

Internet of Things for Intelligent Transportation Systems



Internet of Things for Industry and Human Applications

Internet of Things
for Intelligent Transportation Systems

TRAININGS



**Ministry of Education and Science of Ukraine
Ternopil National Economic University
Volodymyr Dahl East Ukrainian National University
National Aerospace University “Kharkiv Aviation Institute”**

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Internet of Things for Industry and Human Applications

Internet of Things for intelligent transport systems

Trainings

Edited by A.O. Sachenko, I.S. Skarga-Bandurova

**Project
ERASMUS+ ALIOT “Internet of Things: Emerging Curriculum for
Industry and Human Applications”
(573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP)**

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The materials of the practical part of the study course “ITM3. IoT Application for Intelligent Transport Systems”, developed in the framework of the ERASMUS+ ALIOT project “Internet of Things: Emerging Curriculum for Industry and Human Applications” (573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP).

The structure of work on verification of residual knowledge in the discipline, the corresponding practical material, examples of tasks and criteria of evaluation are given. In the learning process, the theoretical aspects of development and implementation of IoT-based systems are presented. The basic concepts and approaches of data science for IoT systems are given.

It is intended for engineers, developers and scientists engaged in the development and implementation of IoT-based systems, for postgraduate students of universities studying in areas of IoT, computer science, computer and software engineering, as well as for teachers of relevant courses.

Ref. – 82 items, figures – 72, tables – 7.

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Інтернет речей
для
індустріальних і гуманітарних застосунків

ІНТЕРНЕТ РЕЧЕЙ ДЛЯ ІНТЕЛЕКТУАЛЬНИХ
ТРАНСПОРТНИХ СИСТЕМ

Тренінги

Редактори Саченко А.О., Скарга-Бандурова І.С.

Проект ERASMUS+ ALIOT
“Інтернет речей: нова освітня програма для потреб
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Викладено матеріали тренінгової частини курсу ІТМЗ «IoT для інтелектуальних транспортних систем», підготовленого в рамках проєкту ERASMUS+ ALIOT “ Internet of Things: Emerging Curriculum for Industry and Human Applications” (573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP).

Курс присвячений створенню бази знань для досліджень застосувань IoT для інтелектуальних транспортних систем та розробці навчальної програми для магістрів та аспірантів з Інтернет Речей. З точки зору методики було подано наступні програми: опис тренінгів та рекомендації щодо вивчення курсу. Книга орієнтована для студентів магістратури / докторантури, випускників, спеціалістів, державних та приватних компаній, ВНЗ, професійних асоціацій, науково-дослідних центрів, співробітників національної та європейської IT-індустрії, що діють у різних сферах застосування IoT. Це може бути корисно для викладачів, які проводять заняття на відповідних курсах.

Бібл. – 82, рисунків – 72, таблиць – 7.

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INTRODUCTION

Training support package for a course “IoT for Intelligent Transport Systems” was designed as practical part for students within the framework of Erasmus+ Programme of the European Union – ALIOT, which is acronym of “Internet of Things: Emerging Curriculum for Industry and Human Applications”. Project Number: (573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP)¹.

Its goal is the practical use of earned students knowledge’s in computational intelligence with the followed training in different applications of intelligent transport systems within IoT environment.

The module TM 3.1 “Intelligent System for Monitoring the Transport Flows” contains the three trainings. The first training is intended to study the hardware of traffic intensity monitoring. The second training is intended to recognize and data processing of the objects in a video frame. The third training is intended to recognize and process data of the objects array in a video stream

The module TM 3.2 “IoT for Public Transport Information Service Delivering” contains the four laboratory works. The first lab is exploring the components for vehicle location tracking device. The second lab is exploring the various ways to calculate the distance between geographic coordinates. The third lab is exploring the information board components. The fourth lab is exploring the integrated development environment.

The module TM 3.3 “IoT and Cooperative Human-Machine Interfaces for Transport Safety” contains one seminar and one laboratory work. The seminar No 1 is dedicated by developing and applying the cooperative human-machine interfaces for intelligent transport systems based on the IoT. The lab No 1 describes applying the modified method of HAZOP risk analysis for the safety assessment of cooperative human-machine interfaces of vehicle systems considering the IoT communications.

¹ *The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

The module TM 3.4 “Internet of Drone-Based Systems” includes the two trainings. The first training is determining the optimum number of single operator controlled unmanned aerial vehicles for Nuclear Power Plant monitoring missions. The second training is dedicated by optimal redistribution of UAVs in case of changing monitoring zones after an NPP accident.

The course is intended for MSc/Doctoral Students, graduates, young professionals, state and private companies, universities, professional associations, research centers, staff of national and EU IT-industry, acting different application domains of IoT. It could be useful for lecturers who conduct classes on corresponding courses.

Trainings are prepared by Prof., DSc Sachenko A.O., Assoc. Prof., Dr Kochan V.V., Dr Bykovyy P.E., Dr. Zahorodnia D.I., Dr Osolinskyi O.R., Department for Information Computing Systems and Control and Research Institute for Intelligent Computer Systems, Ternopil National Economic University (Module 3.1); Prof., DSc Skarga-Bandurova I.S., Ph.D. Student Derkach M.V., Computer Science and Engineering Department, V. Dahl East Ukrainian National University (Module 3.2); Prof., DSc Kharchenko V.S., Prof., Dr Orekhov O.O., Dr Stadnik A.O., Assoc. Prof., Dr Fesenko H.V., Computer Systems, Networks and Cyber Security Department, National Aerospace University “KhAI” (Modules 3.2, 3.3).

A general editing was performed by Prof., DSc Sachenko A.O., Prof., DSc Skarga-Bandurova I.S..

Module TM 3.1 “Intelligent System for Monitoring the Transport Flows”

TRAINING 1. STUDYING THE HARDWARE OF TRAFFIC INTENSITY MONITORING

Aim: studying the hardware for implementing the task of controlling the intensity of traffic by a webcam.

Learning Objectives:

1. To study the used hardware;
2. To study the used software and its implementation;
3. To study the creation of images database;

Practical tasks:

1. Learning the hardware used in training;
2. Learning the software used in trainings and its implementation;
3. Learning the formation of the base image;

Research tasks:

Exploring the different types of used video cameras.

In preparation for the training needs:

1. To get the topic of the analytical review and clarify the conditions of the task.
2. To develop a work plan and distribute responsibility between members of the group (students arrange among themselves parts of the work for which they will report).

Training implementation

During the training:

1. Searching the information of training topic and received task.
2. Performing the necessary actions to complete the received task.
3. Get the results needs to complete the task.
4. Develop a plan of the report and presentation, which illustrates the implementation of the received task.
5. Write a report.
6. Prepare a presentation.

Defending the training results

1. Present a work and defending the report of the task results.
2. Evaluation of work.

1.1 Theoretical information

1.1.1 General structure of monitoring system

The overall structure of the IoT system should consist of data collection and transmission modules, a server (cloud) part, and the user/administrator who requests the server and receives the required information (Fig. 1). Also, if implementation permits, then the user can contact directly the devices to collect and transfer data without involving the server.

Load capacity of roads depends on the number of cars per unit of road area, and on their dimensions, maneuverability, etc. it is necessary to know the intensity of the traffic flow for its operational management. This will enable the reasonably making decisions about changing the recommended routes either changing the ratio of switching traffic lights at crossroads or creating a "green street".

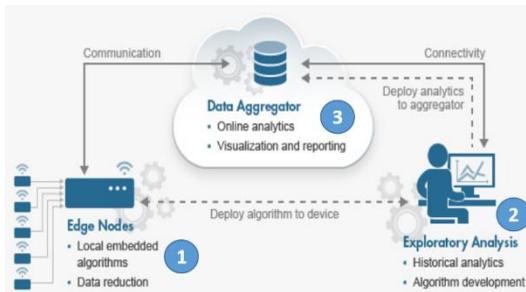


Figure 1 – Structure of the IoT-system

Different methods for determining the number of vehicles passing through the road at fixed intervals are possible. Let's consider examples:

1). Using single infrared sensors. These sensors should be positioned across the road above it so as to overlap all lanes of vehicles (Fig. 2).

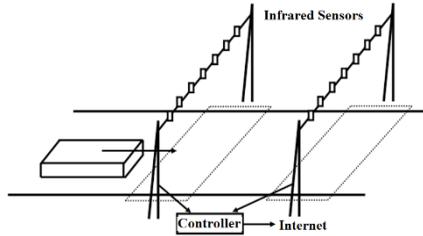


Figure 2 – The placement of infrared sensors across the road

They should be placed with a certain gap that will allow the identification of individual vehicles. The main drawback of this method is the following: single infrared sensors, with a large gap between them may not be small and relatively cold vehicles. Such vehicles, when placed in the zone between the sensors, create a relatively small signal that does not exceed the threshold for sensor operation. Increasing sensor sensitivity leads to the detection of non-existing vehicles due to thermal impediments (heat fluxes that are obstructed by people, animals, sun-heated sections of the road). Also, due to the excess sensitivity of the sensors, simultaneous detection of one vehicle by several sensors may be possible. Therefore, such a method of determining the number of vehicles passing through the road at fixed intervals should be considered as the unreliable one, and its use is not feasible.

2). Using a set of integrated infrared (pyrometric) sensors.

These sensors are often used in access control systems for apartments. They should also be located across the road with a certain gap, which will ensure the recognition of vehicles across the entire width of the road (Fig. 3). However, the contradiction between distance and sensitivity can be bypassed. To do this, one should not recognize individual vehicles, but integrate the intensity of infrared radiation at given fixed intervals of time. This method can even take into account, to some extent, the size of vehicles. Therefore, such a method is much more promising. However, the influence of heat streams that are not derived from vehicles cannot be eliminated when using this method. Although humans and animals create a relatively small heat flux (it will have little effect on the integral heat flux from vehicles with an intense traffic flow), the heat flow that creates the sun-heated section of the road can greatly distort the results

of determining the intensity of the traffic flow. Therefore, this method should also be considered as unreliable one, and its use is inappropriate.

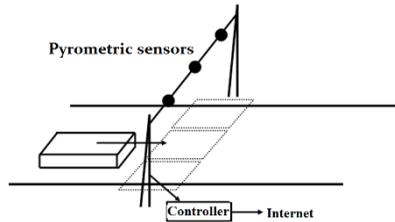


Figure 3 – Placement of group of integrated passive infrared (pyrometric) sensors

3). Using single magnetic sensors. These sensors, similar to single infrared sensors, should be positioned across and over the road so as to cover all lanes of vehicles (Fig. 4). They should be placed with a certain gap that will enable the identification of individual vehicles. The disadvantage of this method is that single magnetic sensors, with a large gap between them may not be able to detect small vehicles, especially those that are made using the latest technologies, that is, using plastics and lightweight (non-magnetic) materials. Such vehicles, especially when entering the zone between sensors, create a relatively small signal that does not exceed the threshold for sensor operation. Increasing the sensitivity of sensors or reducing the gap between them leads to the simultaneous detection of one vehicle by several sensors. However, the main drawback of the method is the considerable complexity of its implementation. When infrared sensors should be positioned above the road, magnetic sensors should be close to these vehicles for reliable vehicle fixation. Due to the fact that the vehicles have a very different height, the magnetic sensors should be placed under the road surface. Therefore, such a method of determining the number of vehicles passing through the road at fixed intervals should be considered very labor-intensive and insufficiently reliable, and its use is not feasible.

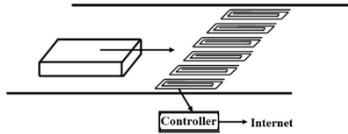


Figure 4 – Placement of single magnetic sensors

4). Using of magnetic sensors. For the integrated flow of vehicles detection magnetic sensors can be used (Fig. 5) the same way as infrared sensors (see above). However, with some advantages, the method has a very significant disadvantage – at low speeds of vehicles magnetic sensors stop detect (the amplitude of the generated voltage of the integrated magnetic sensor – the coil of inductance, covering the entire width of the road – is directly proportional to the rate of change of the magnetic flux). Namely, in difficult traffic situations (traffic jams), when data on the intensity of the traffic flow is most needed, the speed of vehicles is reduced and the electromagnetic sensors cease to work. Therefore, such sensors can only be used on highways, where the probability of a critical reduction in the speed of vehicles is relatively small. But the main drawback of the method – the considerable complexity of its implementation remains. Therefore, such a method of determining the number of vehicles passing through the road at fixed intervals should be considered as the very labor-intensive and insufficiently reliable one. Its use, especially at the intersection, where the likelihood of a critical reduction in the speed of vehicles or even their stops is very high, should be considered as the inappropriate one.

5). Using a Camera. In this case, the determination of the number of vehicles passing through the road at fixed intervals is reduced to the classical methods of image processing. Each vehicle is recognized, for example, by recognizing its shape using an appropriately trained neural network.

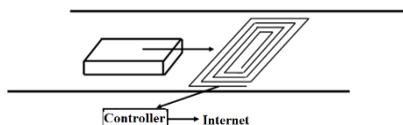


Figure 5 – Placement of magnetic sensors for the integral flow

The appearance of a new vehicle is getting by the camera (Fig. 6). Then it is accompanied until the disappearance in the camera's field of view. The number of vehicles that have passed through the field of view of the camera at fixed intervals is also calculated. It can be also taken into account the dimensions of each vehicle by counting the number of pixels in the image that contains the contour of the vehicle. This method is relatively cheap, since modern webcams and computing devices have a relatively low price. Moreover, the introduction of such a method does not require significant costs – webcams can be placed on the back of the lantern or the wall of the house adjacent to the road.

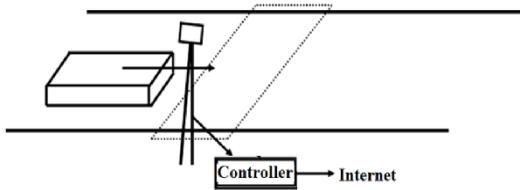


Figure 6 – Webcam location

6). Using Tracers. The most reliable and straightforward is the use of tracers – microcontrollers, which (similar to the corresponding devices in aviation), upon request, either continuously transmit the type, traffic parameters (direction and speed) and vehicle coordinates on the Internet (Fig. 7). It is advisable to use the known communication protocols (Zigbee, Bluetooth, etc.). Such a decision is already being used in public transport vehicles to control their passage along the route. But in order to determine the number of vehicles passing through the road at fixed intervals, such a decision requires the equipping of all vehicles with appropriate tracers. Therefore, such a decision is not yet available.

Taking into account the survey above, it is suggested to consider monitoring of transport using video cameras.

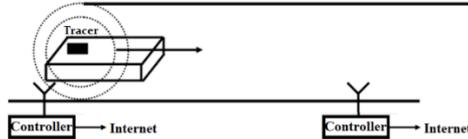


Figure 7 – Use of tracers

Under the term "determining the intensity of the traffic flow" we consider the number of vehicles that pass through the road at fixed intervals. For this purpose, a different hardware could be used, for example:

- A web camera that connected to the computer via USB port.
- A web camera connected via USB port to a wireless USB extender, which transmits information to computer via Wi-Fi.
- A web camera connected via a USB port to a single-board module with the ability to involve external peripherals, like Raspberry Pi. It enables transmitting the information to appropriate computer or server.
- IP-camera, which transmits images to a computer or server.

Web camera that connects via USB to a computer and web camera connecting with the Wireless USB Extender, which in turn transmits the information to a computer by means of Wi-Fi are represented in Fig. 8.



Figure 8 -Using a USB web camera with/ without, a Wireless Extender

An intermediate option between a regular webcam with a computer and the IP camera, we can consider usage of modules with the ability to connect external peripherals and independent power supply, such as Raspberry Pi (Fig. 9). On early Raspberry Pi models, it was possible to install Linux OS, and starting from Raspberry Pi 2 and Pi 3 models, it's possible to run Windows 10 IoT Core, which enables to migrate to Raspberry previously written Windows and debugged applications. The first (early) models of Raspberry use the single-core ARM processor Broadcom BCM2835 with a frequency of 700 MHz.

Currently Raspberry Pi 3 use the more powerful 64-bit processor Broadcom BCM2837, which is located on 4 core ARM Cortex-A53 at 1.2 GHz, with RAM up to 1 GB (Fig. 40.9).

Moreover, it’s possible to use IP cameras, which, unlike traditional analog monitoring devices, make it easy to check traffic conditions in geographically remote locations and transmit information both through wired or wireless channels (Fig. 10).

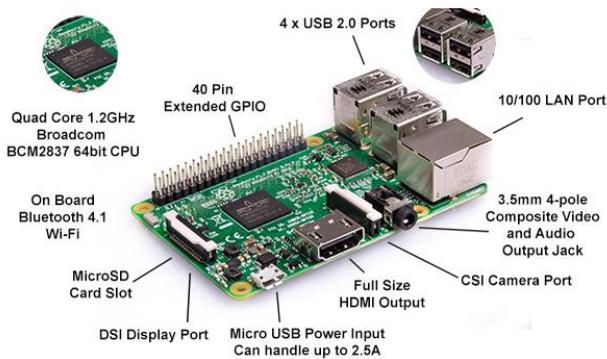


Figure. 9 – Raspberry Pi 3 B

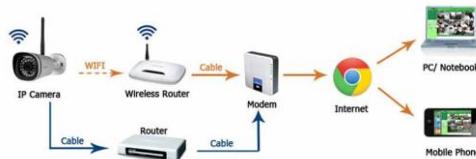


Figure 10 – Example IP camera usage

1.1.2 Used Software

LabVIEW is one of the National Instruments' products. LabVIEW is an abbreviation that stands for Laboratory Virtual Instrumentation Engineering Workbench. It shows the orientation of laboratory studies, measurement and data collection. The process of developing a SCADA system in LabVIEW is simpler than using the "traditional" development tools.

LabVIEW software modules called "Virtual Instruments" or VI. They are stored in files with extension *.vi. VIs are "bricks", of which LabVIEW is a program. Any LabVIEW program contains at least one VI. An analogy with the function can be employed in terms of language C, but in LabVIEW one function is contained in one file (toolbars can be created too). One VI can be called from another VI. In principle, each VI consists of two parts – the Block Diagram and the Front Panel. Block diagram is a program code (more precisely, a visual graphical representation of the code), and the front panel is an interface.

LabVIEW is based on the data flow paradigm. In the aforementioned program, the constant and the terminal of the indicator are connected by a line. This line is called Wire. It can be called "conductor". The conductors transmit data from one element to another. All this concept is called Data Flow. The essence of Block Diagrams is "nodes", outputs of some nodes are attached to the inputs of other nodes. The node is activated to execute when all the necessary data for the job comes. The diagram above is two Nodes. One of them is a constant. This node is self-contained – it starts to run immediately. The second node is an indicator. It displays the data that the constant conveys (but not immediately, but as soon as the data arrives from the constant).

All elements will be executed in parallel. The developer does not need to think about how to parallelize tasks to multiple threads, which can be run in parallel on several processor cores. The latest versions enable to explicitly specify which of the processor cores must run at that or another while-loop. It should also be noted that at the disposal of the developer, a rich selection of tools for synchronizing flows – semaphores, queues, etc.

LabVIEW includes a large set of elements for building user interfaces. The speed of creating the user interface exceeds the speed of creating the interface in Visual C ++, Visual Basic, .NET, etc.

The LabVIEW basic package also includes blocks for working with .ini files, the registry, functions for binary and test files, mathematical functions, powerful tools for constructing graphs and the ability to call DLLs. LabVIEW enables to work with ActiveX components and .NET. A support for classes is provided, so it makes some analogy with the object-oriented SW. However LabVIEW is not a full object-oriented language, although the main features of object-

oriented languages – inheritance and polymorphism are presented there. Moreover, the functionality can be extended by additional modules, such as NI Vision Toolkit – for processing images and machine vision, etc., and the executable .exe file can be generated with the Application Builder module. It’s possible to work: with ftp servers using Internet Toolkit, and databases using Database Connectivity Toolkit.

Many users and developers of LabVIEW believe this is an interpreter, and block diagrams are constantly interpreted by the kernel. But this is not the case, LabVIEW is a compiler. Compilation is "on the fly" – at any point in the development process, the program is always ready to launch. LabVIEW code can also be compiled into an executable file that can be run on a computer without installing LabVIEW (requires LabVIEW Run-Time). We can also build our own installation packages without third-party tools like InstallShield.

LabVIEW Cloud Toolkit for Amazon Web Services (AWS) (Fig. 11) provides interfaces from Windows or LabVIEW real-time Amazon Web Services applications for storing data, publishing messages, and queuing operations.

This module provides additional storage for analytics or post-processing operations; we can use cloud services to programmatically store and retrieve any amount of data from PC-based applications or hardware modules, such as CompactRIO. Such integration with AWS cloud services offers an efficient way to store large volumes of measurements and data directly from LabVIEW, ensuring security, reliability and availability.

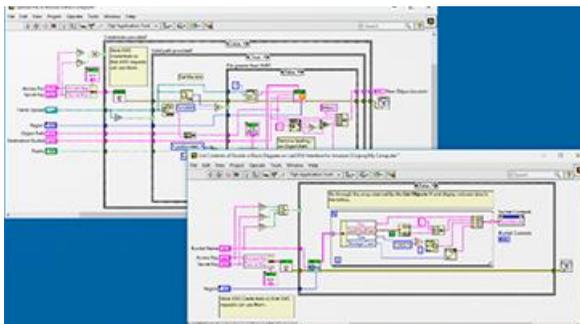


Figure 11 – LabVIEW Cloud Toolkit for AWS

The toolkit supports the following services:

- AWS S3: Simple Storage
- AWS SNS: simple messaging service
- AWS SQS Simple Queuing Service
- AWS IoT Internet of Things

Image and video processing with LabView and Vision Acquisition Software and NI Vision Development Module. Vision Acquisition Software is a software for capturing, displaying, registering and monitoring images from many types of cameras.

Vision Development Module is a set of modules for developing image processing programs that use the LabVIEW and LabVIEW NXG for Windows and real-time systems as well as C, C++ and C# for Windows systems. This package implements all popular image processing algorithms, including filters, morphologies, image matching, 3D image and classification.

1.2 Execution order and discovery questions

1.2.1 Configuration of cameras and creating a new virtual instrument

To get started, it's needed to complete a first phase configuring a webcam, or another that is connected to a PC. For this purpose it's necessary to run Programs> National Instruments> Measurement & Automation Explorer (Fig. 12). Then we need to select Devices and Interfaces> NI-IMAQdx Devices.

After that a list of available equipment is opened, in this case cam0 USB2.0 VGA UVC WebCam for checking the equipment and its selection from the list and run (Fig. 13). Also, in this window the camera can be configured according to the user's requirement.



Figure 12 – Measurement & Automation Explorer

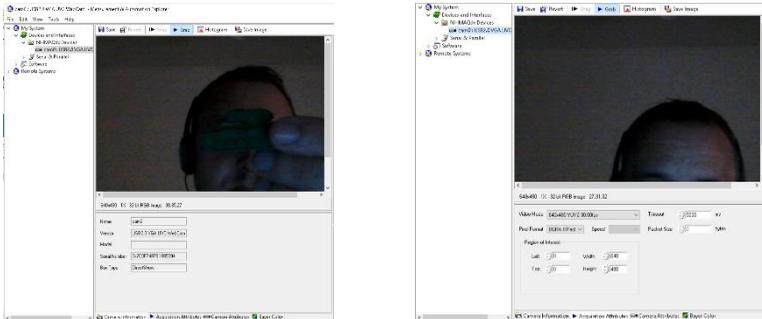


Figure 13 – Camera configuration

After setting up the hardware, it is possible to carry out a second phase creating a new virtual instrument in the LabView environment for image and video processing.

The *first* step of the second phase is to add the required modules in the BlockDiagram field.

To do this, in the BlockDiagram field, select the Vision and Motion> NI-IMAQdx> Open Camera VI, Place the tool and connect a constant in the box that specifies the name of the camera to be used (cam0).

IMAQdx Open Camera VI opens the camera, surveys the camera about its capabilities, downloads the camera configuration file and creates a link to the camera.

In a *second* step it is necessary to select in the Palette functions to choose Vision and Motion > NI – IMAQdx > Snap VI (Fig. 14). and connect the data elements.

IMAQdx Snap VI is employed for equipment with a low speed or for one-time capture of a frame, Snap VI by default uses cam0. If the image type does not match the video format of the camera, this VI changes the image type to the appropriate format.

The *third* step is to select Vision and Motion> Vision Utilities> IMAQ Create (Fig. 15) in the Function palette and connect it to Snap VI.

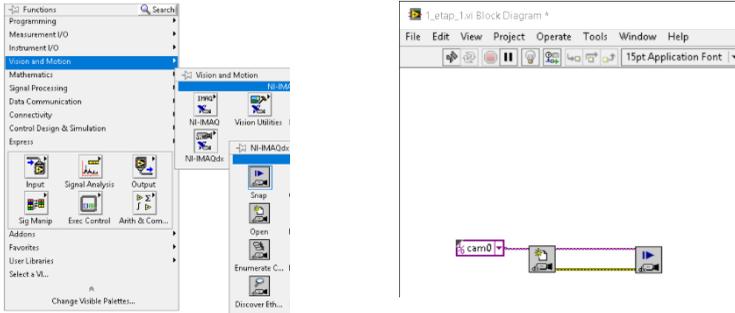


Figure 14 – IMAQdx Snap VI

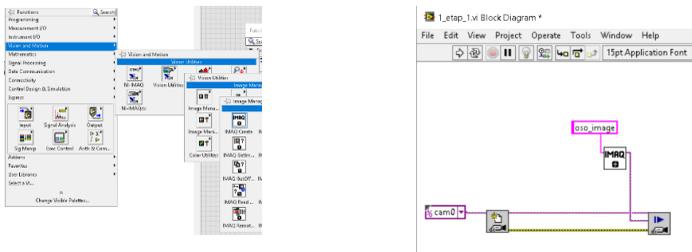


Figure 15 – IMAQ Create VI

IMAQ Create VI creates a temporary memory location for an image.

In the fourth step we need to select the Vision functions in the Palette and Motion > NI – IMAQdx > IMAQdx Close Camera VI (Fig. 16) and connect it to the IMAQdx Snap VI element.

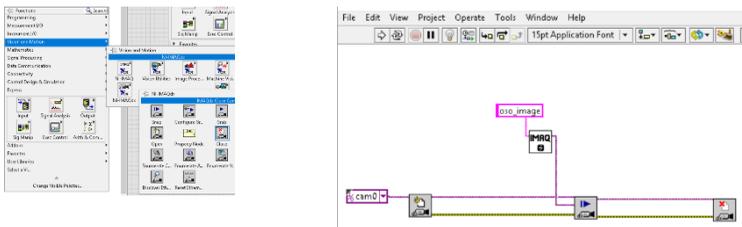


Figure 16 – IMAQ Close Camera VI

To display the results, we go to Front Panel> Vision> Image Display, and in the Block Diagram panel, then connect the Image Display item with IMAQdx Snap VI(Fig. 17). At this stage, the program can receive only one frame from the web camera .

To display all frames, we need to select Programming> Structures> While Loop(Fig. 18) in the Function Palette and put our modules in it.

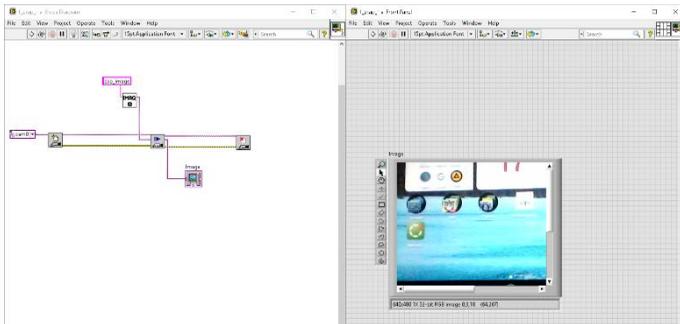


Figure 17 – IMAQdx Snap VI



Figure 18 – While Loop

After that, it will be possible to receive images from the camera in a cyclic manner (Fig. 19).

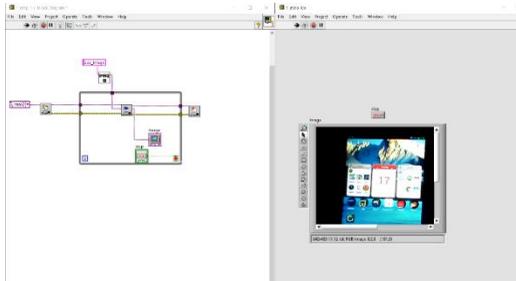


Figure 19 – Retrieve Reference camera image cyclically

However, with this execution, individual images will be output only. To get the video stream, we need to modify this schema, namely to replace the IMAQdx Snap VI element with IMAQdx Grab VI, and after the IMAQdx Open Camera VI element it's necessary to connect the IMAQdx ConFig. Grab VI element. After these changes, a complete video stream should be received.

1.2.2 Formation of images database

To save the processing results in LabVIEW, we have to complete the following steps: (i) modify the previous program

- (ii) add the following blocks  IMAQ AVI Create VI, that create a new AVI file or overwrite the old AVI file and put it after IMAQdx Open Camera VI  and connect according to the block diagrams as it shown below (Fig.20, 21).

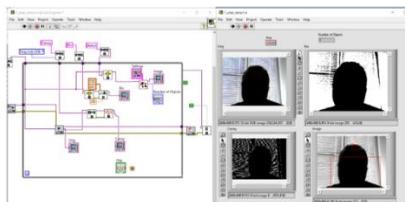


Figure 20 – Program of image processing

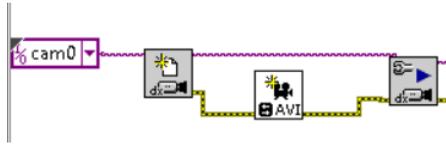


Figure 21 – Improving the image processing program

When setting up IMAQ AVI Create VI it is necessary to specify the location of the video file (Fig. 22).



Figure 22 – The location of the video file

The next block(adding to the program) is IMAQ AVI Write Frame VI . This block writes the image into an AVI file specified by Avi Refnum, which in turn is derived from IMAQ AVI Create VI. The data connection of the blocks is shown below and is marked by red (Fig. 23).



Figure 23 – Connection diagram of IMAQ AVI Write Frame

For the correct completion of the file recording procedure, we have to use the IMAQ AVI Close VI block , which closes the AVI file, associated with AVI Refnum which in turn receives from IMAQ AVI Write Frame VI. The combination of block data is shown below and is marked by red.

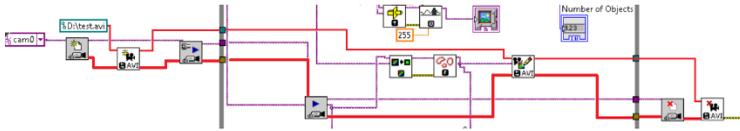


Figure 24 – Connection diagram IMAQ AVI Close VI

After stopping the program, a file was created where the video streaming results are recorded. The results of the modified program are indicated in Fig. 25, created file with the path `D:\test.avi`

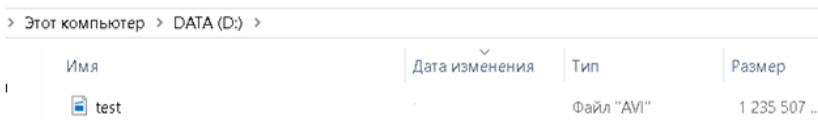


Figure 25 – Result of saving

The saved video (Cany's method) is illustrated by Figure 26.

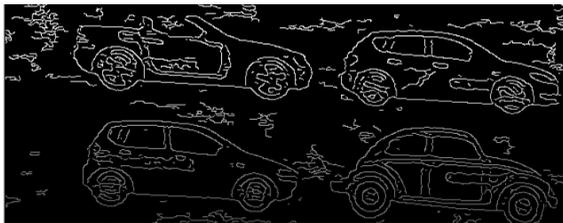


Figure 26 – Video Result (Cany's method)

In turn, the intelligent video surveillance system is a system with its own real-time operating system, which provides high operational reliability and maximally uses computer resources. It enables to achieve maximum speed, the minimum reaction time to events and has long-term stability.

Such systems are characterized by high speed; a large number of cameras; various modes of displaying video information on the screen;

control modes; auto-visualization of channels; scalability; support for many recording formats; changing image parameters: brightness, contrast; intelligent motion detector; event logging work on schedule; catalog of recorded frames.

The first element of an intelligent video surveillance system is video sensors. Examples of video sensors can be digital or IP cameras. From the video image sensor enters the imaging device. After that, the image is pre-processed to improve image quality and reduce the amount of video information and gets on the frame drive. Next, the face area is localized and contour segmentation is carried out.

Contour segmentation consists of selecting a contour, examining it, and selecting the characteristic points. When selecting the contour, it is necessary to obtain an external contour in the form of a closed curve; therefore, approximation methods are often used. The curve approximation method is used for the contour segmentation by selecting an analytically given curve in a set of contour preparation points. If there is information about the expected shape of the object, for example, as in our case (for vehicles), then a rectangle should be taken as an approximating curve. Then we should try to apply the approximation by polynomials using iterative selection methods.

Contour monitoring consists in entering the coordinates of the contour points into a two-dimensional array. Actually the algorithm itself contour resembles the behavior of the "bug". For a binary image, an imaginary “bug” begins its journey on a white field and moves towards the area of the black elements of the image. After the beetle crosses the black element, it turns left and proceeds to the next element. If this element is black, the “bug” turns to the left again, but if the element turns white, the “bug” turns to the right. This procedure continues until the “bug” returns to the starting point (the contour closes). The coordinates of the transition points from black to white or from white to black will be the coordinates of the contour points.

After that, the characteristic points of the contour (points on areas of significant curvature) are highlighted. Based on information about the characteristic points of the contour, an identification procedure is carried out assigning the object (image) to a specific class.

To perform its functions, the vehicle computer recognition system uses a number of hardware and software tools, among which the main

ones are video sensors and a computer. Intelligent video sensors can be programmed to perform high-level procedures such as preprocessing and image segmentation, partially or completely replacing the computer.

A computer in a vehicle recognition system is a hardware complex (microprocessor, RAM, disk drives, and others) and software (software detection subsystem, vehicle recognition, management subsystem of vehicle database, input and output files, and others) and performs as a rule, high-level segmentation and image analysis procedures. Specialized hardware can also be involved in recognition systems: video capture cards, network equipment for distributed recognition systems, and others.

Task options

- Types of cameras
- Camera location

Test questions

- What is a general structure of the monitoring system?
- What are criteria for evaluating the structures of the monitoring system?
- What are advantages and disadvantages of these structures?
- What is Labview?
- What are basic virtual tools for working with a video camera?
- What are Basic Virtual Image Database Tools?

Recommended literature:

1. Jeffrey Travis, Lisa K. Wells, *LabVIEW for Everyone*, Prentice Hall, 2002 – 589p.
2. Peter A. Blume, *LabVIEW Style Book*, Pearson Education, 2007 p. – 400p.
3. Behzad Ehsani, *Data Acquisition Using LabVIEW*, Packt Publishing Ltd, 2016. – 150p.
4. Bruce Mihura, *LabVIEW for Data Acquisition*, Pearson Education, 2001 – 480 p.
5. Jovitha Jerome, *Virtual Instrumentation Using Labview*, PHI Learning Pvt. Ltd., 2010. – 416p.

6. Jeffrey Travis, *Internet Applications in LabVIEW*, Prentice Hall, 2000 – 601p.
7. David J. Ritter, *LabVIEW GUI: Essential Techniques*, McGraw Hill Professional, 2002 – 562p.
8. Thomas Klinger, *Image Processing with LabVIEW and IMAQ Vision*, Prentice Hall; 1 edition (June 21, 2003), 368p.
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12. Simon Monk, *Raspberry Pi Cookbook*, "O'Reilly Media, Inc.", 2013. – 412 p.
13. Brendan Horan, *Practical Raspberry Pi*, Apress, 2013. – 272 p.
14. A. Karapantelakis, J. Markendahl, *Challenges for ICT business development in intelligent transport systems. // Internet of Things Business Models, Users, and Networks*. 2017. pp. 1-6.

TRAINING 2. RECOGNIZE AND DATA PROCESSING OF THE OBJECTS IN A VIDEO FRAME

Aim: calibrating the camera and adjusting the resulting image, calculating the length and width of vehicles different types and receiving and recognizing the images of vehicles different types.

Learning Objectives:

1. To study the Virtual Instruments for calibrating different types of video cameras;
2. To study the features of the Vision Assistant Express package;
3. To study the Virtual Instruments for receiving and recognizing objects in images and video streams.

Practical tasks:

1. Learning usage the Virtual Instruments for calibrating different types of video cameras;
2. Learning usage the features of the Vision Assistant Express package;
3. Learning usage Virtual Instruments for receiving and recognizing objects in images and video streams.

Research tasks:

Exploring the measurement error of vehicle sizes.

In preparation for the training needs:

1. To get the topic of the analytical review and clarify the conditions of the task.
2. To develop a work plan and distribute a responsibility between members of the group (students arrange among themselves parts of the work for which they will report).

Training implementation

During the training:

1. Search of information for training topic and the received task.
2. Perform the necessary actions to complete the received task.

3. Get the results needs to complete the task.
4. Develop a plan of the report and presentation, which illustrates the implementation of the received task.
5. Write a report.
6. Prepare a presentation.

Defending the training results

1. Present a work and defending the report of the task results.
2. Evaluation of work.

1.1 Theoretical information

1.1.1 Calibrate the camera and adjust the resulting image

Geometrical methods can be used to calibrate the camera. For this purpose, is necessary to determine the focal length and angle of view of a video camera by measuring its placement in the environment. The angle of view of the video camera γ and the focal length OD are unknown, they should be looked for experimentally at the stage of camera calibration. For this, the video camera needs to be fixed at a certain distance of the OB relative to the plane of the AC (Fig. 1, a). At the same time, the plane of the AC is projected on the touch panel EK video camera through an optical lens at point A. The horizontal angle of view of the video camera γ can be determined on the basis of the angle δ with the trigonometric properties of the triangle OBC, for which by the cosine theorem:

$$\gamma = 2 * \delta = 2 * \arccos\left(\frac{OB^2 + OC^2 - BC^2}{2 * OB * OC}\right). \quad (40.1)$$

Measurement of BC, OC and OB sizes is provided on the basis of marks taken on the plane and correspond to the last positions of the image (Fig. 1,b). The focal length OD can be calculated from a certain angle γ and the video resolution ED in pixels:

$$OD = ED / \operatorname{tg}\left(\frac{\gamma}{2}\right).$$

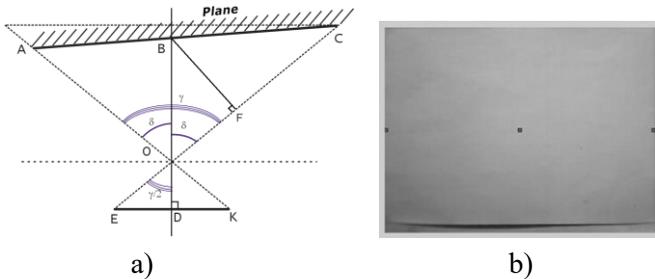


Figure 1 – Geometric representation of the camera calibration process:
 a) geometric representation; b) image obtained during calibration

Another method of calibration is to lower the perpendicular and determine the angle of camera view, as well as the focal length, from right-angled triangles (Fig. 2)

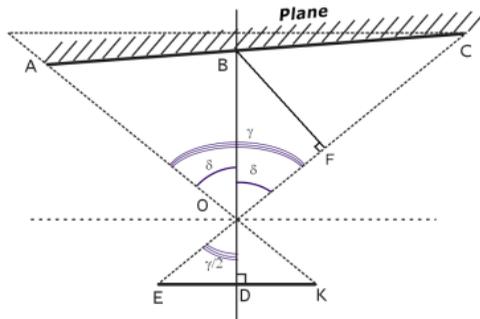


Figure 2 – Geometric representation of another camera calibration method

Calibration of the internal parameters for the camera is performed using the NI Vision Development Module of LabView. Calibration Training has an independent calibration module that makes calibration more convenient and efficient. The calibration process can be divided into three stages: the first is the study of the pattern, a second one is the calibration itself, and the third step is the reading and saving of the calibration results.

There are two types of calibration pattern, a first is the square of the board, and a second is the circular target of the calibration.

The algorithm for extracting stability and positioning accuracy of the circle center exceeds the angle extraction by a checkerboard calibration plate, a simple calibration can be performed with an array pattern of 6 x 8 points (Fig. 3).

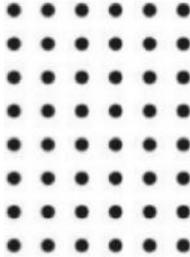


Figure 3 – 6x8 dot array calibration board

The distance from the center between two adjacent points of the distance horizontally and vertically, respectively, is 24 mm.

The calibration algorithm can be described by following steps:

1. Loading the calibration image
2. Extracting the circular contour using a canny filter
3. Running the positioning using round fitting
4. Introducing the calibration image information
5. Configuring the internal camera settings
6. Adjusting the nonlinear optimization
7. Adjusting the external camera settings
8. Saving the calibration results
9. Complete the calibration.

1.2 Execution order and discovery questions

1.2.1 Calculate the length and width of vehicles different types

To determine the length, width and distance between vehicles using LabView is necessary to create the following virtual instruments (Fig. 4) which will help to track objects and obtain their parameters.

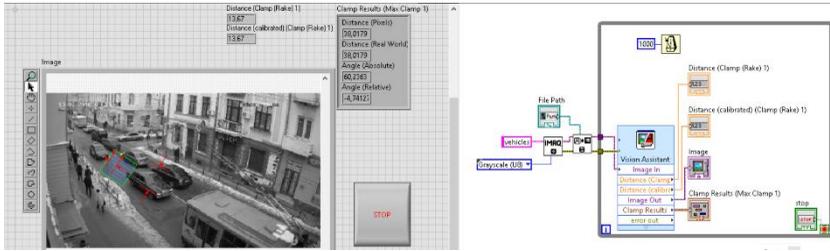


Figure 4 – Virtual instrument for vehicle parameters definition

To create the virtual instrument, the following blocks were used:

1. IMAQ Create VI
2. IMAQ ReadFile VI
3. While loop
4. Vision Assistant Express

IMAQ Create VI and IMAQ ReadFile VI will be described in the subchapter below.

While Loop – Repeats the sub-program inside until the condition is true or when it receives a specific logical value. The logical value depends on the behavior of while cycle. Behavior has two states: "Stop if true" or "Continue if true". Also, the errors cluster can be connected to the conditional terminal. It will allow to perform another condition: "Stop is error" or "Continue if error". The while loop (Fig. 5) is always running at least once.



Figure 5 – While loop (LabView)

Vision Assistant Express – provides the launch and rapid subsystems development for machine vision, image and video processing. Using such instrument the user can select a set of manipulations with video or image and create a macro. After that the Vision Assistant Express will automatically perform actions specified by

the user. The advantage of using this module is the absence of necessity to create the new virtual instruments.

After all components selection it is necessary to adjust the Vision Assistant Express settings according to the requirements. In the first step is necessary to open the main window Vision Assistant (Fig. 6)

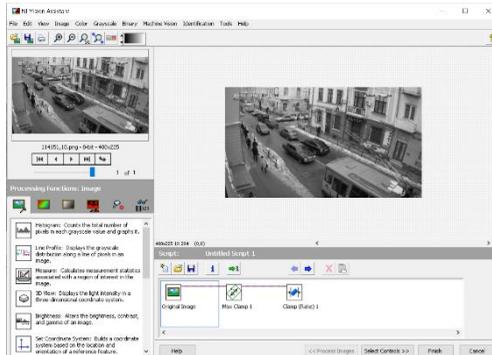


Figure 6 – Main window Vision Assistant

In the second step is necessary to open the Machine Vision tab and select the Max Clamp element (Fig. 7).

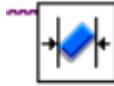


Figure 7 – Max Clamp module

This module finds the edges along the selected area (only rotated rectangle) and measures the distance between most distant opposite points on the found edges. The edges are determined by removing contours from the field of interest and by analyzing their order and geometry. If the reliable calibration information is present then a distance is measured in pixels as well as in real measurement units.

In the third step is necessary to add the next Clamp (Rake) module (Fig. 8). This module measures the distance in the horizontal direction

from vertical sides of search area to the center of search area. The virtual instrument finds ribs along a set of parallel search lines or edges. The edges are determined basing on their contrast and tilt.



Clamp (Rake) 1

Figure 8 – Clamp (Rake) module

After those three steps above the Vision Assistant is ready to work and it can be used in the virtual instrument.

A simple algorithm for compiling a virtual tool is can be stated just in the two steps: (i) Place an IMAQ Create VI element on the chart; (ii) Set up the settings.

1.2.2 Receiving and recognizing the images of vehicles different types

To recognizing objects, the most informative part of the image is the contour. The contour of an object is a part of an object that contains a large amount of information about the shape of an object and does not depend much on the color and texture of the image.

To analyzing the shape of the object can do it by the contour. In many cases, information about the shape of the object is sufficient for the organization of automatic or automated systems. In addition, the transition to the recognition of objects by their contours allows for several orders of magnitude to reduce the amount of information processed, in addition, the contours invariant to brightness transformations.

Since the basic information about the shape of the object is contained in the contour of the object, the selection and description of the contour is an important task of image analysis.

After digitization, each pixel uniquely refers either to the background or to the image. There are different types of criteria for deciding whether each of the pixels belong to the background or the outline of the image.

The contour pixels differ from internal points of the image by the presence of one or several adjacent background cells. At the same time, only horizontal and vertical neighboring cells, or only diagonal cells, are considered as neighboring.

The contour of the binary image is defined by dots in the centers of the cells adjacent to each other. If the grid is shifted by half the length of the side of the square to the right and up, the contour points of the image will be in the nodes of the grid. As a result, the perception of the contour is simplified.

The result of the selection of contours is a contour element – a secondary image of the same size as the original one. At the initial moment, all points of this image are black, and in the process of selecting the contours, the pixels corresponding to the identified limit points of the image are painted in white.

The contour on the color image corresponds to the drop in intensity. However, this definition excludes contours associated with abrupt changes in hue color and intensity in areas with constant brightness.

Representation (coding) of the contour is a stage of obtaining a discrete signal, describes the boundaries of the digitized image.

Requirements for the contour presentation algorithms:

1. reducing the amount of used memory for storage;
2. reducing the time and complexity of further processing;
3. obtain informative features of the object.

Biological systems of visual perception, as research has shown, mainly use contours to select objects, and do not divide objects by brightness. In practice, the drops will NOT be sharp despite the degradation and the limitations imposed by video equipment. Sometimes brightness differences along the boundaries are better traced in the form of jumps of the first derivatives of brightness than by analyzing the values of the brightness itself.

To solving the problem of selecting contours is to try to find a compromise between the number of false contours and the number and size of contour breaks.

It is known that the result of the tracking operation is much less affected by small gaps. They are easier to fix than erroneous contours that are easily confused. The ratio between the number of false contours

and the number and size of discontinuities is determined by the noise immunity of the contour extraction method.

Any region D of the plane of a complex variable contains internal points and contour points (boundary points). The first of them have the peculiarity that not only they themselves, but also some of their neighborhoods entirely belong to domain D . The contour points are not internal, but in any small neighborhood of such points there are internal points of area D and points that do not belong to area D – external (background colors). The domain D has the property of connectedness, which consists in the fact that all its points are connected by a line that is completely in the middle of D .

A contour line of G called convex if the straight line segment connecting its two any points consists entirely of internal points of area D . A contour section is concave if such a segment includes external (background) points.

The internal element (pixel) of a binary digitized image $\omega(m_1, m_2)$ has the property of four-connectivity, that is, the adjacent elements – upper, lower, left and right, also belong $\omega(m_1, m_2)$.

To process the contour analytically, it is necessary to encode it, that is, to assign a certain number to each contour element. The sequence of such numbers is called the contour code.

On a square grid, there are eight possible standard arrangements. Let's consider some methods for encoding contours.

1. Coding by three features: the length of the current elementary vector, the direction of rotation in the transition to the next elementary vector and the angle between adjacent elementary vectors.

2. Coding the current elementary vector three-digit binary code (numbers from 0 to 7). This code was proposed by Freeman and was widely used in image processing tasks.

3. The coding of the current elementary vector by its two projections on the coordinate axes with the origin combined with the beginning of the elementary vector is a two-dimensional code.

4. A polygonal representation of the contour, obtained by approximating it with linear segments (Fig. 9).

Coding consists in fixing the coordinates of the ends of these segments.

This method due to the compactness of the obtained descriptions is widespread. This raises the problem of segmentation, similar to the problem of discretization of signals. In real cases, it is usually associated with the loss of information about the shape of images.

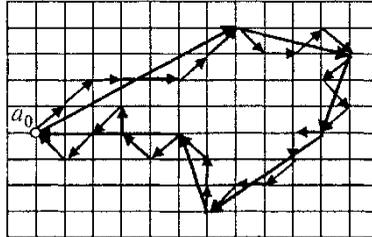


Figure 9 – Polygonal representation by contour approximation of linear segments

The methods for contour extraction can be divided into two large groups: differential and correlation extremal. In differential methods, the intensity drops are amplified by numerical differentiation, then the contour is extracted using a threshold device, after which the binary image is subjected to secondary processing, the purpose of which is to refine the contour to one pixel. The methods are simple to implement and have high speed, but have low noise immunity. The main criterion in assessing the noise immunity of the contour extraction is the position of the brightness difference.

On the other side, two approaches are used to define and describe a contour: selecting the edges or selecting the area of a point of which form an object.

The literature lists and describes a large numbers of algorithms for the selection of contours and boundaries. The most popular methods include: the operator Roberts, Sobel, Prewitt, Kirsch, Robinson, the Kanny algorithm and the LoG algorithm. These algorithms are based on underlining sharp changes in brightness, which are characteristics of the objects contours.

LabVIEW Vision enables to read/create images files and it provides the means to manage these files. Such module has built-in functions for image analysis files (image area selection, intensity

measurement, etc.). LabVIEW IMAQ enables to receive images from cameras.

A set of virtual instruments (LV-Based Vision Tools) (Fig. 10) for working with images and video is described below.

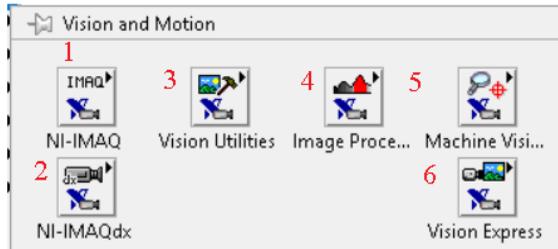


Figure 10 – LV-Based Vision Tools

There are basic virtual instruments of LV-Vision Tools:

- 1) Image data type, Capturing images
- 2) Analyzing images
- 3) Vision Utilities
- 4) Image processing
- 5) Machine vision.

Vision Utilities – VIs is assigned for creating and manipulating images, etc. Image Processing – provides ‘low level’ Vis. Machine Vision – groups many practical Vis for performing image analysis. For example, the “Count and Measure Objects” VI is found under this group. for analyzing images.

Vision Utilities (Fig. 11) is used to create and manipulate images, for example:

- Image management (create, dispose, etc.)
- File handling
- Image manipulation
- Pixel editing
- etc.

To determine objects (vehicles) in LabVIEW it is necessary to create the following virtual instrument. The process of its creation consist of the following steps:

Step 1. Create an empty loop where all the main elements will be placed (Fig. 12)

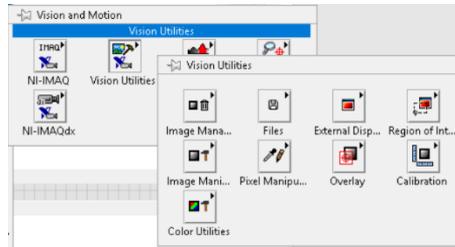


Figure 11 – Vision Utilities

Step 2. Select and place the virtual instrument IMAQ Create VI (Fig. 2.12) into the loop. This instrument is necessary for a temporary memory allocation for images in NI Vision package. The components in Figure 2.12 run the following functions:

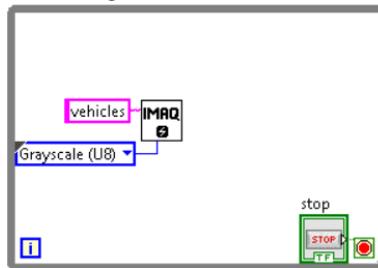


Figure 12 – IMAQ Create VI

Border Size – specifies the size of the border around the image in pixels. The default value is 3 pixels.

Image Name – the name associated with the created image. Each created image should have a unique name.

Error in (no error) – describes the status of an error before running the virtual tool or function. If the error occurs, it transmits from one node to another and the job is not executed while a cycle is running in the idle mode.

Image Type – Sets the image type and has the following representation: grayscale (U8) (0) 8 bits per pixel; grayscale (16) (1) 16 bits per pixel; RGB (U64) (6) 64 bits per pixel and so on.

Step 3. Provide the Image Name and set the Image Type (Fig. 13).

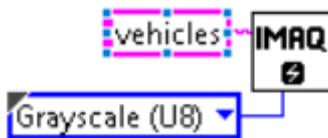


Figure 13 – Setting options for IMAQ Create VI

Step 4. Add the IMAQ ReadFile VI virtual tool. Its main functions are following: reading the image files of the following formats – BMP, TIFF, JPEG, JPEG2000, PNG and AIPD or non-standard user-defined formats.

Step 5. Specify the path of the image location and connect with IMAQ Create VI according to the scheme (Fig. 14)

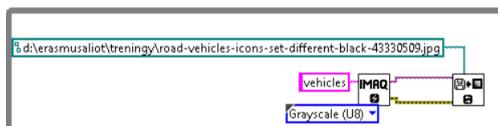


Figure 14 – Opening a file

Step 6. Add the module for objects detection IMAQ Count Objects 2 VI for vehicles selection in the video or image fragment (Fig. 15). This module can be used to measure objects that are listed in

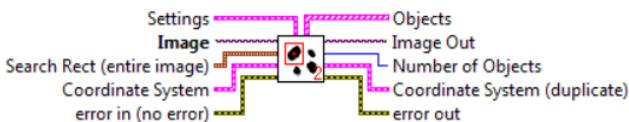


Figure 15 – IMAQ Count Objects 2 VI

the rectangular area. A current virtual tool uses the threshold of pixel intensity to segment objects from their background. To display results and set object search options on the Front panel it is necessary to create the elements for displaying the results: Image display, Number of Objects and search Setting parameters (Fig. 16).

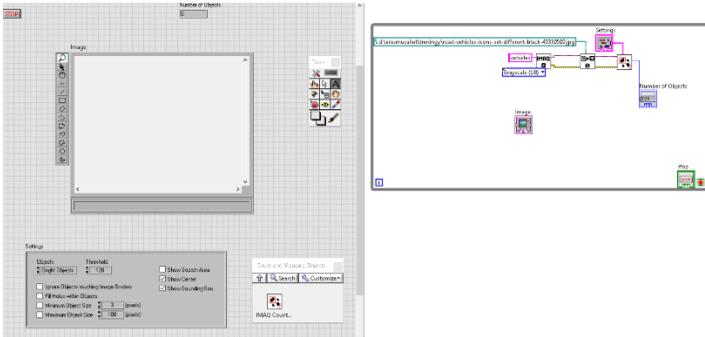


Figure 16 – Connection scheme IMAQ Count Objects 2 VI

Step 7. Add the display element of error processing and connect all components according to the diagram (Fig. 17).

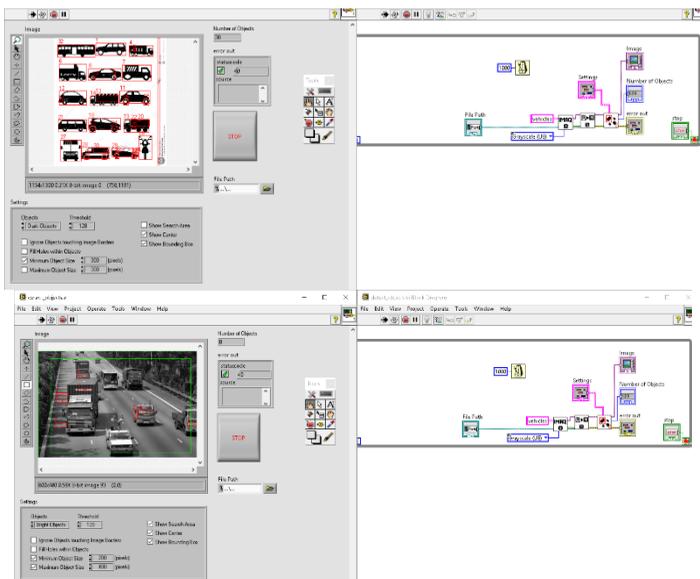


Figure 17 – General view of the system

For the recognition of certain vehicle types it is necessary to improve the previous scheme in the following way.

Firstly, created the two different objects IMAQ Create VI. The first object ((Fig. 18, a left side). serves to open the file with cars on the road,

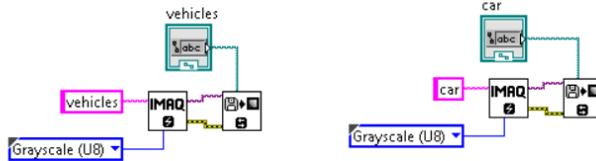


Figure 18 – Improvement of the virtual tool for pattern recognition

the second one is an object of pattern search, in this case, the pattern of a particular car. To solve this problem is necessary to use a virtual tool called IMAQ Find Pattern 3 VI (Fig. 19).

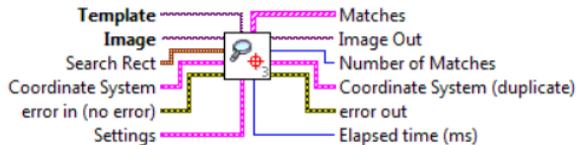


Figure 19 – IMAQ Find Pattern 3 VI

This virtual tool provides a template search in an image rectangular search area. It is not necessary to connect all inputs and outputs for the system work. In this case, the following elements of this virtual tool are important:

Template – is a link to the search image during the comparison process. Template image is an image obtained from the IMAQ Learn Pattern 2 VI output data. If a template is not explored, the virtual tool is initially trained.

Image – link to the original image.

Settings – a cluster that defines the algorithm parameters for template layout and the information which is superimposed on the result image. For example, **Match** defines a technique which is used during the template search in the image and it has the following options: Shift Invariant (0) (Default) – perform a template search in the image, assuming that it is not turned more than 4 degrees; Rotation Invariant (1) – perform the template search in the image without the rotation limitations of the template.

Number of Matches is the number of templates match found in the main image, based on the input settings.

After that, the data elements (virtual tools) are merged in a form (Fig. 20):

Template – is a link to the search image during the comparison process. Template image is an image obtained from the IMAQ Learn Pattern 2 VI output data. If a template is not explored, the virtual tool is initially trained.

Image – is a link to the original image.

Settings – a cluster that defines the algorithm parameters for the template

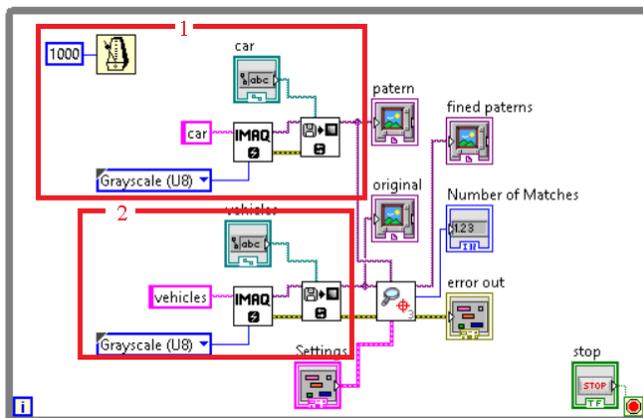


Figure 20 – Connection scheme of virtual tool elements

layout and the information which is superimposed on the result image. For example, **Match** defines a technique which is used during the template search in the image and it has the following options: Shift Invariant (0) (Default) – perform a template search in the image, assuming that it is not turned more than 4 degrees; Rotation Invariant (1) – perform the template search in the image without the rotation limitations of the template.

Number of Matches is the number of templates match found in the main image, based on the input settings.

After that, the data elements (virtual tools) are merged in the following way(see a Fig. 21):

- The processing output of template number 1 connects to the input of Template
- The processing output of the original image number 2 is connected to the input Image
- Error handling results from block 2 are connected to the error processing entry for the virtual tool IMAQ Find Pattern 3 VI
- The pattern indicator connects to Image output Out block number 1
- The original indicator is connected to the Output Image Out of Unit #2
- The fined patterns indicator is connected to Image output Out IMAQ Find Pattern 3 VI
- The Number of Matches indicator connects to the Number of Matches output of the virtual tool IMAQ Find Pattern 3 VI
- Control element Settings is connected to the input Settings of virtual tool IMAQ Find Pattern 3 VI

A Fig. 21 shows the results of the system’s work. According to the results, the 3 cars were found and one car was unidentified using one template.



Figure 21 – Result of cars detection on the road (images)

Task options

- Camera calibration by different ways
- Receiving and processing the images from the camera using the Vision Assistant Express package

- Create a virtual instrument for processing the images from a camera

Test questions

- What are methods of calibration of cameras?
- Which virtual instruments are used to calibrate video cameras?
- What is the Vision Assistant Express package?
- What virtual instruments are used to process images?
- What virtual instruments are used to process a video stream?
- What virtual instruments are used to determine the parameters of objects in images?

Recommended literature:

1. Richard O. Duda, Peter E. Hart, David G. Stork. Pattern Classification (Pt.1) 2nd Edition. Wiley-Interscience, 2000, 688 p.
2. Ya. A. Furman, A. V. Krevetsky, A. A. Rozhentsov, R. G. Khafizov, I. L. Egoshina, A.N. Leukhin. Introduction to the contour analysis: applications to image and signal processing – 2nd ed., M.: FIZMATLIT, 2003, – 592 p. (In Russian)
3. R. C. Gonzalez, R.E. Woods. Digital Image Processing, 3rd Edition, Pearson, 2007. – 976 p.
4. William K. Pratt . Digital Image Processing. PIKS Scientific Inside. 4th Edition. John Wiley & Sons, 2007, – 808 p.

TRAINING 3. RECOGNIZE AND DATA PROCESSING OF THE OBJECTS ARRAY IN A VIDEO STREAM

Aim: Counting the number of vehicles different type passed through the camera field of view at fixed intervals, Determining the coefficient of filling the road by different types of vehicles, Using virtual instruments in IoT.

Learning objectives:

1. To study the principles of creating the virtual instruments for counting the number of vehicles of different types passed through the camera;
2. To study methods for calculating the coefficient of filling the road;
3. To study virtual instruments for creating the IoT structure.

Practical tasks:

1. Learning how to use the virtual instruments for counting the number of vehicles of different types passed through the camera;
2. Learning how to calculating the coefficient of filling the road;
3. Learning how to create virtual instruments for cloud services.

Research tasks:

Creating a primitive for calculating the coefficient of filling the road

In preparation for the training needs:

1. To get the topic of the analytical review and clarify the conditions of the task.
2. To develop a work plan and distribute responsibility between members of the group. (students agree among themselves parts of the work for which they will report)

Training implementation

During the training:

1. Search information of the training topic and the received task.

2. Perform the necessary actions to complete the received task.
3. Get the results needs to complete the task.
4. Develop a plan of the report and presentation, which illustrate the implementation of the received task.
5. Write a report.
6. Prepare a presentation.

Defend training results

1. Present a work and defending the report of the task results.
2. Evaluation of work.

1.1 Theoretical information

1.1.1 Determining the coefficient of filling the road by different types of vehicles

To estimate the state of traffic flows through the road intersections (intensity of the transport environment) it's proposed to use a coefficient that represents a road filling by vehicles. To estimate the filling factor (a first step), is necessary to find the road area size that falls into the range of video camera:

$$S_w = L_w \cdot B_w , \quad (1)$$

where S_w , L_w , B_w – respectively, the area, length and width of the road section covered by video camera.

A second step is the evaluation of the area, occupied by vehicles on the road. For this purpose, the results of determination length and width of each vehicle (described in subsection 3.1) should be used. It should be noted, that in real life vehicles cannot be too tight to each other, and therefore results, obtained in subsection 3.2 above, should be supplemented by the distances between vehicles. These distances depend on the speed of vehicles. But for simplicity it is assumed that they are constant. In this case, the area occupied by vehicles on the road can be calculated by the formula:

$$S_{WEH}^{\Sigma} = \sum_{i=0}^n (L_{WEH}^i + l_{WEH}^i) \cdot (B_{WEH}^i + b_{WEH}^i), \quad (2)$$

where S_{WEH}^{Σ} – the total area occupied by vehicles on the road; i – the current vehicle number assigned during the processing of current frame; L_{WEH}^i – defined in subsection 3.1.2 the length of each vehicle; B_{WEH}^i – defined in section 3.1.2 the width of each vehicle; l_{WEH}^i – distance from one vehicle to another by length (front of one car and back of another); b_{WEH}^i – distance from one vehicle to another by width (side of one car and side of another).

As it was said, values l_{WEH}^i and b_{WEH}^i are constant. Their values are determined by the method of expert evaluations.

After the definition of S_{WEH}^{Σ} and S_w the coefficient K of filling the road by vehicles

$$K = S_{WEH}^{\Sigma} / S_w . \quad (3)$$

Formally, it is difficult to estimate the intensity of the transport situation by the K coefficient, especially in a case the speed of passing road intersection depends not only on the "density" of vehicles on the road, but also on the condition of road surface, weather conditions, driver qualifications and other factors.

1.1.2 Counting the number of vehicles different type passed through the camera field of view at fixed intervals

To track vehicles in a video stream it is necessary to modify previous examples above with images or create a new virtual instrument. For this purpose, the following modules should be used:

IMAQ Create – requires two modules, the first for original image obtained from the video camera, and second one for search sample.

IMAQ ReadFile VI – to open a sample file

IMAQ Setup Learn Pattern 2 VI – to establish the parameters used during the samples training phase

IMAQ Learn Pattern 2 VI – to create a description of the image pattern for which is necessary to perform search operation during the phase confirmation of pattern matching. The description details are attached to the input image template. During the phase confirmation, the template descriptor is extracting from the image template and it is used to search the template in the inspected image.

IMAQ Setup Match Pattern 2 VI – to set the parameters used during confirmation phase of the pattern match.

IMAQ Match Pattern 3 VI –to search the template or image template in the inspected image.

IMAQ Overlay Rectangle VI – to overlay rectangle into the image for the visual tracking.

IMAQdx Open Camera VI – to open the camera, survey the camera about its capabilities, download the camera configuration file and create a unique link to the camera.

IMAQdx ConFig. Grab VI – to conFig. and start frames capturing.

IMAQdx Grab VI – to read the latest frame in Image Out. This module is called only after initiating the IMAQdx ConFig. Grab VI. If the image type does not match the camera video format, this virtual instrument changes the image type into the appropriate format.

IMAQdx Close Camera VI – to stop the camera operation, remove measurement related resources and close the specified camera session.

1.2 Execution order and discovery questions

1.2.1 Virtual instrument for cars detection on the road in video stream

Below is an algorithm of assembling this virtual instrument can be described by following steps (Fig. 1 presents the completed assembly process):

1. Place two modules IMAQ Create and set the appropriate parameters. For this case it is the name and type of image.
2. Install IMAQdx Open Camera VI and connect it to IMAQdx ConFig. Grab VI.
3. Place loop While after these elements.

4. Put the element IMAQdx Grab VI into the while loop, it will merge with the element IMAQdx Close Camera VI only.

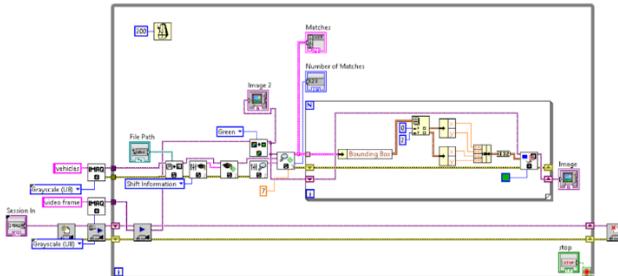


Figure 1 – Block Diagram of virtual instrument for cars detection on the road (video stream)

Put elements into the while loop and connect them in the following sequence:

- IMAQ Create VI with IMAQ ReadFile VI
- IMAQ Create VI (for working with images from video camera) with IMAQdx Grab VI
- IMAQ ReadFile VI with IMAQ Learn Pattern 2 VI
- IMAQ Setup Learn Pattern 2 VI with IMAQ Learn Pattern 2 VI
- IMAQ Learn Pattern 2 VI with IMAQ Match Pattern 3 VI
- IMAQ Setup Match Pattern 2 VI with IMAQ Match Pattern 3 VI
- IMAQ ExtractSingleColorPlane VI with IMAQ Match Pattern 3

The interface of this virtual instrument is shown in Fig. 2



Figure 2 – The result of the cars detection on the road (video stream)

1.2.2 Virtual Instruments with ThingSpeak

– ThingSpeak is a web service (REST API) that collects and stores sensor data in the cloud and using this resource you can develop Internet of Things applications.

– Denmark service supports work with Arduino, Raspberry Pi and MATLAB for which corresponding libraries are implemented.

– But it also works with all kinds of programming languages, because it uses REST API and HTTP.

Figure 3 shows an approximate structure of this service.

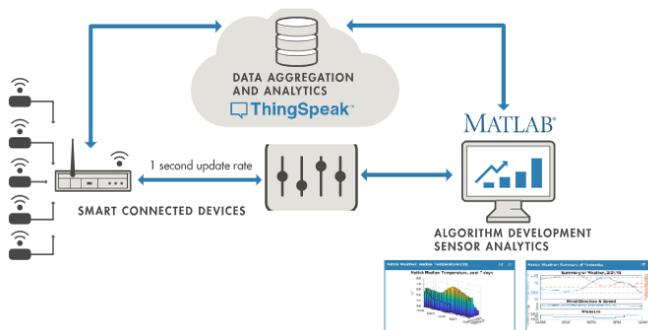


Figure 3 – Structure of the service

This figure shows the general scheme of how ThingSpeak + LabVIEW works. Further, the stages of creating a virtual tool will be presented in the context of a system for analyzing traffic on the road and transferring data to ThingSpeak in the IoT environment.

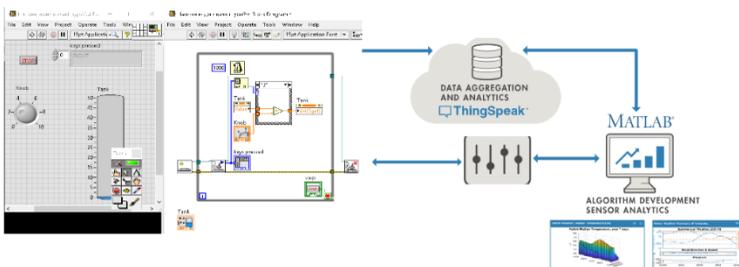


Figure 4 – Structure of ThingSpeak with LabVIEW

First need to create a virtual tool for detecting objects on the road. The creation process has been described above and the working area, and the block diagram is shown below.

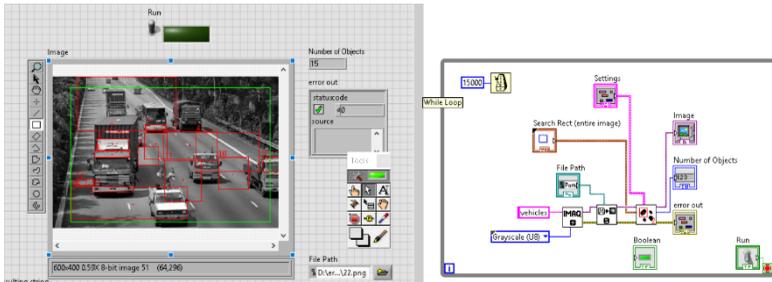


Figure 5 – Car detection VI

Next needs to register on the ThingSpeak service, after which a user window will open (Figure 6), where needs to create a channel by clicking on the New channel button, and the channel settings window will open. After creating a channel, a channel window opens where cans configure access and data transfer on the channel.

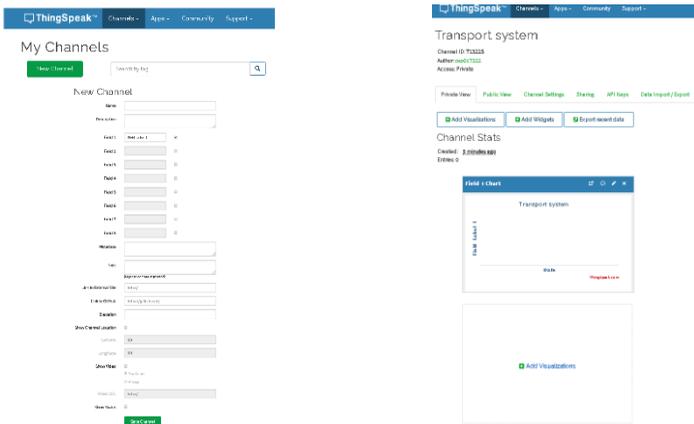


Figure 6 – Channel Setup in ThingSpeak

To transfer data, go to the Data Export / Import tab (Figure 7) and copy the settings how to form a Get request to add data to the server.

Update a Channel Feed

```
GET https://api.thingspeak.com/update?api_key=YK2GQ28DR44H29WQ&field1=0
```

Figure 7 – GET request to add data to the server

- api_key – variable channel access key;
 - field1 is a variable where the measurement values are recorded, in our case, the number of machines in the frame over a period of time;
- Next, needs to modify the previous virtual instrument so that you can send data as shown in Figure 8.

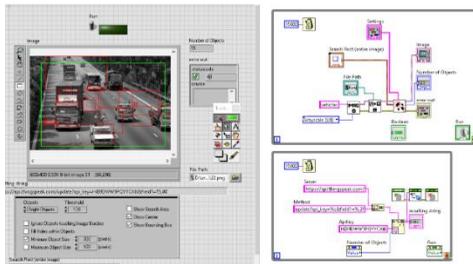


Figure 8 – Modified Virtual Instrument

To do this, needs to create a separate parallel loop (Figure 9).

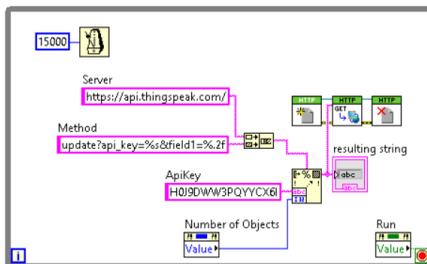


Figure 9 – The separate parallel loop

After that needs to create a connection to the server using the following blocks OpenHandle VI, GET VI, CloseHandle VI (Figure 10)

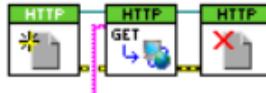


Figure 10 – Server Connection

OpenHandle VI – Opens the client descriptor

GET VI – Sends a web request that returns headers and body data from a server, web page, or web service. This VI uses the GET method.

CloseHandle VI Closes the client descriptor and deletes all saved cookies, authentication credentials and HTTP headers associated with the client descriptor. This VI also terminates all HTTP connections and exits any authentication.

Since GET VI – Sends only a web request and does not send data, for this needs to modify the request so that it cans transfer data in the body of the request. This is done as follows: first needs to divide the request into parts as below.



Figure 11 – Split request into parts

String "Server" contains server address for data sent

string "Method» contains the name of script update, the variable api_key, the variable field1, those variables was created when created the channel.

The string "ApiKey" is the access code for the update script. The access code was allocated separately, because there can be many channels and each channel has a separate access code, and with this arrangement, it is easy to change channels where data is sent.

The variable "Number of Objects" contains the number of the cars for a period of time.

"Concatenate Strings" and "Format Into String Function" are functions used to concatenate strings (Figure 12).

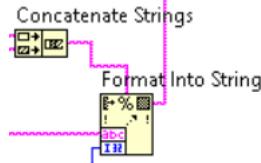


Figure 12 – Concatenate Strings and Format Into String Function

Concatenate Strings» merge the "Server" and "Method" strings, then the "Format Into String Function" inserts the key value into "ApiKey" and number value into "Number of Objects", after that the request is concatenate and can be sent to the server.

Then can go to the channel <https://thingspeak.com/channels/694756>, channel number 694756 is generated when the channel is created and is also displayed in the channel settings (Figure 13)

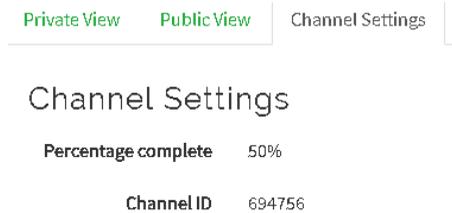


Figure 13 – Channel settings

In addition to displaying data, it is possible to analyze them using MatLab programs that are automatically generate, runs, show results (Figure 14)

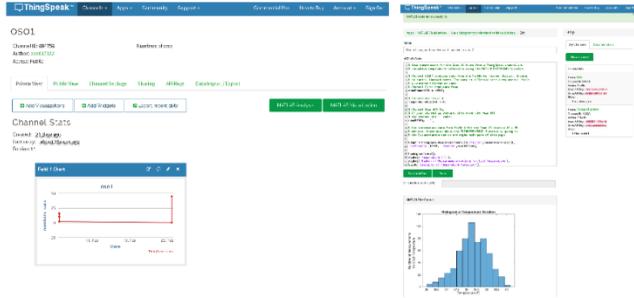


Figure 14 -View the results of tracking the number of cars on the road

Task options

- Developing a virtual instrument for counting the cars depicted in the camera focus
- Developing the virtual instrument for counting trucks in the camera focus
- Develop the virtual instrument for sending the data of the road traffic to a cloud service

Test questions

- What are main modules for counting the number of vehicles?
- What are the main modules for searching the template or image template in the inspected image?
- How to mark the found objects in the general picture?
- What is ThingSpeak ?
- What are REST API and HTTP ?
- How to rate a coefficient of filling the road by vehicles?

Recommended literature:

1. Amirhossein Ghanbari, Andres Laya, Jesus Alonso-Zarate, and Jan Markendahl. Business Development in the Internet of Things: A Matter of Vertical Cooperation. IEEE Communications Magazine. Volume 55, Issue 2, February 2017, pp. 135-141
2. Yang, Y., Zhang, H., Yuan, D., Sun, D., Li, G., Ranjan, R., & Sun, M. Hierarchical extreme learning machine based image denoising

network for visual Internet of things. *Applied Soft Computing*. 2018. pp. 747-759.

3. Adrian N. Bishop, Andrey V. Savkin, Pubudu N. Pathirana. Vision-Based Target Tracking and Surveillance With Robust Set-Valued State Estimation. *IEEE Signal Processing Letters*. 2010 , Volume: 17 , Issue: 3. pp. 289 – 292.

4. C. H. Kuo, C. Huang, R. Nevatia. Multi-target Tracking by On-line Learned Discriminative Appearance Models. *IEEE Conference on Computer Vision and Pattern Recognition*, 2010. pp. 685–692.

5. Zeyu Fu, Pengming Feng, Syed Mohsen Naqvi, Jonathon A. Chambers. Robust particle PHD filter with sparse representation for multi-target tracking. *2016 IEEE International Conference on Digital Signal Processing (DSP)*. 2016. pp. 281-285.

6. Hailun Wang, Mingming Zhang, Renyu Yang, Xuelian Lin, Tianyu Wo, Rajiv Ranjan, Jie Xu. SMTP: An Optimized Storage Method for Vehicle Trajectory Data Exploiting Trajectory Patterns. *2016 IEEE 18th International Conference on High Performance Computing and Communications; IEEE 14th International Conference on Smart City; IEEE 2nd International Conference on Data Science and Systems (HPCC/SmartCity/DSS)*. 2016, pp. 773-780.

7. Hakan Terelius, Karl Henrik Johansson. An efficiency measure for road transportation networks with application to two case studies. *2015 IEEE 54th Annual Conference on Decision and Control (CDC)*. December 15-18, 2015. Osaka, Japan. pp. 5149- 5155.

8. Johan Wahlstrom, Isaac Skog, Peter Handel. Smartphone-Based Vehicle Telematics: A Ten-Year Anniversary. *IEEE Transactions on Intelligent Transportation Systems*, 18(10), 2017, pp. 2802–2825.

Module 3.2 “IoT for Public Transport Information Service Delivering”

LABORATORY WORK 1 EXPLORING OF COMPONENTS FOR VEHICLE LOCATION TRACKING DEVICE

Goal and objectives: this laboratory work allows you to study and independently assemble the device to determine the geographical coordinates of the vehicle.

Learning objectives:

1. study the components of the tracking device;
2. study the principle of the device, the method of information transfer.

Practical tasks:

1. acquire practical skills in working with components for a tracking device;
2. gather information on the technical characteristics of the components of the device;
3. to perform an analysis to select the optimal components for assembly.

Exploring tasks:

1. find the optimal set of components;
2. test the performance of the device.

Setting up

1. to study the theoretical material contained in this manual, as well as a list of references;
2. analyze the most suitable components for assembly.

Recommended software and resources: manuals for such devices.

1.1 Synopsis

In this laboratory work you will get acquainted with all the necessary technical characteristics of the main components for self-assembly of the vehicle positioning device.

1.2 Brief theoretical information:

Used components:

- Arduino Mega 2560/Arduino Uno
- GPS SkyLab SKM53
- SIM900 based GSM / GPRS Shield
- DC-DC 12v-> 5v 3A converter GPS receiver



The selected module is one of the cheapest and simplest. Nevertheless, the manufacturer promises the presence of a battery for storing satellite data. An important parameter of devices connected to the Arduino – power consumption. If you overload the Arduino converter, it may burn. For the receiver used, the maximum power consumption is 45mA.

GSM receiver / transmitter



GSM module – SIM900. It supports GSM and GPRS. Neither EDGE, nor even 3G, are supported. This is probably good for transferring coordinate data – there will be no delays and problems when switching between modes, plus GPRS is almost everywhere now.

1.3 Execution order and discovery questions:

1. Use Arduino Mega 2560 (Arduino Uno), SIM900 – GSM / GPRS module (to send information to the server), GPS receiver SKM53 GPS.

2. We carry out the connection of the GPS receiver. GPS is not controlled, although it has an RX pin. The main thing you can do with this receiver is to read the NMEA data from the TX pin. Levels – 5V, just for Arduin, speed – 9600 baud. We connect VIN to VCC arduino, GND to GND, TX to RX of the corresponding serial. We read the data first manually, then using the TinyGPS library.

3. We carry out the connection of a GSM receiver / transmitter. The module is also controlled by a serial port, with the same level – 5V. After connecting, we are trying to establish communication with the module. We select the port speed – 115200, while it’s good if all the built-in serial ports (4 on mega, 1 on uno) and all software work at the same speed. So you can achieve a more sustainable data transfer.

4. We program the module. The module provides extensive data transfer capabilities. Starting from voice calls and SMS and ending, in fact, GPRS. And for the latter it is possible to perform an HTTP request using AT commands. To get the page at a specific URL, you need to send the following commands:

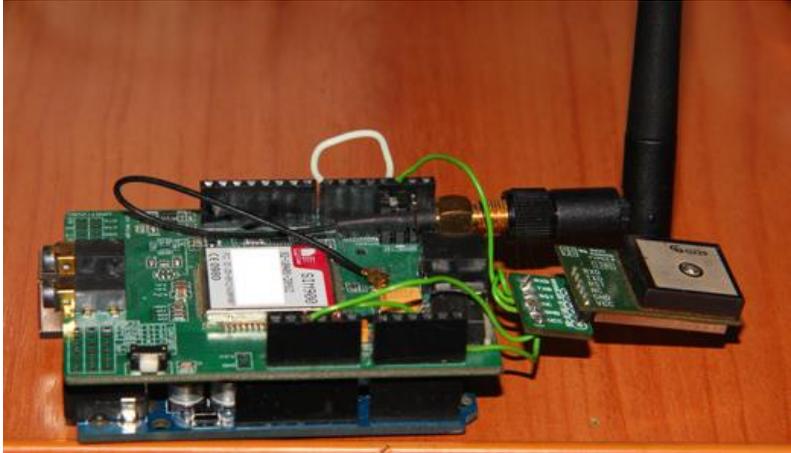
```
AT + SAPBR = 1.1 // Open carrier (Carrier)
AT + SAPBR = 3,1, "CONTYPE", "GPRS" // connection type – GPRS
AT + SAPBR = 3.1, "APN", "internet" // APN, for Megaphone – internet
AT + HTTPINIT // Initialize HTTP
AT + HTTPPARA = "CID", 1 // Carrier ID to use.
AT + HTTPPARA = "URL",
"http://www.example.com/GpsTracking/record.php?Lat=%ld&Lng=%ld" //
Actually URL, after sprintf with coordinates
AT + HTTPACTION = 0 // GET request data
// wait for an answer
AT + HTTPTERM // stop HTTP
```

As a result, if there is a connection, we will receive a response from the server. That is, in fact, we already know how to send coordinate data if the server accepts it via GET.

5. We organize food. Since it was a bad idea to power the GSM module from the Arduino converter, it was decided to buy a 12v-> 5v, 3A converter.

6. We implement the server part.

Appearance of the device without body:



1.4 Requirements to the content of the report

Report should contain 5 sections: Introduction (I), Methods (M), Results (R), and Discussion (D)

- (I): background / theory, purpose and discovery questions
- (M): complete description of the software, and procedures which was followed in the experiment, experiment overview, figure / scheme of testing environment, procedures
- (R): narrate (like a story), tables, indicate final results;
- (D): answers on discovery questions, explanation of anomalies, conclusion / summary

Test questions:

1. Name the components for the tracking device.
2. Describe the technical specifications of the main components.

Recommended literature:

1. Mohamad O. Design and Implementation of Real Time Tracking System Based on Arduino Intel Galileo / O. Mohamad, R. Hameed, N/ Țăpuș // 8th Edition Electronics, Computers and Artificial Intelligence, 2016.
2. L.(n.d.). External GPRS-GSM-UMTS Antenna. Retrieved November 02, 2016, from <https://www.cooking-hacks.com/4g-3g-gprs-gsm-antenna-external>.

LABORATORY WORK 2 EXPLORING VARIOUS WAYS TO CALCULATE THE DISTANCE BETWEEN GEOGRAPHIC COORDINATES

Goal and objectives: this lab allows you to analyze the results of applying various methods for calculating the spherical distance for the actual data set.

Learning objectives:

1. study the mathematical methods of calculating the spherical distance;
2. study the free services for this kind of tasks.

Practical tasks:

1. acquire practical skills in working with Google Maps API tools;
2. gather data representing geographic coordinates;
3. to perform analysis of estimated distance.

Exploring tasks:

1. calculate the distance between geographic coordinates;
2. investigate the dependence of the accuracy of the results obtained by various calculation methods.

Setting up

1. to study the theoretical material contained in this manual, as well as a list of references;
2. analyze the optimal use of the selected method.

Recommended software and resources: Google Maps API service and any available assembly for the Web server.

1.1 Synopsis

In this laboratory work you will learn mathematical methods for calculating the distance between geographic coordinates, a way to simulate the operation of the Google Maps API service.

1.2 Brief theoretical information:

There are three ways to calculate the spherical distance of a large circle.

1. Spherical cosine theorem

In the case of small distances and small digits of calculation (the number of decimal places), the use of a formula can lead to significant errors associated with rounding.

$\phi_1, \lambda_1; \phi_2, \lambda_2$ – latitude and longitude of two points in radians
 $\Delta\lambda$ – the difference of coordinates in longitude
 $\Delta\delta$ – angular difference

$$\Delta\delta = \arccos \{ \sin \phi_1 \sin \phi_2 + \cos \phi_1 \cos \phi_2 \cos \Delta\lambda \}$$

To convert angular distance to metric, you need to multiply the angular difference by the radius of the Earth (6372795 meters), the units of the final distance will be equal to the units in which the radius is expressed (in this case, meters).

2. Formula haversine

Used to avoid problems with short distances.

$$\Delta\sigma = 2 \arcsin \left\{ \sqrt{ \sin^2 \left(\frac{\phi_2 - \phi_1}{2} \right) + \cos \phi_1 \cos \phi_2 \sin^2 \left(\frac{\Delta\lambda}{2} \right) } \right\}.$$

3. Modification for antipodes

The previous formula is also subject to the problem of antipode points; to solve it, the following modification is used.

$$\Delta\sigma = \arctan \left\{ \frac{ \sqrt{ [\cos \phi_2 \sin \Delta\lambda]^2 + [\cos \phi_1 \sin \phi_2 - \sin \phi_1 \cos \phi_2 \cos \Delta\lambda]^2 } }{ \sin \phi_1 \sin \phi_2 + \cos \phi_1 \cos \phi_2 \cos \Delta\lambda } \right\}$$

1.3 Execution order and discovery questions:

1. Implement one of the mathematical methods of calculation presented above programmatically.

Using the haversine formula as an example, you can get the following script to calculate the spherical distance:

```
<?php
define('EARTH_RADIUS', 6372795);
function calculateTheDistance ($φA, $λA, $φB, $λB) {
    $lat1 = $φA * M_PI / 180;
    $lat2 = $φB * M_PI / 180;
    $long1 = $λA * M_PI / 180;
    $long2 = $λB * M_PI / 180;
    $c11 = cos($lat1);
    $c12 = cos($lat2);
    $s11 = sin($lat1);
    $s12 = sin($lat2);
    $delta = $long2 - $long1;
    $cdelta = cos($delta);
    $sdelta = sin($delta);
    $y = sqrt(pow($c12 * $sdelta, 2) + pow($c11 *
    $s12 - $s11 * $c12 * $cdelta, 2));
    $x = $s11 * $s12 + $c11 * $c12 * $cdelta;
    $ad = atan2($y, $x);
    $dist = $ad * EARTH_RADIUS;
    return $dist;
}
?>
```

2. Implement requests to the Google Maps API service.

The second way is to utilize the Google Maps API. It provides information about the real-time location, the distance calculation providing mapping GPS coordinates and getting routes between numbers of points on a map. It is available for Android, iOS, web browsers and via HTTP. In particular, Service Google Maps Directions API allows you to calculate routes between two known points using the HTTP request. However, the Google API does not allow determining the external boundary based on time or distance from a location.

For example:

[https://maps.googleapis.com/maps/api/distancematrix/json?origins=\\$φA,\\$λA&destinations=\\$φB,\\$λB&key=AIzaSyDsqfxhfcYQDgdXCyxov6Bg8puzVJe4Jol](https://maps.googleapis.com/maps/api/distancematrix/json?origins=$φA,$λA&destinations=$φB,$λB&key=AIzaSyDsqfxhfcYQDgdXCyxov6Bg8puzVJe4Jol)

3. Get results for test dataset.

(38.5373116, 48.9453616)

(38.5245632, 48.9408799)

(38.4994433, 48.9413533)

(38.4490865, 48.9381365)

4. Analyze the results, formulate conclusions.

1.4 Requirements to the content of the report

Report should contain 5 sections: Introduction (I), Methods (M), Results (R), and Discussion (D)

–(I): background / theory, purpose and discovery questions

–(M): complete description of the software, and procedures which was followed in the experiment, experiment overview, figure / scheme of testing environment, procedures

–(R): narrate (like a story), tables, indicate final results;

–(D): answers on discovery questions, explanation of anomalies, conclusion / summary

Test questions:

1. Explain the calculation mechanism using the Haversinus method.

2. Explain the calculation mechanism of the Google Maps API tool.

3. Why different mathematical methods and services for calculating the distance between geographic coordinates.

Recommended literature:

1. <http://gis-lab.info/qa/great-circles.html>

2. Googlemaps Android-maps-utils / MathUtil.java.
<https://github.com/googlemaps/android-maps-utils/blob/master/library/src/com/google/maps/android/MathUtil.java>.

3. Using the Google Maps API to book the perfect ride.

LABORATORY WORK 3 EXPLORING OF INFORMATION BOARD COMPONENTS

Goal and objectives: this laboratory work is an opportunity to independently assemble a device for displaying information with optimal technical characteristics of components for assembly.

Learning objectives:

1. study of the components of the information board;
2. study the wiring diagram of components.

Practical tasks:

1. acquire practical skills in working with components for the manufacture of a display device;
2. gather information on the technical characteristics of the components of the information board;
3. perform analysis to select the optimal components for assembly.

Exploring tasks:

1. find the optimal set of components;
2. test the performance of the device.

Setting up

1. to study the theoretical material contained in this manual, as well as a list of references;
2. to analyze the most suitable components for assembly.

Recommended software and resources: manuals for such devices.

1.1 Synopsis

In this laboratory work you will learn all the necessary technical characteristics of the main components for self-assembly of an information board based on LED modules, the wiring diagram of these components.

1.2 Brief theoretical information:

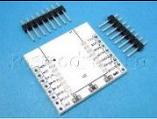
Passenger information services include message boards and kiosk boards at bus stops, web-based information services to deliver information about the public transport routes, scheduling, ticket information, estimated time of arrival/estimated time of departure, on-bus announcements, etc.

You must first obtain GPS data from sensors installed in the vehicle; then follows the processing and analysis of data, where the predicted arrival times are calculated; then the information is transmitted to passengers using information boards and smartphones.

Information board is a central point of alert passengers about the time of arriving public transport to the bus stops. As a rule it displays the time; destinations and bus numbers or routes of vehicles arriving at the particular stop; they help to orient in space, plan your trip, taking into account the traffic in the city, save the time and improve orientation of people in the city. The IoT boards working in real-time mode are activated by prior detection of arriving vehicles to the stop and can display predicting arrival / departure time.

1.3 Execution order and discovery questions:

1. To make the simplest information board you need the following components.

Title	Appearance	Title	Appearance
LED modules MAX7219 (320 × 160 mm, 32 × 16 dots, IP65, 2000 nt)		Power supply 5V 40A 200W	
Wi-Fi module based on ESP8266.		ESP8266- ADAPTER	

2. Modules must be connected in series.

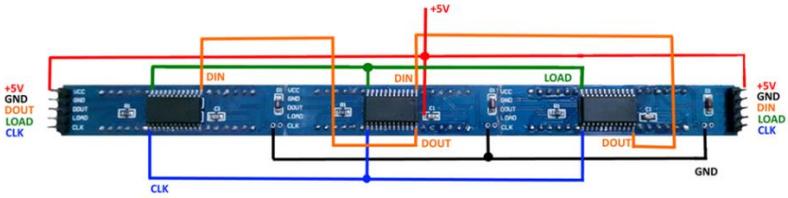


Figure 1 – Serial connection of modules

3. For the correct operation of the chip, it is necessary to implement connection options that provide higher stability. Below are two connection diagrams: with support for autoloading firmware from the Arduino IDE, UDK, Sming, and without it.

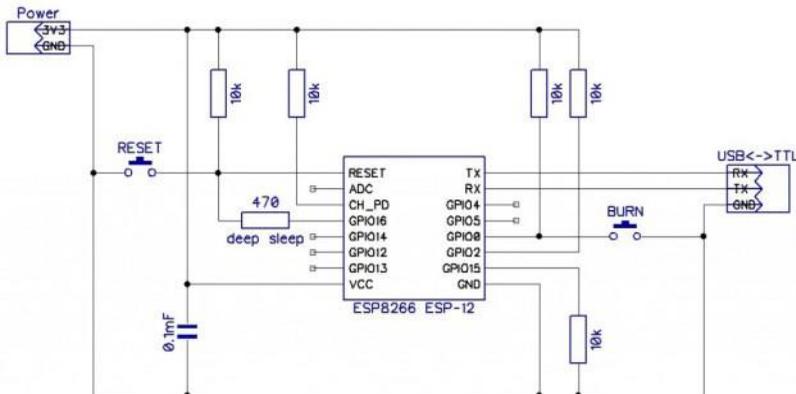


Figure 2 – Connection diagram of ESP8266 (without autoloading the firmware, flashing through the BURN jumper and reloading the module)

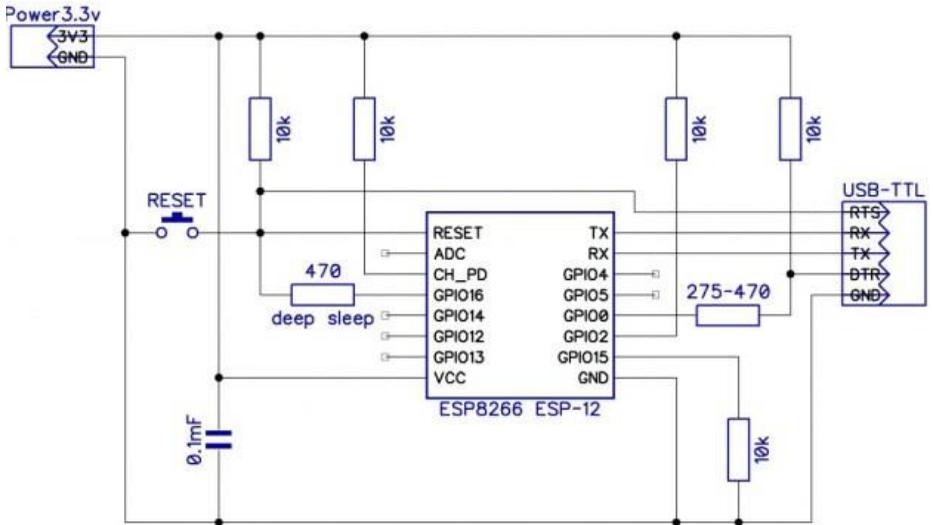


Figure 3 – Connection diagram with support for autoloading firmware from Arduino IDE, UDK, Sming

4. To connect and flash the chip, you must connect the assembly to the computer via the USB interface using a USB-TTL converter.



Figure 4 – USB-TTL Converter PL2303HX USB-UART

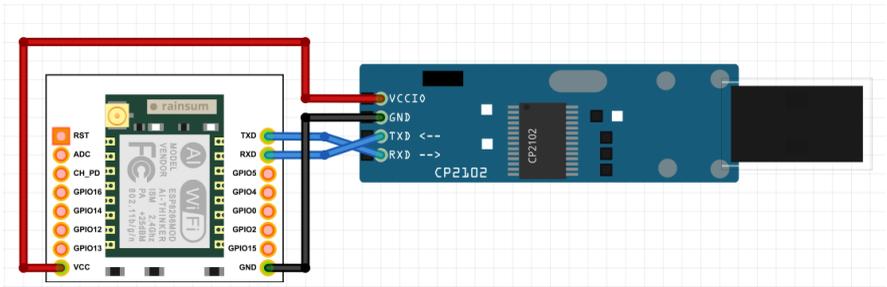


Figure 5 – Wiring diagram of ESP8266-07 to USB-TTL

5. After downloading the sketch to the controller, you need to connect the LED modules and the power supply.

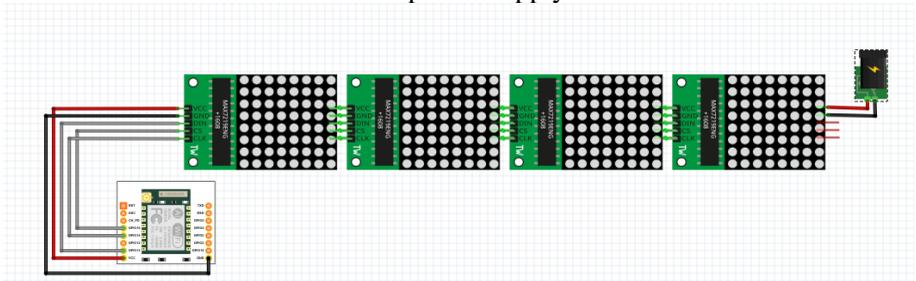


Figure 6 – Wiring diagram of the components of the information board

1.4 Requirements to the content of the report

Report should contain 5 sections: Introduction (I), Methods (M), Results (R), and Discussion (D)

- (I): background / theory, purpose and discovery questions
- (M): complete description of the software, and procedures which was followed in the experiment, experiment overview, figure / scheme of testing environment, procedures
- (R): narrate (like a story), tables, indicate final results;
- (D): answers on discovery questions, explanation of anomalies, conclusion / summary

Test questions:

1. What components are needed to assemble an information board?
2. What are the technical characteristics of LED modules.
3. How are the LED modules connected?
4. What actions need to be done before the device starts to display information?

Recommended literature:

1. Components and Services for IoT Platforms: Paving the Way for IoT Standards G. Keramidas, N. Voros, M. Hübner (Eds), Springer International Publishing Switzerland, 383 p. 2017, doi: 10.1007/978-3-319-42304-3.
2. Google, Inc, Arduino Intel Galileo, “Intel Galileo Getting Started”, <https://communities.intel.com/community/makers/>, May 2015
3. Google, External Antenna 4G-3G-GPRS-GSM, <https://www.cooking-hacks.com/4g-3g-gprs-gsm-antennaexternal>, May 2015
4. External GPS Antenna SMAM + pigtail, <https://www.cooking-hacks.com/external-gps-antenna-5783>, May 2015.

LABORATORY WORK 4 EXPLORING INTEGRATED DEVELOPMENT ENVIRONMENT

Goal and objectives: this lab is an introduction to one of the most famous tools for creating and editing thumbnails, which can then be downloaded to the Arduino board.

Learning objectives:

1. study the IDE;
2. study of request formats for obtaining information from the server.

Practical tasks:

1. acquire practical skills in working with a tool for writing sketches;
2. gather information about completed requests;
3. to perform analysis the method of obtaining information.

Exploring tasks:

1. discover requests to establish communication with the server;
2. analyze the data obtained.

Setting up

1. to study the theoretical material contained in this manual, as well as a list of references;
2. to analyze the way the device interacts with the server.

Recommended software and resources: Arduino IDE programming environment.

1.1 Synopsis

In this laboratory work you will learn the basic steps of writing a sketch for an Arduino board in an IDE development environment to organize interaction with the server.

1.2 Brief theoretical information:

Integrated Development Environment (IDE) a cross platform application is written in self-installable java. The C/C++ languages are used in the Development Environment (IDE), and the IDE is open source and can be downloaded from the Arduino website. The Arduino IDE provides a powerful yet user-friendly programming environment. It gives the user the ability to create and edit sketches that can then be uploaded to the Arduino board using a USB cable. To develop a code in the IDE, two main function are needed: setup() and loop(). These two functions are defined as void, so there is no return value. The setup function is used to initialize the setting and is called once in the start of the application. The loop function is constantly called during the execution of the application.

For example:

```
include<ESP8266WiFi.h>
const char* ssid = "Pranav_AP";
const char* password = "harharmahadev";
WiFiClient wifiClient;
void setup() {
  Serial.begin(115200);
  Serial.print("Connecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());
}
void loop() {
}
```

1.3 Execution order and discovery questions:

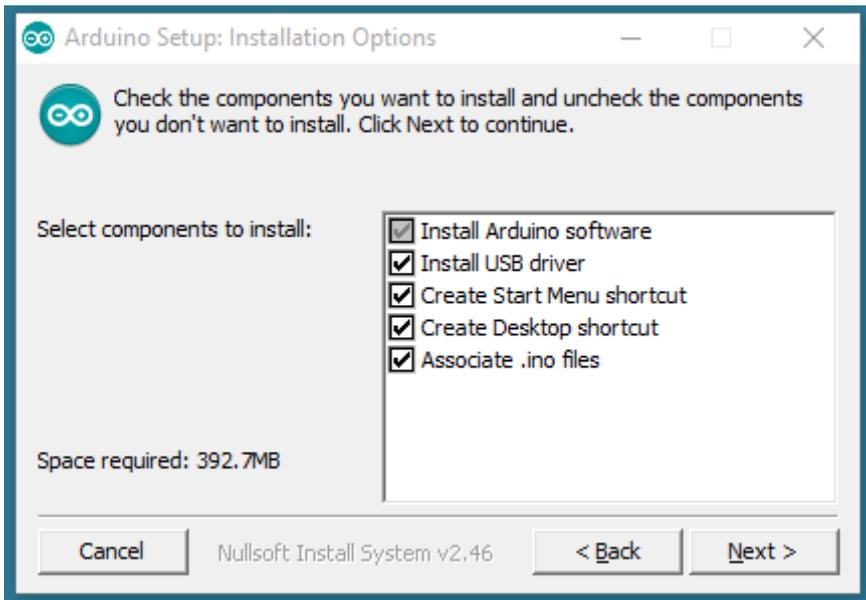
1. First, we'll need to identify the pinout of ESP8266.

To set the ESP8266 in programming mode you need to connect its wires like this:

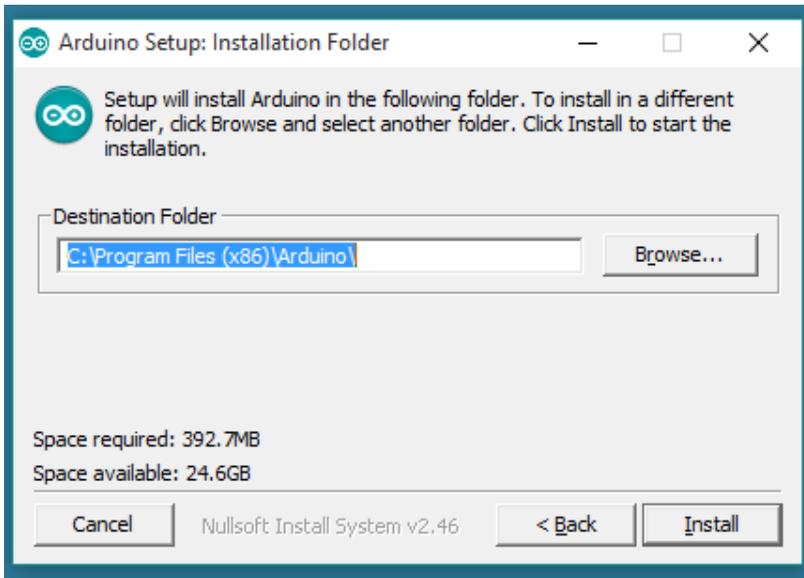
ESP8266	UARTbee	Arduino UNO
RXD	TXD	RX
GPIO0	GND	GND
GPIO2	-----	-----
GND	GND	GND
VCC	3.3V	3.3V
RST	-----	-----
CH_PD	3.3V	3.3V
TXD	RXD	TX

2. Setup the Arduino IDE.

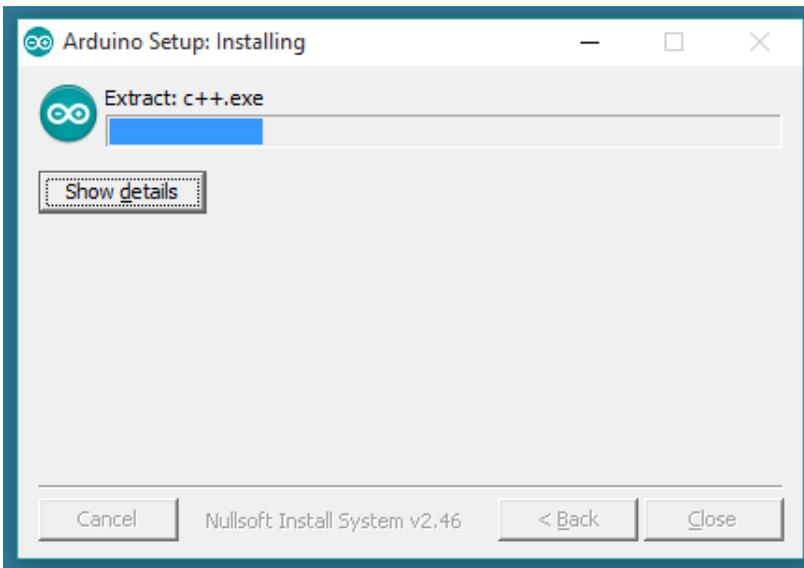
Download Arduino IDE. When the download finishes, proceed with the installation and please allow the driver installation process when you get a warning from the operating system.



Choose the components to install.



Choose the installation directory (we suggest to keep the default one).



The process will extract and install all the required files to execute properly the Arduino Software (IDE).

When the Arduino Software (IDE) is properly installed you can go back to the Getting Started Home and choose your board from the list on the right of the page.

Open you IDE and click on "File -> Preferences".

In "Additional Boards Manager URLs" add this line and click on "OK":

```
"http://arduino.esp8266.com/stable/package_esp8266com_index.json"
```

Go to "Tools -> Board -> Boards Manager", type "ESP8266" and install it.

Go again to "Tools -> Board" and select "Generic ESP8266 Module".

3. Flash your code.

To test the performance of the information board made in a previous lab, you need to write a sketch using the ArduinoIDE software, and then inject it into the internal memory of the microcontroller.

To obtain information, a request is generated to the server through a Wi-Fi module based on ESP8266 and Internet punctures, the response is interpreted.

For example:

```
void getTime()
{
  WiFiClient client;
  if (!client.connect("www.google.com", 80)) {
    Serial.println("connection to google failed");
    return;
  }
  client.print(String("GET / HTTP/1.1\r\n") +
              String("Host: www.google.com\r\n") +
              String("Connection: close\r\n\r\n"));
  int repeatCounter = 0;
  while (!client.available() && repeatCounter < 10) {
    delay(500);
    //Serial.println(".");
  }
}
```

```
repeatCounter++;  
}
```

1.4 Requirements to the content of the report

Report should contain 5 sections: Introduction (I), Methods (M), Results (R), and Discussion (D)

–(I): background / theory, purpose and discovery questions

–(M): complete description of the software, and procedures which was followed in the experiment, experiment overview, figure / scheme of testing environment, procedures

–(R): narrate (like a story), tables, indicate final results;

–(D): answers on discovery questions, explanation of anomalies, conclusion / summary

Test questions:

1. What is the name of the development environment used?
2. What language underlies the development environment?
3. What are the main key stages of writing a sketch?
4. Do I need to install additional extensions to work with different boards?

Recommended literature:

1. Almishari S. Real Time Vehicle Tracking System and Energy Reduction / Waterloo, Ontario, Canada, 2017. – 99 p.

2. Mohamad O. Design and Implementation of Real Time Tracking System Based on Arduino Intel Galileo / O. Mohamad, R. Hameed, N/ Țăpuș // 8th Edition Electronics, Computers and Artificial Intelligence, 2016.

3. L.(n.d.). External GPRS-GSM-UMTS Antenna. Retrieved November 02, 2016, from <https://www.cooking-hacks.com/4g-3g-gprs-gsm-antenna-external>.

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1. [Ezell, S. (2010). Explaining International IT Application Leadership: Intelligent Transportation Systems, The Information Technology and Innovation Foundation, 58.

2. Keramidas, G., Voros, N., and Hübner, M. (eds). (2017). *Components and Services for IoT Platforms: Paving the Way for IoT Standards*. Basel: Springer International Publishing, 383. doi: 10.1007/978-3-319-42304-3
3. Dziekan K. (2008). *Ease-of-Use in Public Transportation – A User Perspective on Information and Orientation Aspects*. Doctoral Thesis in Traffic and Transport Planning, Infrastructure and Planning.
4. Richard J., Edward A., Zhong-Ren P., Simi O. (1998) *State of the art in automatic vehicle location systems. Evaluation of the benefits of automated vehicle location systems*.
5. Ronald N., Thompson R., Haasz J, Winter S., *Determining the Viability of a Demand Responsive Transport System under Varying Demand Scenarios*. In: *Proceedings of the 6th ACM SIGSPATIAL International Workshop on Computational Transportation Science, Orlando, FL, USA, 5–8 November 2013*.
6. *The opportunities of networked telematics (“Internet of things”) for an improval of public transport’s quality and its boundaries (2017)*.
7. Festag, A. (2014). *Cooperative intelligent transport systems standards in Europe*. *IEEE Commun. Mag.*, 52(12), 166–172. doi: 10.1109/MCOM.2014.6979970
8. Williams. B. (2008). *Intelligent Transport System Standards*. London: Artech House, Inc., 827.
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10. M.Basyir, M.Nasir, Suryati, Widdha M. *Determination of Nearest Emergency Service Office using Haversine Formula Based on Android Platform*. *EMITTER International Journal of Engineering Technology*, 2017. Vol. 5, No. 2.
11. Berlin M. A. *Safety Distance Calculation for Collision Avoidance in Vehicular Ad hoc Networks / M. A. Berlin, S. Muthusundari // Scholars Journal of Engineering and Technology (SJET)*, 2016. – 4(1). P. 63-69.

12. Harold, C. M. S. and Kramer, H. ‘Identifying the information needs of users in public transport’, in *Advances in Human Aspects of Road and Rail Transportation*. Boca Raton, FL, USA: CRC Press, pp. 31–340, 2012.

13. Lavanya R., Sheela Sobana Rani K., Gayathri R., Binu D. A Smart Information System for Public Transportation Using IoT / *International Journal of Recent Trends in Engineering & Research (IJRTER)* Volume 03, Issue 04; April – 2017 [ISSN: 2455-1457]

14. Ashour I., Zorkany M. and Shiple M. Design and Implementation of Transportation Management System. In *Proceedings of the 1st International Conference on Vehicle Technology and Intelligent Transport Systems (VEHITS-2015)*, pages 11-18 ISBN: 978-989-758-109-0

Module 3.3 IoT and Cooperative Human-Machine Interfaces for Transport Safety

SEMINAR 1 DEVELOPMENT AND APPLICATION OF COOPERATIVE HUMAN-MACHINE INTERFACES FOR INTELLIGENT TRANSPORT SYSTEMS BASED ON THE INTERNET OF THINGS

1. Seminar objectives

The objectives are to provide knowledge and practical skills on:

- preparation of a report (analytical review or vision and brief specification of developed project – SDP) on design and application of user interfaces for intelligent transport systems based on IoT technologies;
- preparation of a ppt presentation according with report results for short lecture/seminar for other students;
- presentation and defence of received results.

2. Seminar preparation

Seminar preparation includes the following steps.

1) Assignment (choice) of report subject (analytical review, SDP) and tasks specification.

The report subject is to be agreed with the lecturer. It can be chosen by students on their own based on the following suggested list:

- principles, methods, tools, technologies...;
- Internet of things, IoT architectures, data transfer, Internet routing...;
- sensors, sensor devices, intelligent endpoints of IoT, energy sources, power control...;
- wireless personal area network, WPAN, 802.15 standards, Bluetooth, IEEE 802.15.4, Zigbee...;
- Internet protocol, IP, mech networks, 6LoWPAN, Thread, IEEE 802.11, 4GLTE, LoRA, LoRAWAN, Sigfox...;
- cloud computing, fog computing, edge computing...;

- intelligent transport systems, driver assistance systems, M2M, M2I, onboard systems, information systems for transport systems...;
- human-machine interfaces, user interfaces, human factors, cooperative human-machine interfaces ...;
- cyber security, safety of transport systems;
- quality, usability and safety of human-machine interfaces.

Suggested report subjects (can be extended):

- Development trends of cooperative human-machine interfaces based on cloud computing and IoT;
 - Design principles of cooperative interfaces for intelligent transport systems;
 - Requirements to cooperative human-machine interfaces according with standards (ISO, IEC, IEEE and others);
 - Development technologies for human-machine interfaces for critical systems and the Internet of things;
 - Design and quality assessment methods for cooperative user interfaces for transport systems;
 - Safety issues in cooperative human-machine interfaces for information systems in vehicles and V2V, V2IoT systems;
 - Analysis of architecture concepts for cooperative intelligent transport systems;
 - Methods and tools for ensuring the quality of cooperative human-machine interfaces for information systems in vehicles (V2V, V2IoT as well);
 - Development and implementation of Internet of Vehicles for Smart and Safe Driving;
 - Comparative analysis of HMI solutions of leading companies for IoT based automotive communication systems;
 - Communication protocols for in Car Connectivity and IoT etc.
- Report subject is to be agreed with the lecturer and consist with the subject area of the course (IoT for transport systems).

2) Work plan development and responsibility assignment among target group members. Work plan can be presented as a Gantt chart that includes the main events, time-frames and assignment of responsibility among the target group members.

The target group consists of 3 persons. Time resource is $9 \times 3 = 27$ hours (+ 20 minutes for the presentation and defence). The responsibility assignment is determined by the group members.

Suggested responsibility assignment:

- manager responsible for planning and coordination of activities and presents the idea on the seminar (1st part of the overall report – task statement),
- analyst or system developer (2nd part of the report),
- application developer (3rd part of the report + style concept).

3) Search of the information about report subject (library, the Internet, resources from department) and primary analysis. The search of the information is conducted using the keywords given in paragraph 2 (1). Methodological guidelines and the selected readings are given individually (per groups). Please use reference list [1-31]. Theoretical issues for IoT based transport systems and additional references are described in Part XI (sections 39-42) of the book [32].

4) Report and presentation plans development. Report plan includes:

- introduction (relevance, reality challenges, brief analysis of the problem – references, purpose and tasks of the report, structure and contents characteristics);
- systematized description of the main report parts (classification schemes, models characteristics, methods, tools, technologies by groups, selection of indexes and criteria for assessment, comparative studies);
- conclusions (established goal achievement, main theoretical and practical results, result validity, ways of further work on the problem);
- list of references;
- appendixes.

5) Report writing. The report should stand for 15-20 A4 pages (font size 14, spacing 1.5., margins 2 cm) including the title page, contents, main text, list of references, appendixes. Unstructured reports

or reports compiled directly from Internet sources (more 50%), having incorrect terms and no conclusion shall not be considered.

The work plan and responsibility assignment (Gantt chart), presentation slides and an electronic version of all material related to the work are required to be included in appendixes.

6) Presentation preparation. The presentation is to be designed in PowerPoint and be consistent with the report plan (10-15 slides); the time-frame for the presentation is 15 minutes.

The presentation should include the slides as follows:

- title slide (specification of the educational institution, department, course of study, report subject, authors, date);
- contents (structure) of the report;
- relevance of the issues covered, the purpose and the tasks of the report based on the relevance analysis;
- slides with the details of the tasks;
- report conclusion;
- list of references;
- testing questions.

Each slide should include headers with the report subject and authors.

The contents of the slides should include the keywords, figures, formulas rather than the parts from the report.

The information can be presented dynamically.

3. Presentation and defence

The presentation should be given at the seminar during 20 minutes including:

- presentation (10-15 minutes);
- discussion (5-10 minutes).

Time schedule can be specified by lecturer.

4. Report assessment

The work is assessed on the following parameters:

- a) report text quality (form and contents),

- b) presentation quality (contents and style),
- c) report quality (contents, logical composition, timing shared among parts, conclusion),
- d) fullness and correctness of the answers.

Each student is given an individual mark for the report and the presentation based on the results and responsibility assignment.

5. Recommended literature:

1. V. Stepanov, "Organization of traffic. Intelligent transport and two main troubles", Haulier, vol. 108, no. 9, 2009

2. European Statement of Principles, European Statement of Principles for in-vehicle information and communication systems, 1999.

3. Recommended Methodology for a preliminary safety analysis of the HMI of an IVIS, HASTE, Deliverable 4, 2005.

4. A. Anokhin and N. Nazarenko, "Designing interfaces", Biotechnosphere, vol. 8, no. 2, pp. 21-27, 2010.

5. A. Orekhova, "Analysis of the criteria and methods for the design of safe interfaces information and control systems", In Proc. International Conference "ICTM-2010", vol. 2. 2010, p. 219.

6. Commission recommendation of 22 December 2006 on safe and efficient in-vehicle information and communication systems: update of the European Statement of Principles on human machine interface, Official Journal of the European Union. L 32/200. pp. 200-241, 2007.

7. JAMA – Japan Automobile Manufacturers Association Guidelines for In-Vehicle Display Systems, Version 3.0 [Online]. Available: http://www.jamaenglish.jp/release/release/2005/jama_guidelines_v30_en.pdf. [Accessed 18.08.2004.].

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ex.cfm%3Fobjectid%3DD6819130-B985-11E1-9E4C000C296BA163&usg=AFQjCNEbPAVAVmle1dSUIj2D39DOhs2_zA&sig2=n91_IEv8HWlaC_Q2o_ycLg. [Accessed 26.06.2006.].

9. Opel and project URBAN: improvement of safety and cost-effectiveness on moving in cities, 2014. [Online]. Available: [www.opel.ru/experience/ob-opel/novosti opel]

10. What technical innovations has Volvo implemented for last 10 years? 2011. [Online]. Available: [www.autoconsulting.com.ua/news]

11. Toyota Motor Corporation» presents new systems of vehicle safety, 2013. [Online]. Available: [www.major-toyota.ru/news.html]

12. A. Orekhova, “Information technology of I&C systems human machine interfaces safety assessment”, Information processing systems, vol. 108, no 1, pp. 267-271, 2013.

13. A. Orekhova, V. Kharchenko V., and V. Tilinskiy, “Safety case-oriented assessment of human-machine interface for NPP I&C system,” Reliability: Theory & Applications, vol. 26, no. 3, pp. 27 – 38, 2012.

14. Cars In The Future: Human Machine Interface [[Online]. Available: <http://www.rospa.com/roadsafety/policy/carsinthefuture/human-machine-interface.aspx>].

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LABORATORY WORK 1 SAFETY ASSESSMENT OF COOPERATIVE HUMAN-MACHINE INTERFACES OF INTELLIGENT IOT BASED TRANSPORT SYSTEMS

1. Objectives and tasks

Objectives: to study and apply the modified method of HAZOP risk analysis for the safety assessment of cooperative human-machine interfaces (HMI) of vehicle systems considering IoT communications.

Learning tasks:

- to study the safety assessment method for cooperative HMI (CHMI) of intelligent transport systems based on research into hazards and capacity of HAZOP;
- to select the control words and their interpretation for the elements of cooperative HMI.

Practical tasks:

- to learn to work with HAZOP method;
- to identify failures and determine their consequences considering IoT communication for V2V systems.

Exploring tasks:

- to assess the safety of CHMI of the target system;
- to perform a HAZOP research for different control words.

Setting up

to study the theoretical material contained in this manual, as well as a list of references;

to get acquainted with the description of the cooperative human-machine interface of a vehicle system.

Synopsis

In this laboratory work, you will get acquainted with the main elements of HAZOP research and use it for the assessment of the functional safety of CHMI for IoT based V2V systems.

2. Brief theoretical information

The functional safety of the CHMI can be access using risk analysis, for example, HAZOP method. The objects of analysis are the

control elements and their components, data flows, and scenarios of driver’s work.

The table model for the HAZOP research is as follows:

$$Fh_e = \langle e_f, c_f, kw_f, k_f, a_f, p_f, u_f \rangle$$

- where e_f – element (component, system);
- c_f – feature of element;
- kw_f – control word;
- k_f – failure type;
- a_f – consequence (effect) of failure;
- p_f, u_f – severity and probability of failure.

So, each combination of element and failure will correspond with n table lines, where n is the number of command words. The resulting table is given in table 1.

Table 1 – HAZOP table

Component / Element	Feature of element	Control word	Failure type	Consequence (effect) of failure
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The key entities in CHMI are the elements for displaying the information and data flows. The control words take a specific meaning.

The examples of control words developed in this context are given in table 2.

Table 2 – Examples of control words in CHMI

Control word	Data flow to CHMI	Data flow to driver
No	No information is transferred	The driver cannot receive or understand the request or establish the connection

More	Additional information is transferred	The driver understands or communicates more than intended or necessary
Less	The transferred information is not full	The driver understands or communicates less than intended or necessary
Early	The information is transferred earlier than planned	The driver makes “hasty conclusions” and provides wrong answers
Late	The information is transferred later than planned	The driver does not understand or does not send the information early

Specific issues of IoT based CHMI HAZOP analysis are the following:

- Influence of communication (V2V, V2IoT) on cyber security and safety of such systems. Hence possible critical failures caused by communication (hardware and software faults and attacks on vulnerabilities) have to be taken into account;
- Features of CHMI changings and additional risks in comparing with non-cooperative HMI for have to be analysed.

Theoretical material for IoT based transport systems, safety and security issues are described in Part XI (sections 39-42) of the book [3].

3. Execution order

The structure of the safety assessment method for cooperative HMI follows:

- firstly, the elements, that are important and critical for driver’s tasks, are chosen and the characteristics for the analysis are identified. For each element and its characteristics, the deviations are identified using control words;

- next, the causes and consequences of the deviations are identified, the probability and severity of deviation are determined. The importance of deviation and protection mechanisms, possible corrective and mitigative measures are determined;

- at the final stage, a report on the safety of HMI of ITS is prepared.

Table 3 demonstrates the functional safety research into the “map” element of CHMI.

Table 3 Usage of HAZOP for “map” element

Element	Feature of element	Control word	Failure type	Consequences (effects) of failure
Map	Graphic image	Less	Lack of information	Incorrect driver’s reaction (distraction)
Map	Graphic image	More	Excess of information	Incorrect driver’s reaction (distraction)
Map	Graphic image	No	No necessary information	Incorrect driver’s reaction (incorrect actions)

The following reasoning sequence is built to assess CHMI:

1. The map is the key element of CHMI, so we will analyze it.
2. The feature under analysis is the “Graphic image”.
3. The command words applied to the “Graphic image” feature are LESS, MORE, NO.

4. If the information in the CHMI is not sufficient, more than needed or absent, an incorrect driver's reaction is possible resulting in a car accident.

5. Therefore, failure severity is high and failure probability is high as well.

6. At the same time, incorrect image size is possible.

7. It is recommended to set the correct image size.

The scope of the laboratory work includes:

1. Get acquainted with the documentation on the cooperative HMI (understand the ways of information coding, the usage context of HMI).

2. Specify general architecture of IoT based transport system where CHMI is applied.

3. Get the initial element for assessing the functional safety.

4. Identify the characteristics of each element.

5. Select control words for each characteristic.

6. Apply control words to the selected elements and each characteristic to get a particular interpretation.

7. While identifying deviations, research the causes, severity, criticality; suggest corrective measures to eliminate the deviations.

8. Document the research process.

9. Draw a conclusion.

4. Requirements to the content of the report

- The report should include:
- title page;
- research purpose and program;
- description of HMI;
- description of stages of assessment;
- results of the CHMI safety assessment;
- conclusions.

5. Testing questions

1. What the risk analysis is?
2. What risk-analysis methods do you know?

3. In your opinion, why the risk-analysis methods are used today for the assessment of functional safety of intelligent transport systems and their human-machine interfaces?

4. What features should a cooperative human-machine interface have?

5. What control words used in HAZOP method do you know?

6. What are the elements of the table model of?

7. How are the failure severity and criticality measured?

6. Recommended literature:

1. ISO/IEC 31010:2000 Risk management – Risk assessment techniques [Online]. Available: http://www.iso.org/iso/home/store/catalogue_tc.htm.

2. A. Orekhova A., V. Kharchenko V., and V. Tilinskiy, “Safety case-oriented assessment of human-machine interface for NPP I&C system,” *Reliability: Theory & Applications*, vol. 26, no. 3, pp. 27 – 38, 2012.

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Module 3.4 “Internet of Drone-Based Systems”

TRAINING 1. DETERMINING THE OPTIMUM NUMBER OF SINGLE OPERATOR CONTROLLED UNMANNED AERIAL VEHICLES FOR NPP MONITORING MISSIONS

Aim: to study the approach to determining the optimum number of single operator controlled unmanned aerial vehicles for NPP monitoring missions.

Learning Objectives:

1. To study a human factor role in ensuring the required level of UAVs safety.
2. To study a human-machine system Operator – Fleet of UAVs as a queuing system.
3. To study the main steps of algorithm for determining the optimum number of single operator controlled unmanned aerial vehicles for NPP monitoring missions.

Practical task:

to acquire practical skills in working with the approach.

Preparation for the training needs:

1. To get the theoretical information.
2. To develop a work plan in accordance with the achieved variant.

Training implementation during the training needs:

1. Read the theoretical information.
2. Prepare the initial data according to your variant presented in Table 2.
3. Following the recommendations presented in 1.2, you should obtain all the dependencies from 1.3 for your variant.
4. Write a report which should include:
 - 4.1. The aim and tasks.
 - 4.2. The brief theoretical information.
 - 4.3. The obtained results.
 - 4.4. Conclusions on the obtained results.

4.5 Answers the test questions.

5. Prepare a presentation.

Defending the training results

1. Present a presentation and defending the report of the task results.

2. Evaluation of work.

1. Theoretical information

1.1 Introduction

Using drones equipped with radiation sensors, it is possible to rapidly and more accurately identify the radiation source, thus avoiding a costly shutdown. UAVs in NPP monitoring missions can be either controlled by a human operator, usually with standard remote controllers, or fly autonomously, following a predefined route or using an exploration behavior. In both cases, operators for a fleet of UAVs (also known as a ground crew located in a ground control station (GCS)) should oversee the entire operation, being aware of the state of the UAVs, verifying sensor data acquisition and checking for potential obstacles or dangerous conditions related to the mission. 60.2% UAV mishaps involves operations-related human causal factors. The frequency of human factors mishaps is 79.1%, 39.2%, and 62.2% for the Air Force, Army, and Navy/Marines, respectively. Latent failures at the organizational level are the most prevalent and are associated with both operator error and mechanical failures. Reasons for operator errors also may be: (1) inadequate personnel training, (2) personnel fatigue, (3) personnel frustration and lack of experience, (4) inadequate human-machine interface, (5) operator’s wrong reaction to failure, (6) misjudgment due to environmental reasons (mainly weather), (7) poor documentation of procedures, (8) poor workload balance resulting in task saturation with resulting loss of situational awareness, (9) ergonomics of GCS. Thus, human factor plays a huge role in ensuring the required level of UAVs safety and should be taken into account when developing models for a human–machine system Operator – Fleet of UAVs (HMS O-FoUAVs). Taking account the fact that intelligent autonomy provides a single operator with an opportunity

to control multiple vehicles, a developer of a HMS O-FoUAVs architecture should possess a technique for determining the maximum/optimum numbers of UAVs controlled by a single operator.

1.2 Describing the proposed approach

Let’s have a HMS O-FoUAVs (Fig. 1). Assume that each UAV is in an autonomic program flight in accordance with the previously entered flight tasks on NPP monitoring. If abnormal situations occur during the UAV flight (failures of on-board equipment, significant deviations from the specified flight paths, etc.), the UAV is taken under control by an operator using the wireless link. If, at that moment, the operator is a busy, the UAV joins the queue to wait for control.

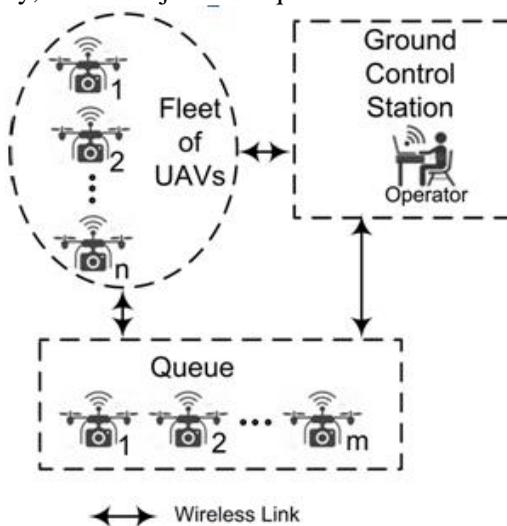


Figure 1 – HMS O-FoUAVs as a queuing system

Taking into account the functional features of HMS O-FoUAVs and approaches presented in [27], consider such a HMS as a queuing system assuming the following limitations and assumptions.

- The HMS O-FoUAVs is an $M/M/1/n$ queuing system (that is exponential process arrivals, exponential service time, one server and space for $n \geq 1$ customers in the system) [28].

- The queue discipline is first-come, first served (FCFS).

- In terms of HMS O-FoUAVs, a server is an operator, customers are UAVs, and a queue is a hardware-software tool for workstation intended for accumulating incoming requests on UAVs control and transferring them to an operator.

- The system is in the steady state.

Let introduce the following parameters.

- n is the number of UAVs.

- T_1 is the average time a UAV spends in a correct autonomic program flight.

- T_2 is the average time a UAV spends under operator control.

- p_{WL} is the probability of failure-free operation of the wireless link equipment.

- p_{OC} is the probability of error-free UAV identification for control by an operator.

Considering the proposed HMS O-FoUAVs, it is necessary to minimize:

- The steady-state probability that there no UAVs for control (p_o).

- The offered load for an operator (r).

Determination of the optimum number of UAVs controlled by an operator comprises the following steps.

1. Calculation of the probability of error-free UAV control

$$P_{contr} = P_{OC} + P_{WL} - P_{OC}P_{WL}. \quad (1)$$

2. Calculation of the average rate that customers arrive to the queue

$$\lambda = \frac{1}{T_1} \text{ (1/hour)}. \quad (2)$$

3. Calculation of the average rate that UAVs are controlled

$$\mu = p_{contr} \frac{1}{T_2} \text{ (1/hour)}. \quad (3)$$

4. Calculation of the control intensity

$$\rho = \frac{\lambda}{\mu}. \quad (4)$$

5. Calculation of the steady-state probability that there no UAVs for control

$$p_0 = [1 + n\rho + n(n-1)\rho^2 + \dots n!\rho^n]^{-1}. \quad (5)$$

6. Calculation of the offered load for an operator

$$r = n - \frac{(1-p_0)(1+\rho)}{\rho} \quad (6)$$

7. Determination of the optimum number of UAVs controlled by an operator

$$p_0 \rightarrow \min. \quad (7)$$

$$r \rightarrow \min. \quad (8)$$

$$n \in \{2, 3, 4, \dots\}. \quad (9)$$

1.3 An example of the proposed approach application

To take an example of the proposed approach application, it was assumed that HMS O-FoUAVs consists of 11 Spectator-M UAVs performing monitoring missions for Zaporizhzhia NPP (Fig. 2).

The results of the proposed approach application comprise:

- Dependencies of the steady-state probability that there no UAVs in the queue on the number of UAVs for various values of the average time a UAV spends under operator control (Fig. 3).

- Dependencies of the offered load for operator on the number of UAVs for various values of the average time a UAV spends under operator control (Fig. 4).

- The optimum number of single operator controlled Spectator-M UAVs for various values of the average time a UAV spends under operator control (Table I).

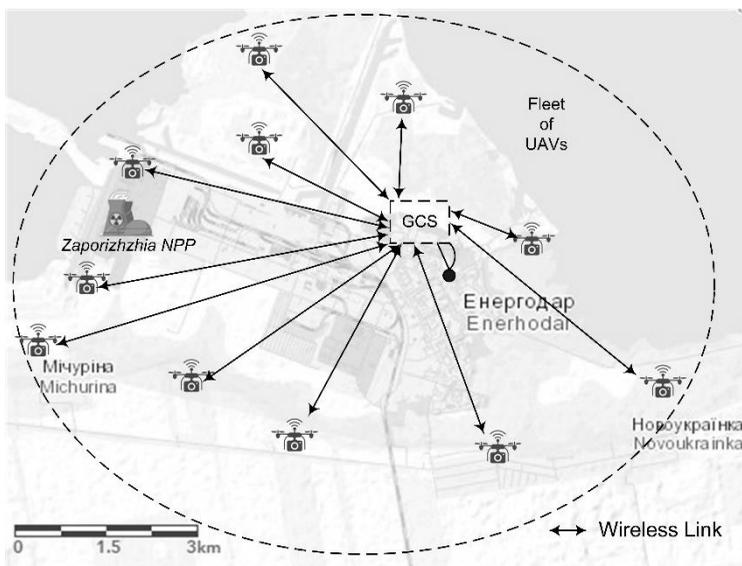


Figure 2 – HMS O-FoUAVs performing monitoring missions for Zaporizhzhia NPP

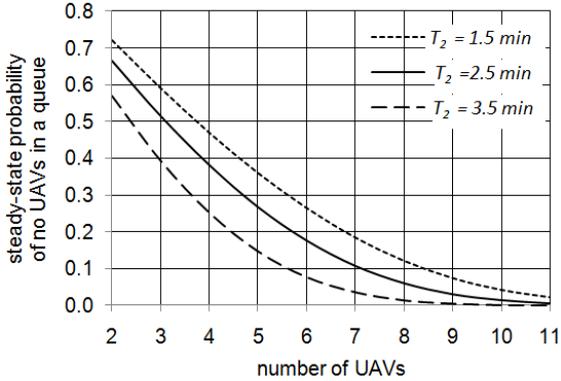


Figure 3 – Dependencies of the steady-state probability that there no UAVs in the queue on the number of UAVs for various values of the average time a UAV spends under operator control: $p_{WL} = 0.99$, $p_{OC} = 0.99$, $T_1 = 12 \text{ min}$

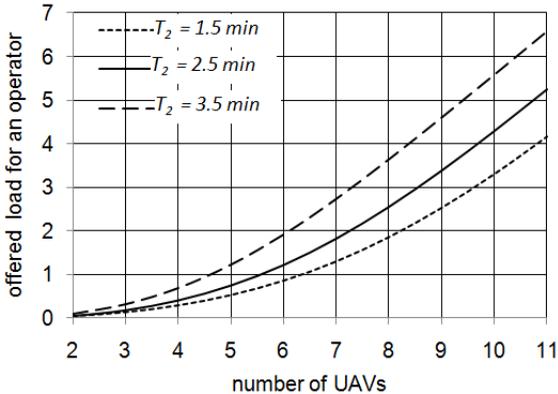


Figure 4 – Dependencies of the offered load for operator on the number of UAVs for various values of the average time a UAV spends under operator control: $p_{WL} = 0.99$, $p_{OC} = 0.99$, $T_1 = 12 \text{ min}$

Table 1 – Optimum number of single operator controlled Spectator-M UAVs for various values of the average time a UAV spends under operator control

Optimum number of single operator controlled Spectator-M UAVs		
<i>$T_2 = 1.5 \text{ min}$</i>	<i>$T_2 = 2.5 \text{ min}$</i>	<i>$T_2 = 3.5 \text{ min}$</i>
7 UAVs	6 UAVs	5 UAVs

Various values of the average time a UAV spends under operator control were used to consider three cases:

- 1) UAVs controlled by a highly trained operator ($T_2 = 1.5 \text{ min}$).
- 2) UAVs controlled by a satisfactory trained operator ($T_2 = 2.5 \text{ min}$).
- 3) UAVs controlled by a poorly trained operator ($T_2 = 3.5 \text{ min}$).

Based on the analysis of the proposed dependencies, the following conclusions can be made:

- Increasing the number of UAVs from 2 to 11 (Fig. 4) leads to an increase in the offered load for operator by: 4, 5, and 6 UAVs for $T_2 = 1.5 \text{ min}$, $T_2 = 2.5 \text{ min}$, and $T_2 = 3.5$, respectively.
- Increasing the number of UAVs from 2 to 11 (Fig. 3) leads to a decrease in the steady-state probability that there no UAVs in the queue: from 0.721 to 0.023, from 0.665 to 0.006, and from 0.0571 to 0.001 for $T_2 = 1.5 \text{ min}$, $T_2 = 2.5 \text{ min}$, and $T_2 = 3.5$, respectively.

The highly trained operator can control 7 UAVs, whereas the satisfactory trained operator and the poorly trained operator can control 6 and 5 UAVs, respectively.

1.4 Test questions

1. What reasons for operator errors do you know?
2. What are , a server , customers, and a queue in terms of HMS O-FoUAVs?
3. What does a $M/M/1/n$ queuing system mean?
4. What parameters should be given to determine the optimum number of UAVs controlled by an operator?

5. What steps does determination of the optimum number of UAVs controlled by an operator comprise?

1.5 Variants

Table 2 – The variants

Variants	p_{oc}	p_{WL}	T_1, <i>minutes</i>	T_2, <i>minutes</i>	n
1	0.99	0.98	10	1.4, 2.4, 3.4	2,3, ..., 7
2	0.97	0.98	11	1.3, 2.3, 3.3	2,3, ..., 8
3	0.99	0.99	12	1.5, 2.4, 3.4	2,3, ..., 9
4	0.97	0.97	13	1.4, 2.5, 3.5	2,3, ..., 10
5	0.99	0.97	10	1.5, 2.5, 3.5	2,3, ..., 11
6	0.98	0.98	11	1.6, 2.5, 3.5	2,3, ..., 12
7	0.99	0.98	13	1.3, 2.3, 3.3	2,3, ..., 12
8	0.97	0.98	10	1.4, 2.4, 3.4	2,3, ..., 11
9	0.99	0.99	11	1.4, 2.5, 3.5	2,3, ..., 10
10	0.97	0.97	10	1.5, 2.4, 3.4	2,3, ..., 9
11	0.99	0.97	11	1.6, 2.5, 3.5	2,3, ..., 8
12	0.98	0.98	12	1.5, 2.5, 3.5	2,3, ..., 7
13	0.99	0.98	13	1.4, 2.4, 3.4	2,3, ..., 12
14	0.97	0.98	10	1.3, 2.3, 3.3	2,3, ..., 11

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15	0.99	0.99	11	1.5, 2.4, 3.4	2,3, ..., 10
16	0.97	0.97	10	1.4, 2.5, 3.5	2,3, ..., 9
17	0.99	0.97	11	1.5, 2.5, 3.5	2,3, ..., 8
18	0.98	0.98	12	1.6, 2.5, 3.5	2,3, ..., 7
19	0.99	0.98	10	1.3, 2.3, 3.3	2,3, ..., 12
20	0.97	0.98	11	1.4, 2.4, 3.4	2,3, ..., 11
21	0.99	0.99	12	1.4, 2.5, 3.5	2,3, ..., 10
22	0.97	0.97	13	1.5, 2.4, 3.4	2,3, ..., 9
23	0.99	0.97	10	1.6, 2.5, 3.5	2,3, ..., 8
24	0.98	0.98	11	1.5, 2.5, 3.5	2,3, ..., 7
25	0.99	0.98	10	1.6, 2.5, 3.5	2,3, ..., 12
26	0.99	0.98	11	1.3, 2.3, 3.3	2,3, ..., 11
27	0.97	0.98	12	1.4, 2.4, 3.4	2,3, ..., 10
28	0.99	0.99	13	1.4, 2.5, 3.5	2,3, ..., 9
29	0.97	0.97	10	1.5, 2.4, 3.4	2,3, ..., 8
30	0.99	0.97	11	1.6, 2.5, 3.5	2,3, ..., 7

TRAINING 2. OPTIMAL REDISTRIBUTION OF UAVS IN CASE OF CHANGING MONITORING ZONES AFTER AN NPP ACCIDENT

Aim: to study an approach to optimal redistribution of UAVs in case of changing monitoring zones after an NPP accident by Linear Programming.

Learning Objectives:

1. To study the benefits of UAVs for radiation monitoring made in comparison with manned aircrafts.
2. To study the tasks for radiation monitoring that a UAV fleet should be able to perform.
3. To study the main steps of algorithm of evaluating the parameters needed to model the problem of minimizing the waiting time to start performing the monitoring mission in the new zone.
4. To study the main steps of modeling the problem of minimizing the waiting time to start performing the monitoring mission in the new zone.

Practical task:

to acquire practical skills in working with the approach.

Preparation for the training needs:

1. To get the theoretical information.
2. To develop a work plan in accordance with the achieved variant.

Training implementation during the training needs:

1. Read the theoretical information.
2. Prepare the initial data in accordance with your variant presented in Table 1. Note that Gausse-Kruger coordinates should be taken from the example in 1.3. Cruising speed $v_{cr} = 40$ km/hrs for all variants.
3. Following the recommendations presented in 1.2, you should:
 - 3.1 To write the objective function and minimize the waiting time to start performing the monitoring mission in the new zone as it is shown in 1.3.

3.2 To illustrate the obtained results by means of a figure similar to Fig. 1. The map to make a copy and use for the obtained result illustration you may find here:

https://drive.google.com/open?id=1B9IIUSvtNIIg3qWzr-_Ka_UA-Ezc8jj9&usp=sharing

4. Write a report which should include:

4.1. The aim and tasks.

4.2. The brief theoretical information.

4.3. The obtained results.

4.4. Conclusions on the obtained results.

4.5 Answers the test questions.

5. Prepare a presentation.

Defending the training results

1. Present a presentation and defending the report of the task results.

2. Evaluation of work.

1. Theoretical information

1.1 Introduction

After the Fukushima accident, UAVs are actively used for radiation monitoring and mapping to safely identify irradiated areas in the event of a NPP accident.

The benefits of UAVs for radiation monitoring can be made in comparison with manned aircrafts:

- Small-size mobile equipment facilitates effective and timely countermeasures.

- Take-off and landing at user-selected locations (no airfields necessary) and at user-defined times.

- No dependence on the road network.

- The missions can be carried out safely in remote locations (the operator can stay in an uncontaminated area).

- Low cost of the platform compared to the manned aircraft.

- Low cost of the sampling and radiation measurement instrumentation.

- Contamination of the platform does not cause major problems.

A UAV fleet should be able to perform the following tasks for radiation monitoring:

- Investigate nuclear and radiation accidents areas on emergency; detect radioactive contamination sources and radioactive plume movement.
- Examine nuclear energy facilities for corresponding to the standards.
- Monitor ground and air radioactive ecological pollution.
- Scientific research.
- Serve as an instrument for initial assessment of radiation situation when using as a part of mobile radiation monitoring labs.
- Perform other tasks requiring urgent detection of x-rays and gamma emission sources.

1.2 Describing the proposed approach

Consider a UAV fleet each UAV i ($i = \overline{1, n}$) of which is performing the monitoring mission in its own zone $i(Z_i)$. At the moment the UAV fleet has to perform the monitoring mission in the zone $i + 1$ (Z_{n+1}). As UAV fleet has no free UAVs, a UAV i can be dispatched to Z_{n+1} after finishing its monitoring mission in Z_i only.

It is necessary to minimize the waiting time (τ_{n+1}^w) to start performing the monitoring mission in Z_{n+1} .

Assume the following limitations and assumptions.

1. UAVs within their own fleet are identical.
2. The monitoring mission in Z_{n+1} has to be performed via one UAV only.
3. Each UAV can get to Z_{n+1} with or without making the intermediate stop at the starting position (SP) for the UAV battery replacement.
4. Each UAV can be used for performing its monitoring mission in Z_{n+1} after finishing its current one only.

5. Each UAV after performing its new mission in Z_{n+1} has to return to the SP.

Let introduce the following parameters.

1. $(X_i(m), Y_i(m))$ are Gausse-Kruger coordinates of the centre of Z_i .

2. $(X_{n+1}(m), Y_{n+1}(m))$ are Gausse-Kruger coordinates of the centre of Z_{n+1} .

3. $(X_{SP}(m), Y_{SP}(m))$ are Gausse-Kruger coordinates of the centre of the SP.

4. v_{cr} is the UAV cruising speed (km/hrs).

5. τ_i is the time that the UAV i needs to complete its monitoring mission in Z_i (min).

6. τ_{n+1} is the time to perform the monitoring mission via a UAV in Z_{n+1} (min).

7. τ_i^{cbl} is the current battery life of UAV i at the moment of emergence of Z_{n+1} for monitoring (min).

8. τ_{rl} is the time to replace the UAV battery at the SP (min).

9. τ_{bl} is the UAV new battery life (min).

Consider the algorithm of evaluating the parameters needed to model the problem of minimizing τ_{n+1}^w .

8. Calculation of the UAV flight time from Z_i to Z_{n+1} without making the intermediate stop at the SP for battery replacement

$$T_{i,n+1} = \frac{6\sqrt{(X_i - X_{n+1})^2 + (Y_i - Y_{n+1})^2}}{100v_{cr}} \text{ (min)}. \quad (1)$$

9. Calculation of the UAV flight time from Z_{n+1} to Z_{SP}

$$T_{n+1,SP} = \frac{6\sqrt{(X_{n+1} - X_{SP})^2 + (Y_{n+1} - Y_{SP})^2}}{100v_{cr}} \text{ (min)}. \quad (2)$$

10. Calculation of the UAV flight time from Z_i to Z_{SP}

$$T_{i,SP} = \frac{6\sqrt{(X_i - X_{SP})^2 + (Y_i - Y_{SP})^2}}{100v_{cr}} \text{ (min)}. \quad (3)$$

11. Calculation of the UAV flight time from Z_i to Z_{n+1} with making the intermediate stop at the SP for the UAV battery replacement

$$T_{ri,n+1} = T_{i,SP} + \tau_{rl} + T_{n+1,SP} \text{ (min)}. \quad (4)$$

12. Calculation of the waiting time for a UAV i , not making the intermediate stop at the SP for the UAV battery replacement, to start performing its monitoring mission in Z_{n+1}

$$\tau_i^w = \tau_i + T_{i,n+1} \text{ (min)}. \quad (5)$$

13. Calculation of the waiting time for a UAV i , making the intermediate stop at the SP for the UAV battery replacement, to start performing its monitoring mission in Z_{n+1}

$$\tau_{ri}^w = \tau_i + T_{ri,n+1} \text{ (min)}. \quad (6)$$

14. Calculation of the current battery life for a UAV i , not making the intermediate stop at the SP for the UAV battery replacement, at the start of its monitoring mission in Z_{n+1}

$$\tau_{i,n+1}^{cbl} = \tau_i^{cbl} - \tau_i^w \text{ (min)}. \quad (7)$$

15. Calculation of the current battery life for a UAV i , making the intermediate stop at the SP for the UAV battery replacement, at the start of its monitoring mission in Z_{n+1}

$$\tau_{ri,n+1}^{cbl} = \tau_{bl} - T_{n+1,SP} \text{ (min)}. \quad (8)$$

16. Calculation of the UAV current battery life needed to perform its monitoring mission in Z_{n+1}

$$\tau_{n+1}^{cbl} = \tau_{n+1} + T_{n+1,SP} \text{ (min)}. \quad (9)$$

Modeling the problem of minimizing the waiting time to start performing the monitoring mission in Z_{n+1} comprises the following steps.

Step 1: Identify the decision variables.

a_i is a variant to use a UAV i for performing its monitoring mission in Z_{n+1} without making the intermediate stop at the SP for battery replacement. If the variant is used, $a_i=1$, otherwise $a_i=0$.

a_{ri} is a variant to use a UAV i for performing its monitoring mission in Z_{n+1} with making the intermediate stop at the SP for battery replacement. If the variant is used, $a_{ri}=1$, otherwise $a_{ri}=0$.

Step 2: Write the objective function.

$$\text{Minimize } \tau_{n+1}^w = \sum_{i=1}^n \tau_i^w a_i + \sum_{i=1}^n \tau_{ri}^w a_{ri} \quad (10)$$

Step 3: Write the constraints.

$$\sum_{i=1}^n \tau_{i,n+1}^{cbl} a_i + \sum_{i=1}^n \tau_{ri,n+1}^{cbl} a_{ri} \geq \tau_{n+1}^{cbl} \quad (11)$$

$$a_i \in \{0,1\}, a_{ri} \in \{0,1\}, i = \overline{1,n} \quad (12)$$

$$\sum_{i=1}^n a_i + \sum_{i=1}^n a_{ri} = 1 \quad (13)$$

1.3 An example of the proposed approach application

Let us take the example of the proposed approach application.

Assume that five electric UAVs Furiia (UAV1, UAV2, UAV3, UAV4, UAV5) are performing their monitoring missions in the possible Zaporizhzhia NPP accident monitoring zones (Z_1, Z_2, Z_3, Z_4, Z_5) (Fig. 1).

At the moment the UAV fleet has to perform the monitoring mission in zone 6 (Z_6).

It is necessary to minimize the waiting time (τ_6^w) to start performing the monitoring mission in Z_6 .

The needed parameters are the following:

$$X_1 = 5274444 \text{ m}, Y_1 = 6623599 \text{ m};$$

$$X_2 = 5272297 \text{ m}, Y_2 = 6606125 \text{ m};$$

$$X_3 = 268648 \text{ m}, Y_3 = 6623798 \text{ m};$$

$$X_4 = 5264083 \text{ m}, Y_4 = 6605188 \text{ m};$$

$$X_5 = 5260820 \text{ m}, Y_5 = 6634815 \text{ m};$$

$$X_6 = 5265595 \text{ m}, Y_6 = 6619440 \text{ m};$$

$$X_{SP} = 5260257 \text{ m}, Y_{SP} = 6615717 \text{ m};$$

$$\tau_1 = 10 \text{ min}; \tau_2 = 22 \text{ min}; \tau_3 = 15 \text{ min}; \tau_4 = 11 \text{ min};$$

$$\tau_5 = 13 \text{ min}; \tau_6 = 15 \text{ min}; \tau_1^{cbl} = 39 \text{ min};$$

$$\tau_2^{cbl} = 30 \text{ min}; \tau_3^{cbl} = 34 \text{ min}; \tau_4^{cbl} = 35 \text{ min};$$

$$\tau_5^{cbl} = 43 \text{ min}; \tau_{bl} = 150 \text{ min}; \tau_{rl} = 7 \text{ min};$$

$$v_{cr} = 65 \text{ km/hrs.}$$

Calculate the parameters needed to model the problem of minimizing τ_6^w according to (1)-(9) and write the objective function as follows:

$$\begin{aligned} \text{Minimize } \tau_6^w = & 19a_1 + 14a_2 + 20a_3 + 24a_4 + \\ & + 28a_5 + 38a_{r1} + 49a_{r2} + 39a_{r3} + 34a_{r4} + 44a_{r5}. \end{aligned}$$

Write the constraints as follows:

$$\begin{aligned} 20a_1 + 16a_2 + 14a_3 + 11a_4 + 15a_5 + \\ + 144(a_{r1} + a_{r2} + a_{r3} + a_{r4} + a_{r5}) \geq 21. \end{aligned}$$

$$\sum_{i=1}^5 a_i + \sum_{i=1}^5 a_{r_i} = 1.$$

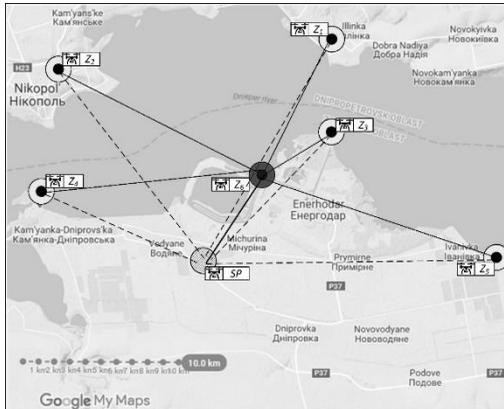


Figure 1 – UAVs which are performing their monitoring missions in the possible Zaporizhzhia NPP accident zones

Using the special tools on solving optimization problems (Matlab, Excel etc), we can obtain the following solution: to minimize

τ_6^w we should use UAV4 making the intermediate stop at the SP for the UAV battery replacement. $\tau_6^w = 34$ min.

1.4 Test questions

1. What benefits of UAVs for radiation monitoring can be made in comparison with manned aircrafts?
2. What tasks for radiation monitoring should a UAV fleet be able to perform?
3. What parameters should be given for the approach use?
4. What parameters should be obtained for the approach use?
5. What steps does modeling the problem of minimizing the waiting time to start performing the monitoring mission in the new zone comprise?

1.5 Variants

Table 1 – The variants

Variant	τ_1 , min	τ_2 , min	τ_3 , min	τ_4 , min	τ_5 , min	τ_6 , min	τ_1^{cbl} , min	τ_2^{cbl} , min	τ_3^{cbl} , min	τ_4^{cbl} , min	τ_5^{cbl} , min
1	14	11	13	11	10	15	36	32	35	36	41
2	14	11	13	11	10	19	36	30	35	36	41
3	14	11	13	11	10	12	36	30	35	36	41
4	14	11	13	11	10	16	36	30	35	36	41
5	14	11	13	11	10	26	36	30	35	36	41
6	14	11	13	11	10	13	36	30	35	36	41
7	14	11	13	11	10	15	36	32	35	36	41
8	14	11	13	11	10	19	36	30	35	36	41
9	14	11	13	11	10	12	36	30	35	36	41
10	14	11	13	11	10	16	36	30	35	36	41
11	14	11	13	11	10	26	36	30	35	36	41
12	14	11	13	11	10	13	36	30	35	36	41
13	14	11	13	11	10	15	36	32	35	36	41
14	14	11	13	11	10	19	36	30	35	36	41
15	14	11	13	11	10	12	36	30	35	36	41
16	14	11	13	11	10	16	36	30	35	36	41

Module 3.4 “Internet of Drone-Based Systems”

17	14	11	13	11	10	26	36	30	35	36	41
18	14	11	13	11	10	13	36	30	35	36	41
19	14	11	13	11	10	15	36	32	35	36	41
20	14	11	13	11	10	19	36	30	35	36	41
21	14	11	13	11	10	12	36	30	35	36	41
22	14	11	13	11	10	16	36	30	35	36	41
23	14	11	13	11	10	26	36	30	35	36	41
24	14	11	13	11	10	13	36	30	35	36	41
25	14	11	13	11	10	15	36	32	35	36	41
26	14	11	13	11	10	19	36	30	35	36	41
27	14	11	13	11	10	12	36	30	35	36	41
28	14	11	13	11	10	16	36	30	35	36	41
29	14	11	13	11	10	26	36	30	35	36	41
30	14	11	13	11	10	13	36	30	35	36	41

**COURSE PROGRAM
DESCRIPTION OF THE MODULE**

TITLE OF THE MODULE	Code
IoT for intelligent transport systems	TM 3

Teacher(s)	Department
<p>Coordinating: Prof., DSc Sachenko A.O.</p> <p>Others: Assoc. Prof., Dr Kochan V.V., Dr Bykovyy P.E., Dr. Zahorodnia D.I., Dr Osolinskyi O.R., Prof., DSc Skarga-Bandurova I.S., Ph.D. Student Derkach M.V., Prof., DSc Kharchenko V.S., Prof., DSc Orekhov O.O., Dr Stadnik A.O., Assoc. Prof., Dr Fesenko H.V.</p>	<p>Information Computing Systems and Control, TNEU</p> <p>Computer science and Engineering, V. Dahl EUNU</p> <p>Computer Systems, Networks and Cyber Security Department of National Aerospace University “KhAI”</p>

Study cycle	Level of the module	Type of the module
Trainings	A	Full-time tuition

Form of delivery	Duration	Language(s)
Full-time tuition	One semester	English

Prerequisites	
<p>Prerequisites:</p> <p>Intelligent Systems, Neural Networks and Evolutionary Algorithms, Intelligent Robotic Systems, Digital electronics, Microcontrollers, Cooperative Human-Machine Interfaces, In-Vehicle Information Systems, Internet of things</p>	<p>Co-requisites (if necessary):</p>

Credits of the module	Total student workload	Contact hours	Individual work hours
1	30	20	10

Aim of the module (course unit): competences foreseen by the study programme
<p>A goal of the module is the practical use of earned students knowledge's in computational intelligence with the followed training in different applications of intelligent transport systems within IoT environment</p>

Learning outcomes of module (course unit)	Teaching/learning methods	Assessment methods
<p>At the end of module, the successful student will be able to:</p>	<p>Seminars, individual work</p>	<p>Module Evaluation Questionnaire</p>

<p>1. Understand the general concepts and areas of applying the IoT in transport systems and in cooperative human-machine interfaces. Acquire practical skills in working an integrated, formal and automated methodology for public transport information services</p>		
<p>2. Using the IoT equipment in transport area. Study and independently assemble the device to determine the geographical coordinates of the vehicle. Using the IoT for development cooperative HMI systems</p>	<p>Seminar, labs, team work</p>	<p>Module Evaluation Questionnaire</p>
<p>3. Developing the algorithms and software for Intelligent Transport Systems Analyze the results of applying various methods for calculating the spherical distance for the actual data set. Evaluate of cooperative human-machine interfaces of</p>	<p>Seminar, labs, team work</p>	<p>Module Evaluation Questionnaire</p>

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intelligent transport systems		
4. Independently assemble a device for displaying information with optimal technical characteristics of components for assembly. Creating and edit thumbnails, which can then be downloaded to the Arduino board. Applying the IoT in mobile vehicles for a special purpose.	Seminar, labs, team work	Module Evaluation Questionnaire

Themes	Contact work hours						Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practical work	Laboratory work	Placements	Total contact work	Individual work
1.Studying the hardware of traffic intensity monitoring 1.1 General structure of IoT monitoring system 1.2 Used Software Training: Studying the hardware of traffic intensity monitoring	2			4		6	4	1.3 Formation of images database

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<p>2. Recognition and data processing of objects in a video frame</p> <p>2.1 Calibrate the camera and adjust the resulting image</p> <p>2.2 Calculate the length and width of vehicles different types</p> <p>Training: Recognize and data processing of the objects in a video frame</p>	2			4		6	5	2.3 Receiving and recognizing the images of vehicles different types
<p>3 Recognizing and data processing of objects array in a video stream</p> <p>3.1 Counting the number of vehicles different type passed through the camera field of view at fixed intervals</p> <p>3.2 Determining the coefficient of filling the road by different types of vehicles</p> <p>Training: Recognize and data processing of the objects array in a video stream</p>	2		2			4	5	3.3 Virtual Instruments with ThingSpeak
<p>4. Public transport (PT) systems</p> <p>4.1 Automatic vehicle location</p> <p>4.2 Demand responsive transport and IoT</p>	2						2	4.3 PT priority systems and new innovations in PT delivery and operation
<p>5. Tools and techniques for real-time public transport information acquisition and arrival time prediction based on GPS Data</p> <p>5.1 Real-time PT information service infrastructure</p> <p>5.2 Objective and challenges</p> <p>Lab. Exploring of components for vehicle location tracking device</p> <p>Lab. Exploring various ways to calculate the distance between geographic coordinates</p>	2			8			3	5.3 Arrival time prediction models
<p>6. PT monitoring, analysis, and management</p> <p>6.1 General strategy of PT information service delivering and sharing</p> <p>6.2 Information boards, ETA/ETD on bus-stops</p>	2			8			3	6.4 Case studies

Course program

6.3 Implementation of ITS to support the principles of demand management Lab. Exploring of information board components Lab. Exploring integrated development environment								
7. Areas of applying the IoT for cooperative human-machine interfaces	2		4					6 7.1 Examples of possible using the IoT for cooperative human-machine interfaces. 7.2 Development trends of cooperative HMI of intelligent transport systems based on the Internet of things.
8. Development of IoT based cooperative HMI systems	2							5 8.1 Communication and protocols 8.2 On-board systems interaction
8. Assessment of cooperative human-machine interfaces of intelligent transport systems Seminar: Development and application of cooperative human-machine interfaces for intelligent transport systems based on the internet of things Lab: Safety assessment of cooperative human-machine interfaces of intelligent iot based transport systems	2			4				5 8.1 Methods of safety assessment for cooperative HMI 8.2 Safety assessment method for cooperative HMI based on research into hazards and capacity of HAZOP;
9. Internet of drone-based systems 9.1. Introduction into drone fleets 9.2. Internet of drones 9.3. Case studies Training 1: Determining the optimum number of single operator	6			6				9.4. Airborne Communicate on networks for small unmanned aircraft systems 9.5. Flying ad-hoc networks: Routing

Course program

controlled unmanned aerial vehicles for npp monitoring missions Training 2: Optimal redistribution of UAVS in case of changing monitoring zones after an NPP accident										protocols, mobility models, issues
In total	24		4	8	28			16	38	

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special hometask	10	2,4	<p>90–100% (A) – Outstanding work, showing a full grasp of all the questions answered.</p> <p>85–89% (B) – Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material.</p> <p>75–84% (C) – A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics.</p> <p>65–74% (D) – There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions.</p> <p>60–64% (E) – Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect.</p> <p>35–59% (F) – There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places</p> <p>1–34% (FX) – Very little or nothing that is correct and relevant.</p>
Learning in laboratories	30	3,4	90% – 100% An outstanding piece of work, superbly organised and presented, excellent achievement of the objectives, evidence of original thought.

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			<p>85-89% (B) – Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organisation and presentation.</p> <p>75-84% (C) -. Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. When performing laboratory work student completely provide results and make the right conclusions, but admits inaccuracies or errors.</p> <p>65-74 (D) – The student can solve simple problems and has the ability to perform basic operations and basic transformation and some algorithmic, but is not able to independently formulate task and determine the solution. When performing laboratory work the student execute it with errors. He draws conclusions, but not sufficient to understand the purpose of work.</p> <p>60-64% (E) – The student can solve simple problems by using teacher support to perform basic operations and basic transformation, but not able to formulate the problem by verbal description to determine the solution.</p> <p>35-59% (F) – When performing practical (laboratory) work the student knows how to use computers, but is unable to complete the task. The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly.</p> <p>1-34% (FX) – The student does not perform the tasks. Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.</p>
Module Evaluation Quest	60	4	The score corresponds to the percentage of correct answers to the test questions

Course program

Author	Year of issue	Title	No of periodical or volume	Place of printing. Printing house or internet link
Recommended literature				
Perallos A.	2015	Intelligent Transport Systems: Technologies and Applications	9	John Wiley & Sons
Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stefan Avesand, Stamatis Karnouskos and David Boyle	2014	From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence	Academic Press	http://www.sciencedirect.com/science/book/9780124076846
Stephen Ezell	2010	Explaining International IT Application Leadership: Intelligent Transportation Systems	The Information Technology & Innovation Foundation	https://www.itif.org/files/2010-1-27-ITS_Leadership.pdf
G. Keramidas, N. Voros, and M. Hübner	2017	Components and Services for IoT Platforms: Paving the Way for IoT Standards		Basel: Springer International Publishing
N. Ronald, R. Thompson, J. Haasz, S. Winter	2013	Determining the Viability of a Demand Responsive Transport System under Varying Demand Scenarios		Proceedings of the 6th ACM SIGSPATIAL International Workshop on Computational Transportation Science
A. Festag	2014	Cooperative	52(12)	IEEE Commun.

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		intelligent transport systems standards in Europe		Mag.
M. Basyir	2017	Determination of Nearest Emergency Service Office using Haversine Formula Based on Android Platform	5	EMITTER International Journal of Engineering Technology
M. Cebecauer, E. Jenelius, W. Burghout	2015	Integrated Framework for Real-time Urban Network Travel Time Prediction on Sparse Probe Data		IET Intelligent Transport Systems
Stepanov V.	2009	Organization of traffic. Intelligent transport and two main troubles	vol. 108, no. 9	Haulier
A. Anokhin and N. Nazarenko	2010	Designing interfaces	vol. 8, no. 2	Biotechnosphere
J. Stoltzfus	2012	Cloud Computing for Vehicles: Tomorrow's High-Tech Car		http://www.techopedia.com/2/28137/trends/cloud-computing/cloud-computing-for-vehicles-tomorrows-high-tech-car
Lynn Walford	2014	Volvo New Connected Car Features-Magnets	Real-Time Cloud Road Data & Driver Sensi	http://www.autoconnectedcar.com/2014/03/volvo-new-connected-car-features-

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			ng	magnets-real-time-cloud-road-data-driver-sensing/
Michael Sheehan	2011	Cloud Computing Cars and Mobile Devices		http://scoop.intel.com/cloud-computing-cars-and-mobile-devices/
E. Bauer and M. Lotz	2012	PRORETA 3: An Integrated Approach to Collision Avoidance and Vehicle Automation	no.12	At – Automatisierungstechnik
A. Orekhova A., V. Kharchenko V., and V. Tilinskiy	2012	Safety case-oriented assessment of human-machine interface for NPP I&C system	vol. 26	Reliability: Theory & Applications
A. Orekhova	2013	Information technology of I&C systems human machine interfaces safety assessment	vol. 108, no 1	Information processing systems
Additional literature				
Aldona Jarašūniene	2010	Research into intelligent transport systems (ITS) technologies and efficiency	Transport, 22:2	http://dx.doi.org/10.1080/16484142.2007.9638100
Xiao, Laishen, and Zhengxia Wang	2011	Internet of Things: a New Application for Intelligent Traffic	JNW 6.6	https://www.researchgate.net/profile/Laisheng_Xiao/publication/220383965_Internet_of_

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		Monitoring System.		Things_A_New_Application_for_Intelligent_Traffic_Monitoring_System/links/5673d5ae08ae04d9b09be27f/Internet-of-Things-A-New-Application-for-Intelligent-Traffic-Monitoring-System.pdf
Cardoso, Raul Mariano, Niederauer Mastelari, and Murilo Frônio Bassora	2013	Internet of things architecture in the context of intelligent transportation systems—a case study towards a web-based application deployment	22nd International Congress of Mechanical Engineering	http://www.abcm.org.br/anais/cobem/2013/PDF/1921.pdf
Al-Sakran, Hasan Omar	2015	Intelligent traffic information system based on integration of Internet of Things and Agent technology	International Journal of Advanced Computer Science and Applications (IJACSA) 6.2	https://pdfs.semanticscholar.org/c9ae/ef4e3c23509bf2eebef20e38cbc1c64e55ae.pdf
Robert P. Loce, Raja Bala, Mohan Trivedi	2017	Computer Vision and Imaging in Intelligent Transportation Systems	Wiley-IEEE Press	ISBN: 978-1-118-97160-4

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Sumit Ghosh, Tony S. Lee	2010	Intelligent Transportation Systems: Smart and Green Infrastructure Design, Second Edition	CRC Press	ISBN 9781439835180
Picone, M., Busanelli, S., Amoretti, M., Zanichelli, F., Ferrari, G.-L.	2015	Advanced Technologies for Intelligent Transportation Systems	Springer International Publishing	ISBN 978-3-319- 10668-7
M. A. Berlin	2016	Safety Distance Calculation for Collision Avoidance in Vehicular Ad hoc Networks	4(1)	Scholars Journal of Engineering and Technology
C. M. S. Harold and H. Kramer	2012	Identifying the information needs of users in public transport		Human Aspects of Road and Rail Transportation
R. Lavanya, K. S. S. Rani, R. Gayathri, D. Binu	2017	A Smart Information System for Public Transportation Using IoT	03	International Journal of Recent Trends in Engineering & Research
I. Ashour, M. Zorkany and M. Shiple	2015	Design and Implementatio n of Transportation Management System		In Proceedings of the 1st International Conference on Vehicle Technology and Intelligent Transport Systems
	2005	Recommended Methodology for a preliminary safety analysis		HASTE, Deliverable 4

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		of the HMI of an IVIS		
	2007	Commission recommendation of 22 December 2006 on safe and efficient in-vehicle information and communication systems: update of the European Statement of Principles on human machine interface	L 32/200	Official Journal of the European Union
	2006	Alliance of Automobile Manufacturers (AAM) Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems		https://www.google.com.ua/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiC763ntq_JAhVILHIKHS8FBM4QFggcMAA&url=http%3A%2F%2Fwww.autoalliance.org%2Findex.cfm%3Fobjectid%3DD6819130-B985-11E1-9E4C000C296BA163&usg=AFQjCNEbPAVAVmle1dSUIj2D39DOhs2_zA&sig2=n91_Iev8HWlaC_Q2o_ycLg

АНОТАЦІЯ

УДК 004.415/.416:[656.1:004.896](076.5)=111

А.О. Саченко, В.В. Кочан, П.Є. Биковий, Д.І. Загородня, О.Р. Осолінський, І.С. Скарга-Бандурова, М.В. Деркач, О.О.Орехов, А.О. Стадник, В.С. Харченко, Г.В. Фесенко. **Інтернет Речей для інтелектуальних транспортних систем, Тренінги** / За ред. А.О. Саченко, І.С. Скарги-Бандурової – МОН України, Тернопільський національний економічний університет, Східноукраїнський національний університет імені Володимира Даля, Національний аерокосмічний університет ім. М. Є. Жуковського «ХАІ», 2019. – 135 с.

Викладено матеріали тренінгової частини курсу ІТМЗ «ІоТ для інтелектуальних транспортних систем», підготовленого в рамках проекту ERASMUS+ ALIOT “Internet of Things: Emerging Curriculum for Industry and Human Applications” (573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP).

Навчальний посібник присвячений вивченню інтелектуальної системи моніторингу транспортних потоків та ІоТ для надання інформації службі громадського транспорту, а також дослідженню сумісних людино-машинних інтерфейсів ІоТ для безпеки транспорту та Інтернет дрон-базованих систем.

Посібник призначений для інженерів, дизайнерів та вчених, які займаються розробкою та впровадженням систем на базі ІоТ, магістрів та аспірантів, які вивчають сфери ІоТ, комп'ютерних наук, комп'ютерної та програмної інженерії, а також для викладачів відповідних курсів.

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