size, complexity, reuse, productivity, quality. [1]

If we observe the software development life cycle, it is possible for each specific phase of software development methodologies to define specific software measures that will result with numeric metric. In addition to any action in the stage of software development, it is possible to define applicable metrics with the preparatory-final stages.

Object-oriented (OO) programming is tremendously different from the models of procedural, structural or functional programming. For the quality of object-oriented structure, special OO metrics are used. Object-oriented metrics respects the principles that are uniquely characteristic of object-oriented design, such as classes, objects, methods, inheritance, polymorphism, encapsulation, composition, delegations and other OO concepts.

CONSTRUCTION OF QUALITY METRICS

There are no standardized and universal applicable software metrics. Software metrics should provide control of the software development project, its maintenance, support in decision-making by software managers, monitoring and initiating corrective actions. Construction of a highly reliable software depends on the participation of the attributes of quality at every stage of the life cycle of development with emphasis on the prevention of errors, especially in the early stages. In order to measure these attributes so as to improve the quality and reliability of software, it is necessary to define metrics for each development stage (required documentation, source code, test plans and testing).

A common case is that there is an excessive number of metrics that should be reduced to a small number of simple and friendly metrics depending on the environment and aspect.

Customer requirements are specified functionality that must be included in the final software, which must be structured, complete and clear communication between the designer and the user. Two important metrics for evaluating the ambiguity of the term are a number of imprecise and general phrases (e.g. adequate, appropriate, normal, etc.) and number of optional phrases (e.g. may be optionally etc.). Incomplete terms such as "should be something added and should be specified" should also be avoided.

SOFTWARE METRICS AND BANKING

One of the most useful metric defined a long time ago (1976, Thomas J. McCabe) is cyclomatic complexity. This metric account the complexity of the whole or part of the program code by finding the number of linearly independent paths in the graph arising from the structure of the program code (Figure 1).
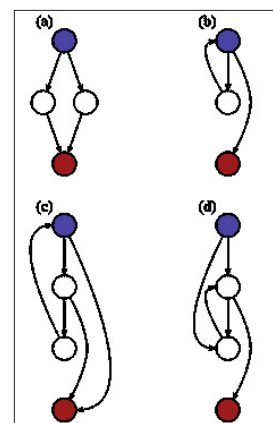
Figure 1. *Example of control flow graphs for cyclomatic complexity, adapted from [20]*

There are a number of software for the calculation of the metrics. This paper aims at banking information system of a general type of small banks with around 150,000 clients in the Republic of Srpska (en-

tity of Bosnia & Herzegovina). Aamong others, Visual Studio IDE is used for developing software solution. NDepend can be used as a general software for the calculation of the metrics. It is also used for other purposes in order to improve the targeted software. In version 6 it there 86 software metrics that cover six application areas [2]. However this software is too big for the needs of the respective banks.

Risk management is one of the most important concerns of modern banking. It is also the important work of software managers because the banks' operations are based 99% on the use of computer equipment and corresponding software. Software manager is obliged to provide all the risks that could arise during the operation and realization of software projects. Then it is necessary to adequately respond to these risks, minimizing or completely avoiding them. This is based on the statistical data after the application-specific metrics.

Development teams, or software managers, using specific metrics can identify risks, see the stage and the situation in which the current project is located and track progress during software development lifecycle. As better and a free software tool for the needs of the target bank, Code Metrics Viewer is chosen.

A set of metrics that are crystallized in the bank's projects and written in Microsoft Visual Studio 2019 environment is given below and are demonstrated by plug-in Code Metrics Viewer [3]: MI - maintainability index, CyC - cyclomatic complexity, DOI - depth of inheritance, CoC - code coupling (coupling of a program code with the code of another class), and the most simple metrics LOC - lines of code (the number of lines of program code) (Figure 2).

In the Code Metrics Viewer, we may request result of software metrics for the entire solution or project, namespace, class, method, or section.

CONCLUSION

The idea and goal of this optimized model of software metrics is to address all potential problems in a way that will offer a set of metrics and their parameters. This will allow developers to provide information on optimum values for writing quality program code, i.e. limits within which they can write their own program code, which complexity their codes could have, how to maintain index that their codes must have, depth of inheritance in the program code, and the required lines of code per writing module.

However, it was noted that this is not enough per se. It is necessary to calculated the software metrics connects to one of the methodology for software development, especially for the phases of planning and testing. As a candidate, the movement, approach and practical techniques titled DevOps is taken into consideration.

The contribution of this paper is reflected in the testing and presentation of metrics and metrics software. It is concluded that this approach greatly improves the work of software engineers and users of software produced by this approach. Details of the metrics themselves have not been released due to strict regulations on data confidentiality in the banking sector and internal rules and decisions of the bank.

Figure 2. Software metrics in Code Metrics Viewer 2015

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