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Журнал зарегистрирован Управлением Федеральной службы по надзору в сфере связи, информационных технологий и массовых коммуникаций (свидетельство о регистрации от 10.11.2015 ЭЛ № ФС 77 - 63681) и Международным центром ISSN (ISSN 2328-1391 (print), ISSN 2227-930X (online)).

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На основании заключения Президиума Высшей аттестационной комиссии Минобрнауки России журнал включен в Перечень российских рецензируемых научных журналов, в которых должны быть опубликованы основные научные результаты диссертаций на соискание ученых степеней доктора и кандидата наук.

Статьи, поступающие в редакцию, рецензируются. За достоверность сведений, изложенных в статьях, ответственность несут авторы публикаций. Мнение редакции может не совпадать с мнением авторов материалов. При перепечатке ссылка на журнал обязательна.

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ПРИМЕНЕНИЕ KAHOOT! ПРИ ГЕЙМИФИКАЦИИ В ОБРАЗОВАНИИ

Царев Р.Ю.

Современный уровень развития общества диктует новые требования к организации образования. Одним из актуальных направлений развития образования является геймификация образования, которая позволяет добиться высокой мотивации и вовлеченности студентов в образовательный процесс.

Целью работы *является проверка гипотезы о том, что использование игровых моментов в обучении, основанных на активном применении информационных технологий, в частности интернет-ресурса Kahoot!, повышает вовлеченность студента в образовательный процесс, его мотивацию при обучении, формирует комфортную среду, вызывающую интерес к изучению предметной области.*

Новизна исследований *состоит в методической организации процесса обучения, в рамках которого выполняется текущий контроль усвоения материала, тем самым реализуя активные методы обучения. При реализации предлагаемого подхода использовалось интернет-ресурс Kahoot!, предоставляющий возможности активизации внимания и контроля усвоения материала студентами.*

Представленные в статье ***результаты*** *подтверждают эффективность предложенного подхода и использования в его рамках Kahoot!, который позволил сформировать интерактивную электронную образовательную среду.*

Ключевые слова: *образование; геймификация; мотивация; вовлечение; Kahoot!*

APPLICATION OF KAHOOT! IN EDUCATION GAMIFICATION

Tsarev R.Yu.

The modern level of society development sets higher requirements for education. One of the most important trends in the development of education nowadays is the gamifacation, which allows to achieve high motivation and involvement of students into the educational process.

The ***aim of the work*** *is to test the hypothesis that the use of gaming moments in education, involving information technology, in particular the Internet-resource Kahoot!, increases the student's involvement into the educational process, raise one's motivation, and creates a comfortable educational environment that causes interest in subject learning.*

The ***novelty of the research*** *consists in the methodological organization of the learning process, within which the current control is carried out, thereby realizing active teaching methods. When implementing the proposed approach the Internet-resource Kahoot! was used. It provides opportunities for activating attention of the students and controlling the learning progress.*

The ***results*** *presented in the article confirm the effectiveness of the proposed approach and the use within its framework of Kahoot!, which allowed to create an interactive electronic educational environment.*

Keywords: *education; gamification; motivation; involvement; Kahoot!*

Введение

Геймификация в целом представляет собой концепцию внедрения игровых технологий в различных областях, в том числе в образовании, целью которой является мотивация и вовлечение студентов в образовательный процесс [3]. Активное применение игровых моментов при обучении обусловлено развитием информационных и коммуникационных технологий [2]. Компьютеры, смартфоны, Интернет стали неотъемлемой частью нашей повседневной и профессиональной жизни.

Расширяя возможности современных студентов, информационно-телекоммуникационные технологии также могут провоцировать утрату интереса и мотивации к обучению традиционными методами [4]. В связи с этим образовательная система должна адаптироваться к современным запросам, формировать и развивать новые методы обучения, используя активные методы обучения с учетом достижений в области информационных технологий [1].

Введение игровых элементов в образовательный процесс, повышая эффективность усвоения материала, развивая практические компетенции, а также поддерживая высокий уровень вовлеченности студента, положительно отличает геймификацию от прочих подходов в обучении [7]. Исследования последних лет показывают прямую взаимосвязь между игрой и повышенной мотивацией обучающегося [10]. С одной стороны геймификация в образовании мотивирует и вовлекает студентов в процесс обучения, с другой стороны, способствуют их развитию и помогает раскрывать таланты даже в ранее неизвестных им областях [11].

Применение геймификации как одного из подходов к обучению позволяет обычные проблемы и задачи превратить в интересные и увлекательные, в том числе, за счет эффекта неопределенности и неожиданности, что делает геймификацию мощным инструментом, который целесообразно использовать при решении разнообразных проблем современного образования [8]. При этом новые методы обучения должны основываться на эффективном использовании информационных и компьютерных технологий в учебном процессе и создавать эффективную интерактивную образовательную среду [6].

Интерактивная образовательная среда

Эффективная интерактивная образовательная среда может быть организована посредством образовательных ресурсов сети Интернет и собственных смартфонов студентов. Одним из вариантов реализации такой среды является использование возможностей по интерактивной оценке усвоения знаний и приобретения компетенций, предоставляемых сайтом Kahoot! (getkahoot.com) [5].

Данный ресурс позволяет проводить опрос непосредственно во время лекционных или практических занятий. При этом оценка ответов студентов отображается ресурсом незамедлительно. Непосредственная обратная связь усиливает вовлеченность студентов. На рис. 1 представлен внешний вид сайта Kahoot! с одним из вопросов и четырьмя вариантами ответов. Кроме этого, на рис. 1 представлен внешний вид смартфона студента, на котором отображены пиктограммы соответствующие предлагаемым ответам, один из которых должен выбрать студент, нажав на пиктограмму ответа.

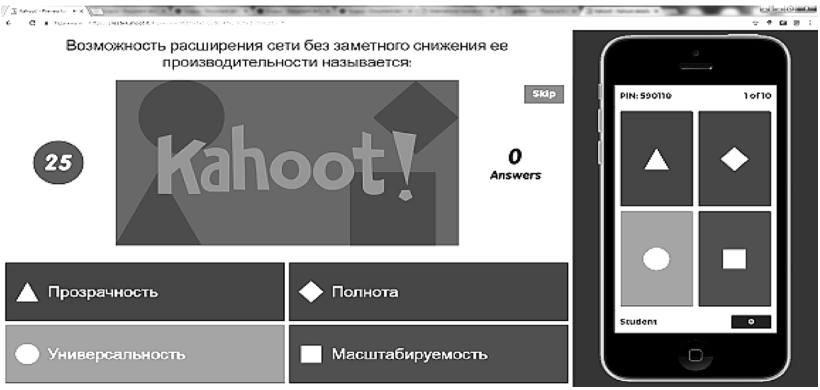

Рис. 1. Внешний вид сайта Kahoot! и смартфона студента

Kahoot! позволяет создавать онлайн тесты и опросы, которые могут быть показаны проектором на большом экране или интерактивной доске. Кроме текста Kahoot! предоставляет возможность встраивать рисунки, графики, таблицы, а также аудио и видео контент [9]. Студенты отвечают на вопросы теста с любого подключенного к Интернету устройства. Как показывает практика применения на занятиях ресурса Kahoot!, особенно увлекательным студенты находят возможность использовать для этих целей собственные смартфоны.

Достоинством сайта Kahoot! является возможность сохранить полученные результаты для дальнейшего анализа преподавателями. Это позволяет пересмотреть содержание и представление учебного материала на следующий учебный год с целью повышения его усвоения студентами. Кроме этого, полученные результаты могут быть использованы для более глубокого изучения понятий и разделов, вызвавших трудности у студентов.

Опыт практического применения Kahoot!

Возможности ресурса Kahoot! позволили расширить спектр применяемых на занятиях активных методов обучения и повысить интерактивность при изучении теоретического материала и оценке полученных знаний. Апробация данного подхода в геймификации обучения проводилась в рамках дисциплин «Информатика» и «Информационные технологии» со студентами 1-го и 2-го курсов, общим количеством 256 человек.

Каждое занятие было построено следующим образом. В начале занятия проводилась оценка остаточных знаний с момента проведения предыдущего занятия посредством Kahoot!-теста. В конце занятия проводилось тестирование по материалу, пройденному в течение текущего занятия. Кроме начального и конечного тестирования, студенты выполняли тесты после изучения отдельных тем. Количество вопросов в начале и конце занятия было рано десяти, количество вопросов в конце изучения темы – пяти. При этом первый и заключительный тесты были индивидуальные, а прохождение тестов после изучения темы могли носить как индивидуальный, так и групповой характер.

По окончании теста студенты могли оставить в системе Kahoot! свое мнение о выполнении тестов в предложенном формате. Усредненные результаты опроса представлены на рис. 2.

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Кроме этого, был проведен опрос студентов об их мнении о результатах обучения с применением Kahoot! Полученные ответы представлены на рис. 3.

Полученные результаты позволяют судить о положительном эффекте применения ресурса Kahoot! при подготовке студентов.

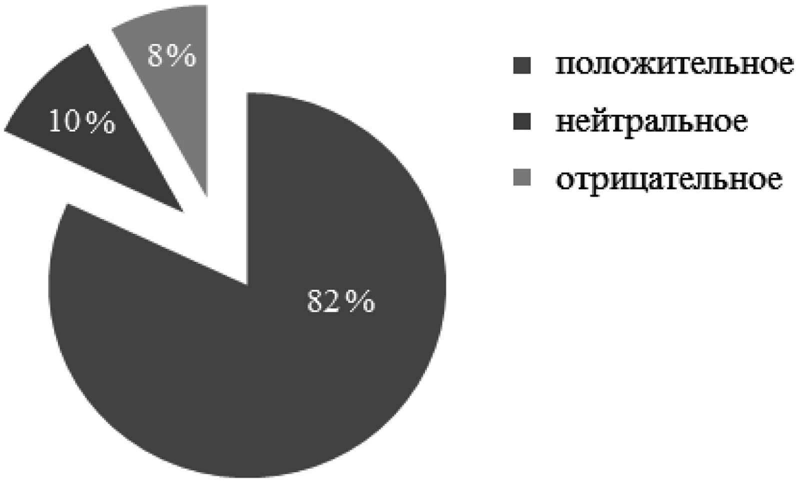

Рис. 2. Мнение студентов относительно выполнения тестов в формате Kahoot!

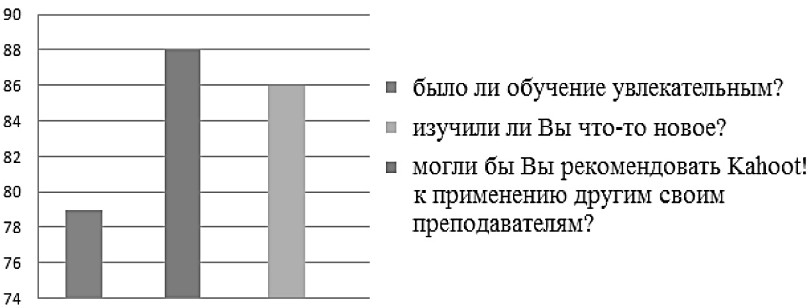

Рис. 3. Обратная связь от студентов

Заключение

Геймификация образования позволяет добиться высокой мотивации и вовлеченности студентов в образовательный процесс. В статье был рассмотрен один из инструментов – интернет-ресурс Kahoot!, который позволяет сформировать или расширить интерактивную образовательную среду. Представленные результаты апробации подтверждают эффективность предложенного подхода.

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DEVELOPING INCIDENT DETECTION ALGORITHM BASED ON THE MAMDANI FUZZY INFERENCE ALGORITHM

Nikolaev A.B., Sapego Yu.S.

Application of fuzzy logic in the incident detection system allows making a decision under uncertainty. The phase of incident detection is a process of finding difficulties in traffic. The difficulty in traffic is the main sign that there was a road accident and requires a reaction for its elimination. This leads to the use of input data that must be relevant to the vehicles and the road. These data must be considered together, and should be compared with the corresponding values for further analysis. The main parameters of the traffic flow, which can characterize its current state, are a flow rate, a volume flow.

Necessary to analyze the input data received from the sensors. After processing the input data, using the previously entered fuzzy rules, will be taken action that will improve the situation in traffic or at least not allow it worse.

Keywords: *Mamdani fuzzy inference algorithm; incident detection system.*

Introduction

Components of the system based on fuzzy logic can be implemented by various methods. Lotfi Zadeh developed the idea of the formalization of fuzzy control algorithm using the logical rules [16, p. 338]. For obtaining output of vaguely formulated data can use logical rules with vague predicates. Consider more detail the algorithm Mamdani fuzzy inference that will be used in this paper, as the most useful for the implementation of fuzzy control systems.

Mamdani algorithm describes several sequential steps. Each successive stage receives input values obtained in the previous step (**fig. 1**):

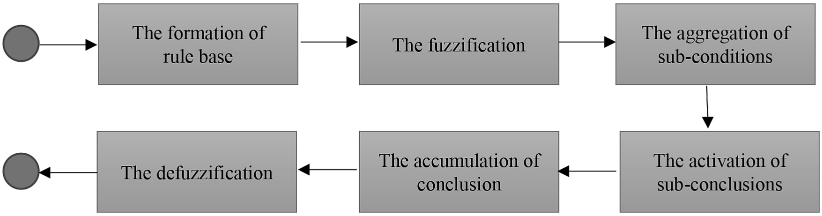

Fig. 1. Phases of Mamdani algorithm

Consider in more detail each of the steps on the example of incident detection system, further linguistic parameters will be introduced.

Determining of linguistic variables

Linguistic variables are input and output variables of the fuzzy system. Linguistic variables consist of words or sentences of a natural language, which allows to express certain conditions and to understand them without the need for measurement or calculation to make a definite conclusion, for example, "on the section of the road was filled with" instead of "on the section of the road was 100 cars."

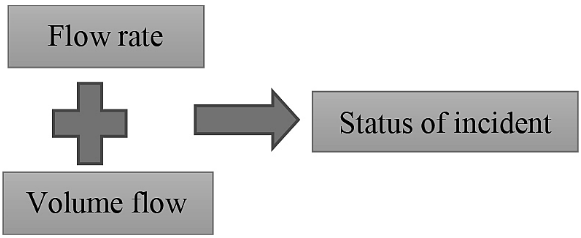

Fig. 2. The input and output linguistic variables

The next linguistic variables in incident detection system will be used to determine the occurrence of incidents (**fig. 2**):

- Flow Rate = {small (SM_SP), medium (ME_SP), large (LA_SP)}

On sections of road where the accident occurred the rate of traffic flow will certainly be slower than in an area where nothing prevents movement. Therefore this variable is necessary for the determining the occurrence of the incident.

- Volume flow = {small (SM_V), medium (ME_V), large (LA_V)}

The volume flow is the number of vehicles crossing the road section in a predetermined unit of time. If the incident occurred on the road, the number of cars is less than in free motion. It should be noted pattern of volume on flow rate: if the vehicle speed is high and the volume is small, it is considered that the road is free. If the volume of vehicles remains unchanged, the flow rate drops, it means that traffic incident probability occurred.

- Status of incident = {false, true}

This variable has two values: "false" – no incident, "true" – incident occurred.

Each specified linguistic variable measures certain traffic conditions; with these conditions form the rules governed the system. Stage of the determination of linguistic variables is an important step because they effect on the efficiency of the system. These variables must be translated into the fuzzy controller by using membership functions; therefore they should be defined for the above variables.

The formation of fuzzy rule base

When an incident occurs, it is formed on the road a congestion. As soon as incident is considered to be cleaned, the road capacity is increased and congestion dissipates. The algorithm determines the state of traffic changes according to the volume and rate of flow.

Define fuzzy rules that are used to describe the relationship between inputs and outputs data, as the current state of road can determine using fuzzy rules. As a result received 9 rules (**Table 1**):

Table 1.

Fuzzy rules for determining the current status of the road

№	Flow Rate	Volume flow	Status of incident
1	Small (SM_SP)	Small (SM_V)	true
2		Medium (SM_SP)	true
3		Large (LA_SP)	true
4	Medium (ME_SP)	Small (SM_V)	true
5		Medium (SM_SP)	false
6		Large (LA _SP)	false

End of the table

7	Large (LA_SP)	Small (SM_V)	false
8		Medium (SM_SP)	false
9		Large (LA _SP)	false

The algorithm of incident detection will issue one of the following results:

1. Normal traffic
2. Probability of occurrence of the incident
3. Incident is detected

During a certain period of time traffic conditions will be analyzed for occurrence of the incident. If the analysis shows that the movement is not normal, it is considered «likely the incident occurred» (situation 2) or – a situation 1. If during 3 time periods measured traffic is not normal, it is considered that an incident occurred on the road, then the output will be situation 3. If the flow is returned to normal, it means that the incident was resolved, and the output will be situation 1 again.

The fuzzification

A characteristic of a fuzzy set is membership function, which is responsible for the process of fuzzification necessary to compensate for the lack of inaccurate input data from sensors because the equipment cannot provide reliable indication for various reasons.

For term-sets certain linguistic variables that are uncertainty such as "is in the range", should be used trapezoidal membership function (**Fig. 3**):

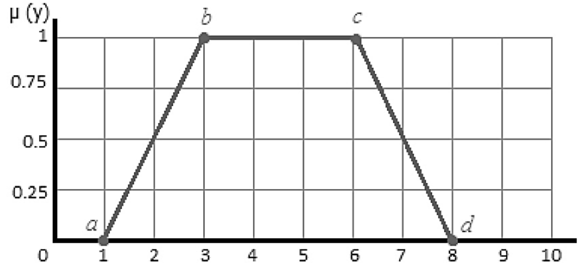

Fig. 3. An example of a trapezoidal membership function

The trapezoidal membership function, in general, can be defined analytically by the following expression:

$$\boldsymbol{f(x,a,b,c,d)} = \begin{cases} \mathbf{0}, x \le a \\ \frac{x-a}{b-a}, a \le x \le b \\ \mathbf{1}, b \le x \le c \\ \frac{d-x}{d-c}, c \le x \le d \\ \mathbf{0}, d \le x \end{cases} \quad (1)$$

where *a, b, c, d* – some numerical parameters that take arbitrary real values and the ordered relationship: $a \le b \le c \le d$. The parameters *a* and *d* describe the lower base of the trapezoid, and the parameters *b* and *d* – the upper. Furthermore, this membership function generates a normal convex fuzzy set with the characteristics: interval (*a*, *d*), boundaries (*a*, *b*) (*c*, *d*), core [*b*, *c*].

Define the membership functions for the linguistic variable:

- Flow rate (**Fig. 4**):

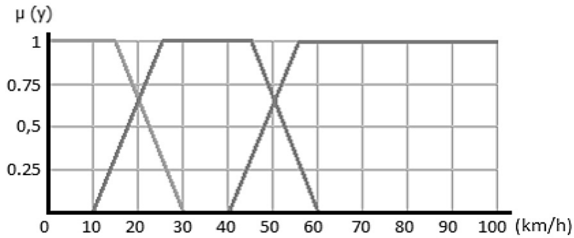

Fig. 4. Membership function for the characteristic "flow rate", where 1 – small (SM_SP), 2 – medium (ME_SP), 3 – large (LA_SP)

The value "small":

$$\mu_{\text{sm}}(SP) = \begin{cases} 1, \ SP \le \ 15 \\ \frac{30-SP}{15}, 15 \le SP \le 30 \end{cases} \quad (2)$$

The value "medium":

$$\mu_{\text{me}}(SP) = \begin{cases} \frac{SP-10}{15}, 10 \le SP \le 25 \\ 1, \ 25 \le SP \le 45 \\ \frac{60-SP}{15}, 45 \le SP \le 60 \end{cases} \quad (3)$$

The value "large":

$$\mu_{\mathrm{la}}(SP) = \begin{Bmatrix} \frac{SP-40}{15}, 40 \le SP \le 55 \\ 1,\ 55 \le SP \end{Bmatrix} \quad (4)$$

- Volume flow (**Fig. 5**):

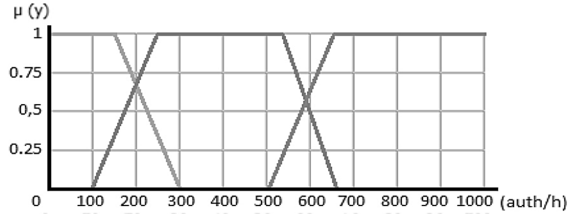

Fig. 5. Membership function for the characteristic "volume flow", where 1 – small (SM_V), 2 – medium (ME_V), 3 – large (LA_V)

The value "small":

$$\mu_{\mathrm{sm}}(V) = \begin{Bmatrix} 1,\ V \le 250 \\ \frac{300-V}{150}, 150 \le V \le 300 \end{Bmatrix} \quad (5)$$

The value "medium":

$$\mu_{\mathrm{me}}(V) = \begin{Bmatrix} \frac{V-100}{150}, 100 \le V \le 250 \\ 1,\ 250 \le V \le 550 \\ \frac{650-V}{100},\ 550 \le V \le 650 \end{Bmatrix} \quad (6)$$

The value "large":

$$\mu_{\mathrm{la}}(V) = \begin{Bmatrix} \frac{V-500}{150}, 500 \le V \le 650 \\ 1,\ 650 \le V \end{Bmatrix} \quad (7)$$

Fuzzy inference

Fuzzy inference consists of three main stages [3, p. 333]:

- Aggregation
- Activation
- Accumulation

Aggregation is a procedure for determining the degree of truth of a_i conditions for each fuzzy rules from inference system. If the condition of fuzzy rule is a simple fuzzy statement, the degree of its truth corresponds to the value of the membership function corresponding to the term of a linguistic variable. If the condition is a composite statement (such as incident detection system), the degree of truth of a complex statement is determined based on the known values of the truth of its component elementary statements using fuzzy logic operations previously introduced in one of the pre-specified bases. For incident detection systems, it will be determined as follows:

$$a_i = \min\{\mu_{i1}(SP_i), \mu_{i2}(V_i)\} \tag{8}$$

where μ_{i1} – membership function for the characteristic «flow rate» (SP).

μ_{i2} – membership function for the characteristic «volume flow» (V).

$i = (1..n)$ – number of fuzzy rules.

Activation is the process of finding the degree of truth of each the sub-conclusion of the fuzzy rules. If the conclusion of fuzzy rule is simple fuzzy statement, the degree of its truth is algebraic multiplication of weight and the degree of the truth of the antecedent of the fuzzy rules.

If the conclusion is a composite statement, the truth degree of each of the elementary statements is algebraic multiplication of weight and the degree of the truth of the antecedent of the present fuzzy rules. If weight coefficients are not specified explicitly in the stage of forming the basis of the rules, their default values equal 1.

Membership functions $\mu(y)$ of each elementary sub-conclusions consequent all fuzzy rules are determined by using the method of fuzzy composition – min-activation:

$$\mu_{acti}(SP, V) = \min\ \{a_i, \mu_{i1}(SP_i), \mu_{i2}(V_i)\} \tag{9}$$

Accumulation is the procedure of finding the membership function for each output linguistic variables. The aim of this stage is obtaining a fuzzy set (and their associations) for each output variables. Association membership functions of all sub-conclusion carried out by using max-associations method:

$$\mu_{acc} = \max\ \{\mu_{acti}(SP, V) \ldots \mu_{actn}(SP, V)\} \tag{10}$$

where $n \in N$ – total number of fuzzy rules.

The final stage is the defuzzification: process of transition from the membership functions of the output linguistic variable to its crisp (numeric) value. This phase in the developed system of incident detection is not required, as the incident detection algorithm returns a boolean value (true or false).

Implementation of the developed algorithm

Example of system that described natural language and has two input and one output variables. If the flow rate is high and the volume flow is medium, it is considered that incident didn't occur on the road. Membership function of these linguistic variables are calculated and formed by using a fuzzy model. The final stage is operation of defuzzification operation that produces a crisp output action.

Let monitoring system returned following value of parameters: flow rate (SP) – 47 km/h, volume flow (V) – 565 auth/h. Calculate for each membership function values according to the formulas **2–7**:

Flow rate:

$$\begin{gathered}\mu_{sm}(47) = 0\\ \mu_{me}(47) = 0{,}86\\ \mu_{la}(47) = 0{,}47\end{gathered} \qquad (11)$$

Volume flow:

$$\begin{gathered}\mu_{sm}(565) = 0\\ \boldsymbol{\mu_{me}(565) = 0{,}85}\\ \mu_{la}(565) = 0{,}43\end{gathered} \qquad (12)$$

Further, it is necessary to determine the degree of membership for each rules of the fuzzy inference system. According to the above-calculated values of membership functions for each fuzzy rule receives an activation of sub-conclusion by using min-activation method (**Table 2**):

Table 2.

Degree of membership for each fuzzy rule

Volume / Rate	$\mu_{sm}(565)$	$\mu_{me}(565)$	$\mu_{la}(565)$
$\mu_{sm}(47)$	min{0; 0} = 0	min{0; 0,85} = 0	min{0; 0,43} = 0
$\mu_{me}(47)$	min{0,86; 0} = 0	min{0,86; 0,85} = 0,85	min{0,86; 0,43} = 0,43
$\mu_{la}(47)$	min{0,47; 0} = 0	min{0,47; 0,85} = 0,47	min{0,47; 0,43} = 0,43

The final step in the fuzzy inference is a stage of accumulation, on that receive fuzzy set (or association) for each of the output variables by using max-associations method:

$$\mu = \max\{0;0;0;0;0{,}85;0{,}47;0;0{,}43;0{,}43\} \qquad (13)$$

Get the total value 0.85 for the fuzzy rule: «rate = medium» and «volume = medium». According to the table 1 the system displays the status of the incident «false», which means that the incident did not appear on the investigated section of the road.

Conclusion

In this paper, fuzzy algorithm of Mamdani was discussed in detail: defined linguistic variables, formed fuzzy rule base, offered fuzzy inference algorithm, as well as illustrates an example of the implementation of the described algorithm for incident detection system.

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INTERACTIVITY OF THE MODERN AUTOMATED SYSTEMS OF THE HELP TO THE DRIVER

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In this article the current technologies in the field of intelligent transportation systems are investigated. The latest systems on control of the safe movement on roads are considered. The analysis of the systems of the help to the driver implemented in cars is carried out. The system concept of the help to the driver of «System help» is offered. Algorithms of work of this system which is based on the principles of interactivity and interaction are investigated. By results of researches experiment on quality of work of system concept of «System help» is made.

Keywords: *automation; transport; car; System help; ITS; controller; algorithm; LEGO.*

Introduction

The movement safety issue on roads already long time remains priority worldwide. Processes of ensuring reliable and safe movement on roads affect various areas of road infrastructure, technical means, science and education in general. The package of measures for identification of factors which are capable to increase quality of work of system of regulation of traffic and quality of functioning of internal system of the vehicle is undertaken.

Modern innovations in ITS

Today there is a number of innovative solutions on safety on roads. These decisions affect two main areas: external (extends to road transport infrastructure) and internal (the implemented systems increasing safety of use of the vehicle).

To external it is possible to carry:

- installation of adaptive traffic lights (incorporate the sensors which are reading out density and flow rate, meteoconditions and other factors then information goes to uniform control center on a wireless communication);

- means of automatic fixing of violations of the rules of traffic – traffic regulations (probing devices and means of a photo of fixing and video of fixing of a road flow and separate elements);
- electronic information displays (reflect a situation in roads in the mode onlayn6 the high-speed mode, weather conditions, jams on roads and a way of a detour, an arrival time to this or that point on the map, etc.);
- detectors of a transport flow (are equipped with several sensors of different type: a microwave radar for measurement of speed, the ultrasonic detector for an assessment of dimensions and classification of vehicles by classes and the multichannel infrared detector for ensuring calculation of cars and determination of intensity of the movement);
- system of automatic lighting;
- road controllers and automatic road meteorological stations [1];

It is possible to carry to internal innovative solutions:

- system of detection of pedestrians;
- system of recognition of route signs;
- system of deduction of a lane;
- monitoring system of degree of fatigue of the driver;
- system of the auto pilot;
- system of the automatic parking, etc.

All above-mentioned internal systems are similar among themselves in the constituting components and the interacting nodes. Sensors of collection and scanning of information of an external situation, cameras and radars (lidars) are the cornerstone of such systems. The onboard computer (controller) which carries out all main computing functions and management functions by all system [2] acts as control center of such systems.

However the modern implemented technologies not always meet the requirements which were set earlier by it. Some systems have a limited scope. Not all systems are capable to guarantee the high level of protection of the driver and the car against possible incidents. Systems, which possess high adaptability to surrounding conditions and a capability independently to make decisions, have the greatest efficiency.

Within this article, authors have researched modern systems of cars and their possibility of the automated work. During researches and experiments the conclusion has been drawn that the most effective are those systems which possess a capability quickly to adapt to changes in environment and a possibility of communication between the interacting elements. Such systems are capable to increase quality of work of the car and safety of its use.

The automated system «System help»

The principle of work of this system consists in an assessment of the surrounding situation by collection of information arriving from external sensors on the onboard computer of the vehicle and decision making on impact on the hardware executive mechanisms, and also, to informing all active participants of traffic (**fig. 1**). Active participants of movement are understood as those vehicles with which physical contact is possible (collision, a contact etc.).

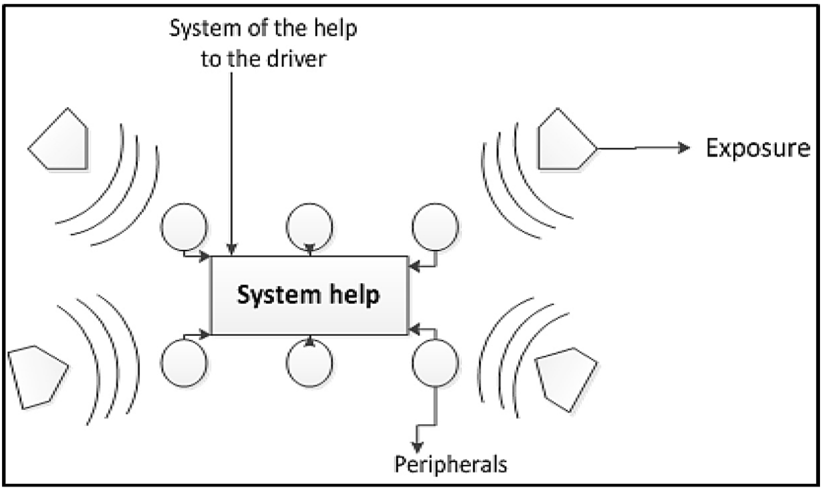

Fig. 1. Work of the system «System help»

The system makes the decision, analyzing all arriving data. Therefore influences, as the hardware executive mechanisms, on which it is established and on the hardware executive mechanisms of active participants (provided that all the hardware are equipped with this system), if it is necessary (**fig. 2**). The principle of interaction of one system happens to another on the «System – to – System» model. Interaction happens only to systems of one type. The system of the car equipped with "System help" can address system of the car with the same system of n-times (where n=1 … ∞).

Depending on the existing danger, it is possible to allocate 3 ways of interaction between systems:

1. Giving of the warning signal or the message on the instrument panel of the car (in **fig. 2** it is represented as "!!!").
2. Projection of the warning sign or the corresponding message on a rear screen of the car (in **fig. 2** it is represented as "Stop").

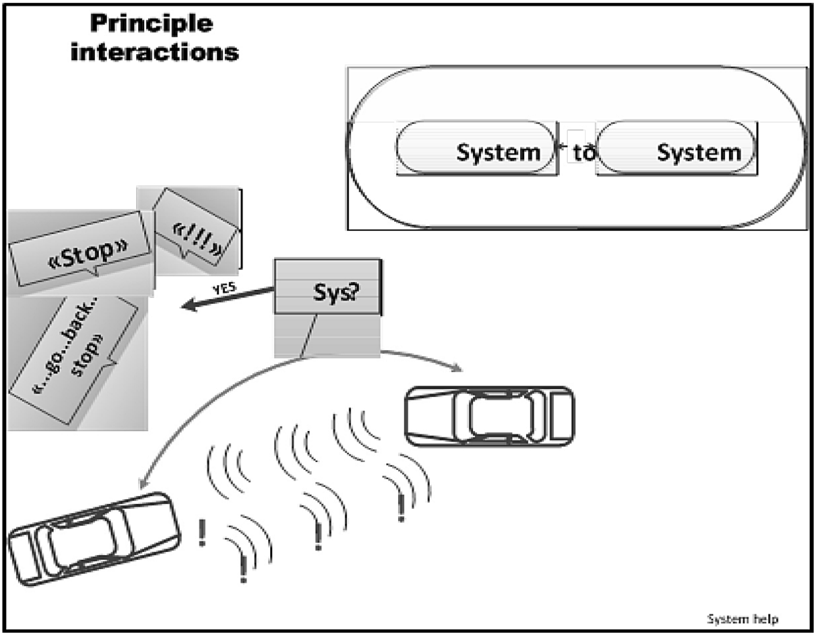

Fig. 2. Principle of interaction between systems
(Sys-a condition of verification of system like "System help")

3. Giving of the operating signals on the operating hardware mechanisms (in **fig. 2** as «go …back … stop»).

Interactivity of the system «System help»

Advantage of "System help" consists in ability of systems of cars to the automated interactivity. At danger detection the system initially informs the driver on the arisen hindrances and if the driver for any reasons ignores signals of system, "System help" transfers work of the car to an off-line mode.

At an off-line mode of work the system interrogates participants of the movement who are in the radius of action of system and, at an affirmative answer on request, makes connection to system of other car (**fig. 3**).

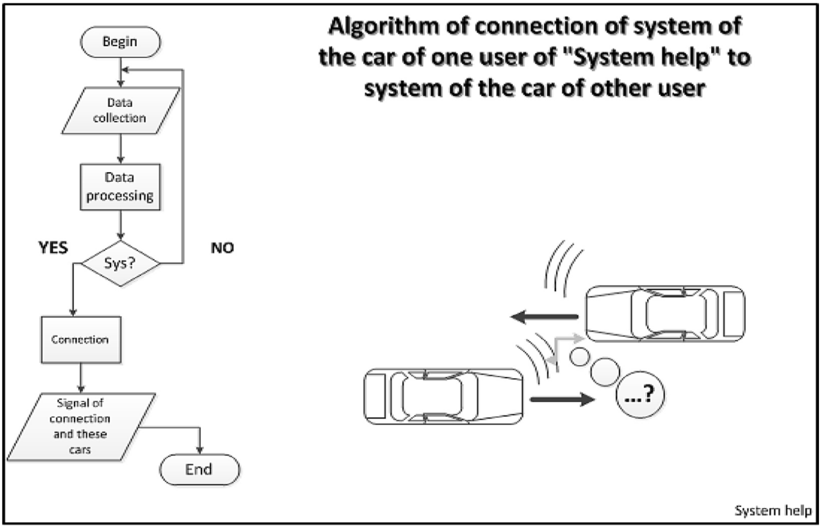

Fig. 3. Algorithm of connection of one system "System help" to another (Sys-a condition of verification of presence of system like "System help")

After connection of one system to another, on the screen of the instrument panel it is given the corresponding signal and the message on connection and these cars, which participate in "communication" (serial number of the car, model and make of the car and identification number in the «System help» system).

In figure 4 (**fig. 4)** the algorithm of interactivity between systems on which interaction between participants of traffic is step by step described is presented. The element S is check of the contacting object on existence of the system «System help». Element W – is danger condition.

Experiment on interaction

Within researches, experiment on interaction of systems has been delivered. Testing and the analysis of influence on changes of traffic of the used principles of the «System help» system was held.

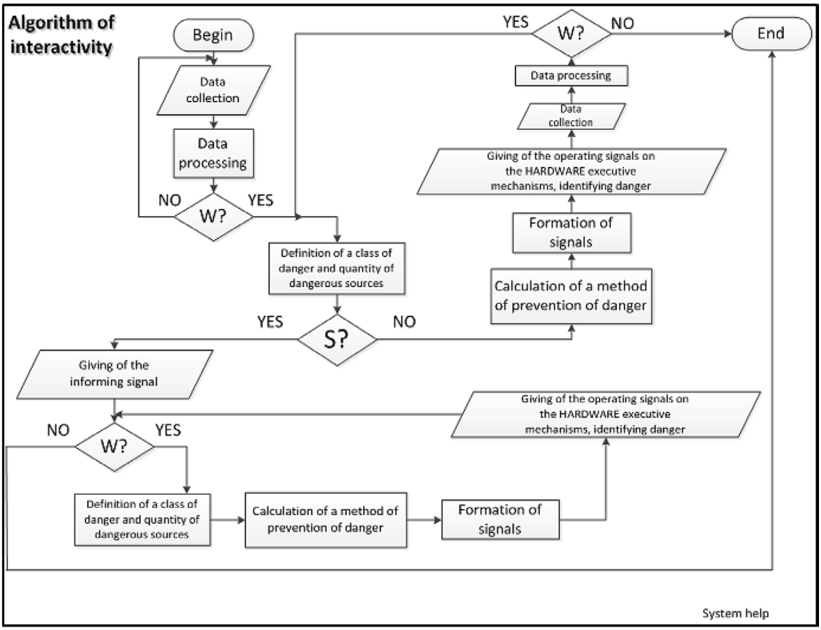

Fig. 4. Algorithm of interactivity

In experiment three robots (**fig. 5**) were used. Two robots are created on the basis of the designer LEGO MINDSTORMS complex, with use of the EV3 and NXT controller. Programs with use of a programming environment of LEGO MINDSTORMS Education EV3 and LEGO MINDSTORMS NXT were developed for each robot.

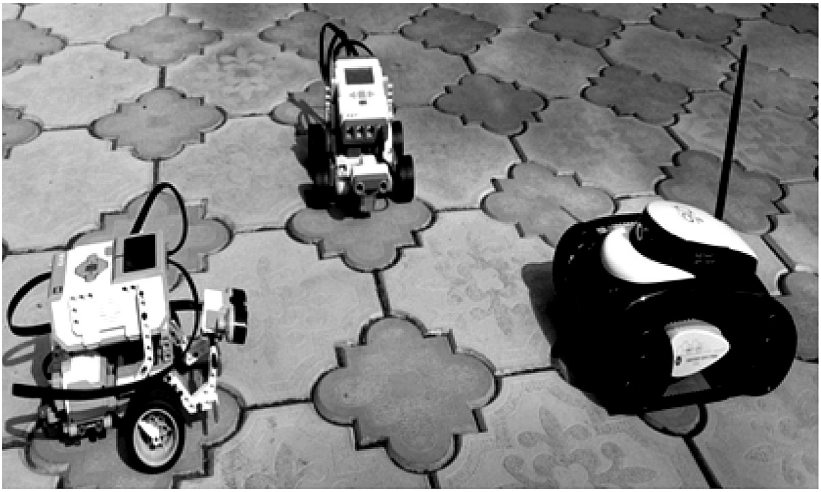

Fig. 5. Experiment on interaction

As the third object the i-Spy Tank robot which was used as system which isn't equipped with the principles of "System help" has been used. It is played a role of the object creating hindrances for two other robots (**fig. 6**). It was necessary for additional check of level of readiness of system to react to numerous external hindrances.

LEGO robots worked in an off-line mode. For their movement the trajectory imitating journey of the intersection has been constructed. The i-Spy Tank robot received management remotely from the tablet, using the created Wi-Fi network for connection.

During numerous changes of a trajectory of the movement of the i-Spy Tank robot for the purpose of creation of new hindrances, LEGO robots successfully avoided collision with each other, being based on interactivity and timely transfer of the informing and managing signals. As a result of carrying out 10 experiments, only in one case there was a collision of the LEGO robot with i-Spy Tank. It has been connected with purposefully fast changing of a trajectory of i-Spy Tank.

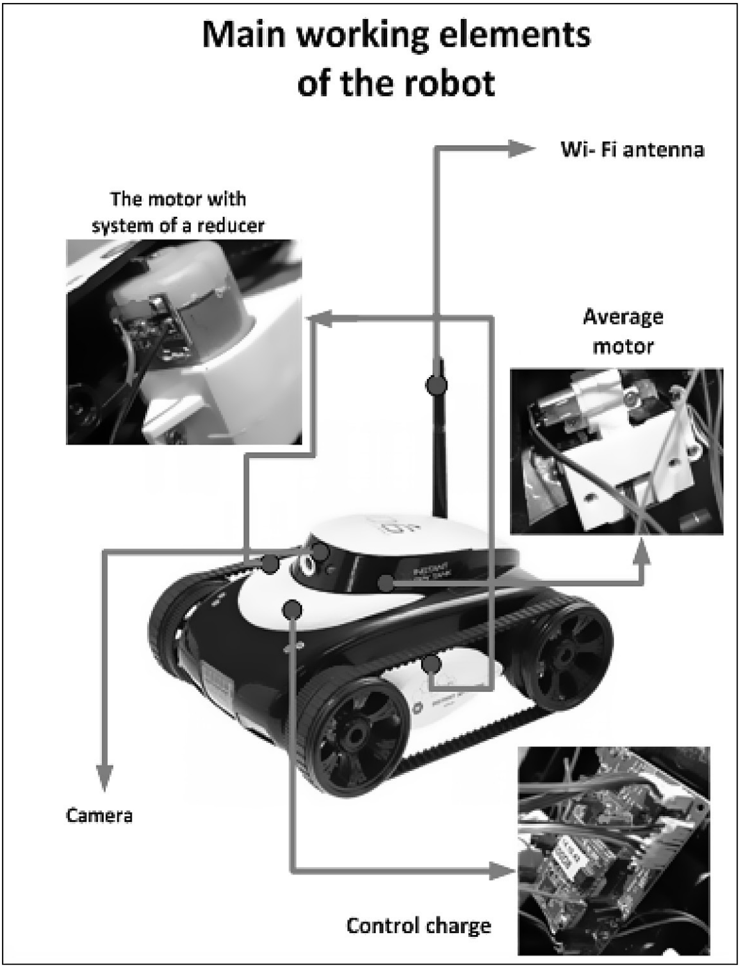

Fig. 6. Robot i-Spy Tank

Conclusion

Automation the processes of the car is very necessary and important area in automotive industry. Traffic safety directly depends on modernization of this area.

The system «System help» as has shown experiment on interaction, is capable to provide comfortable and safe use of the car, and also, to help the driver with difficult and dangerous situations on roads, making autonomous decisions.

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MODELLING OF DYNAMIC SPEED LIMITS USING THE MODEL PREDICTIVE CONTROL

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The article considers the issues of traffic management using intelligent system "Car-Road" (IVHS), which consist of interacting intelligent vehicles (IV) and intelligent roadside controllers. Vehicles are organized in convoy with small distances between them. All vehicles are assumed to be fully automated (throttle control, braking, steering). Proposed approaches for determining speed limits for traffic cars on the motorway using a model predictive control (MPC). The article proposes an approach to dynamic speed limit to minimize the downtime of vehicles in traffic.

Keywords: *intelligent transport system; intelligent car; simulation; traffic safety; model MPC; control in IVHS; speed limit.*

1. Introduction

The ever increasing demand for mobility leads to traffic jams on the roads in worldwide. One of the most promising approaches to reduce the frequency and impact of congestion is the use of advanced traffic management methods that control measures (traffic lights, dynamic route information displays, dynamic speed limits, etc.) are used to control the flow of vehicles in order to reduce traffic congestion and improve highways crossing abilities.

Modern traffic control technology based on the modern transport infrastructure based on the use of information and communication technologies, including intelligent equipment in cars. In road transport, such systems are called intelligent vehicle highway system (IVHS). All vehicles are equipped with additional IVHS equipment which allows them to move in groups with a distance of two meters between the vehicles and the distance up to 30–60 meters between such groups. High speed and short distances between vehicles in the group can increase the capacity of the motorway. The proposed approach does not ignore the usual traffic control measures. In this paper, we will consider how to determine the appropriate speed limits for vehicles in groups IVHS to optimize the performance of traffic system, to reduce travel time and fuel consumption, improve security and reliability.

2. The hierarchical framework for management in IVHS

The hierarchical traffic management framework in IVHS (Figure 1) provides increased throughput and reduces the risk of traffic jams, and contains several levels:

- High-level controllers (regional, supraregional and district administration) ensure coordination of the upper levels of management.
- Roadside controllers. Each group of vehicles in the road network is considered the roadside controller as a single unit. This greatly reduces the complexity of managing the problem, compared with a case where every single vehicle will be controlled by roadside controller. As a result, all network traffic can be managed more efficiently.
- Groups of vehicles controllers – receive commands from the roadside controllers, and are responsible for the oversight and coordination of each car group within the vehicles. They provide the coordinated motion of group of vehicles, including maneuvers and maintaining safe distances between vehicles in the group.
- Vehicle Controllers – receive commands from groups of vehicles controllers and translate these commands into control signals for actuators, which installed in every vehicles (throttle, braking, steering).

The main objective of the roadside controller is to determine the speed of movement of the group of vehicles and the safe distance to avoid collisions between vehicles, to determine the best size of the group of vehicles according to the specific traffic conditions, dynamic routing for groups of vehicles and output commands to change the number and size of the group of vehicles.

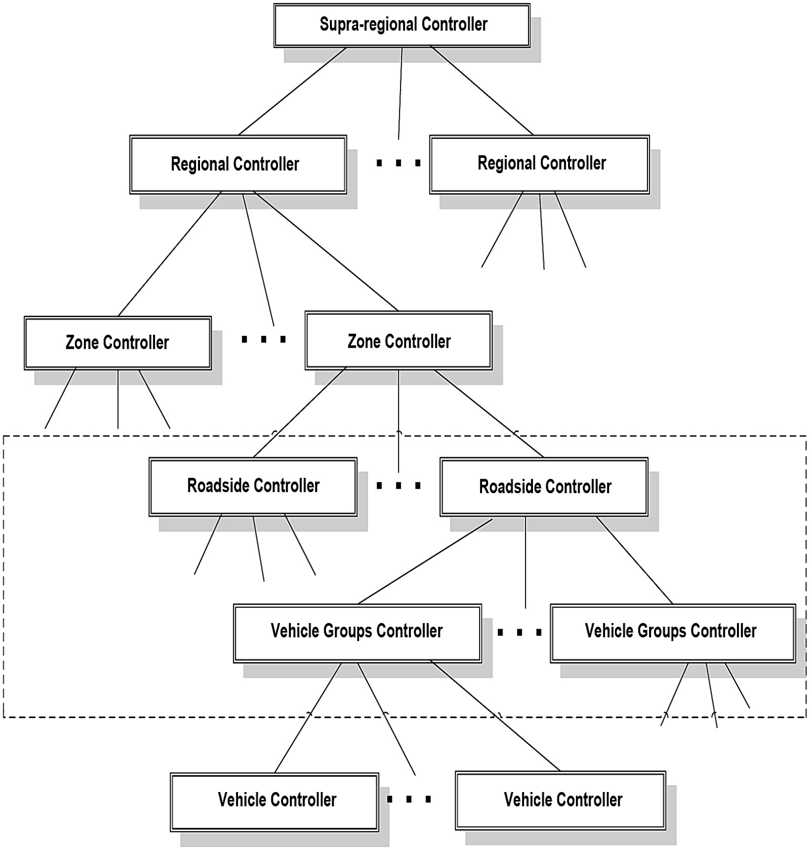


Fig. 1. The hierarchical management structure IVHS

3. Model predictive control for traffic management using IV

Model predictive control (MPC) has originated in the process industry and has been successfully implemented in many other industries. MPC uses a model with discrete time T_{ctrl}. At each control step, MPC controller determines the current state *x(k)* of the system. Next, using an explicit prediction model determined the values of the control commands for a prediction determined period of N_p (Figure 2).

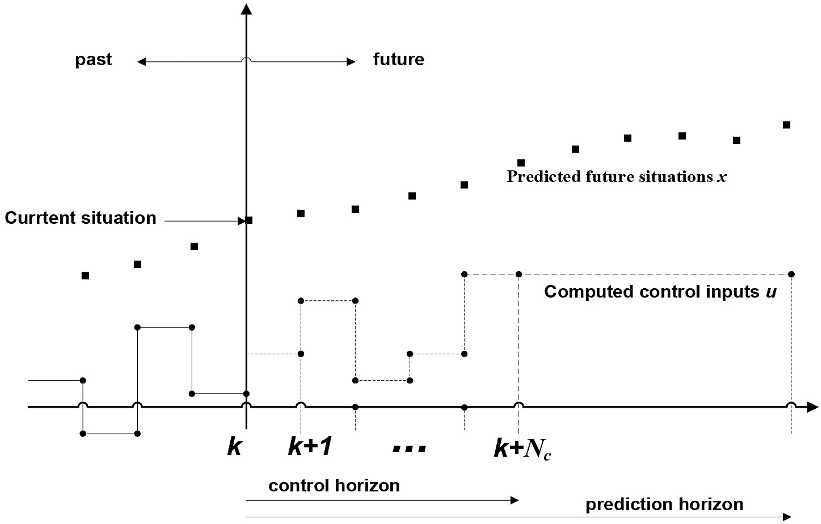


Fig. 2. Prediction Management horizon in MPC

In order to reduce the computational complexity of the problem, often impose the restrictions in the form of $u\ (k + j) = (k + j\text{-}1)$, for $j = N_c$,. ,,, N_p-1 where N_c is called the prediction horizon. In each control step, the control command generated by $u^*(k)$, which is an element of optimal control sequence $u^*(k), ..., u^*(k + N_c\text{-}1)$. Further, the prediction horizon is shifted one step forward, and forecasting process is repeated using the newly obtained values. Consider the possibility to control the speed within the IVHS using MPC.

Roadside controller works with groups of vehicles as basic entities. In this case, the control signal must be set the speed limit for the main vehicle in the group, and the time of travel controller. Today, there is a wide range of traffic patterns in the area. An important factor that determines the selection of models for use in the MPC is a compromise between accuracy and computational complexity, since at each control step k the model will be used repeatedly in real time during the entire running time. As a consequence, very detailed (microscopic) simulation model of the motion, as a rule, are not suitable as a predictive model of MPC. Instead, usually used simplified (aggregated) model. However, it should be noted that the MPC is constructed in a modular fashion. In that case, the model predicting inadequate computational efficiency, it can easily be replaced by another predictive model. As a performance criteria $J_{perf}(k)$ for MPC for IVHS are the total time, overall throughput, the total fuel consumption, safety, or combination of these, evaluated for the time period $[kT_{ctrl}, (k + N_p) T_{ctrl})$.

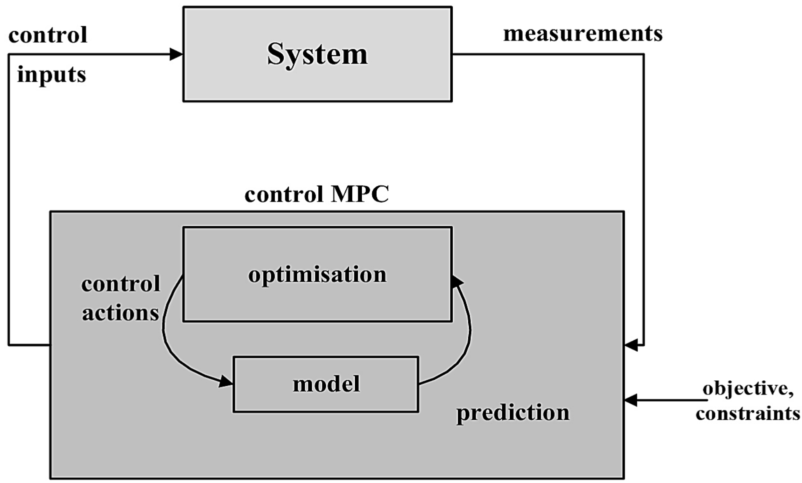


Fig. 3. The control structure MPC

In order to prevent the traffic pulsation in the control signals is often added a penalty on variations in the control signal u, which leads to increased productivity of complexity functions:

$$J_{tot}(k) = J_{perf}(k) + \alpha \sum_{j=0}^{N_c-1} \left\| u(k+j) - u(k+j-1) \right\| 2 \quad (1)$$

the control step k, where $\alpha > 0$ is a weighting factor.

MPC controller can also explicitly take into account the operational constraints such as the minimum distance between the groups of vehicles and maximum speed, minimum advance, etc.

4. Components of models IVHS

This section describes a simplified model of vehicle and groups of vehicles, which can be used as a predictive model in a roadside controller using MPC. In the absence IVHS, vehicles can move at any speed within a permitted speed (e.g. 120 km/h). As the traffic demand increases, the vehicles start to follow their predecessors at closer distances and at reduced speeds (50–80 km/h). When the capacity of the highway is being utilized at its maximum, decreases speed to 0–40 km/h.

4.1. Vehicle Model

To simulate the dynamics of vehicle movement using the equation:

$$x_i(\ell+1) = x_i(\ell) + v_i(\ell)T_{sim} + 0.5\,a_i(\ell)T_{sim}^2 \quad (2)$$

$$v_i(\ell+1) = v_i(\ell) + a_i(\ell)T_{sim} \quad (3)$$

where the ℓ – simulating step number, T_{sim} – simulation time step, $x_i(\ell)$ – coordinate the longitudinal position of the vehicle (i) for the time $t = \ell T_{sim}$, $v_i(\ell)$ – speed of the vehicle (i) for the time $t = \ell T_{sim}$ and $a_i(\ell)$ – acceleration of transport equipment (i) at time $t = \ell\, T_{sim}$. Acceleration is present in (2)–(3) and is calculated in accordance with the current driving situation, as will be explained below. Furthermore, the acceleration is limited between the maximum acceleration value $a_{\mathrm{acc,max}}$, and the maximum value of acceleration comfortable deceleration $a_{\mathrm{dec,max}}$.

4.2. Model for Driver

In that case, if the of group of vehicle reach the next ahead exceeds than the critical value, it is considered that the vehicle moves independently, rather than as a group. Otherwise, it is assumed that the moves of vehicles in the group. As described, there are various types of vehicle models in the following [5]: a model to stimulate the response [6], the model of collision avoidance [7], psychophysical model [8], and models of cellular automata [9]. We use the model to stimulate the response [6] to describe the behavior of the driver, since this model is the most commonly used and easy to implement. Model stimulus response [11] is based on the hypothesis that each vehicle is accelerated or decelerated in accordance with the relative velocity and the distance between the vehicles and its predecessor. Then, acceleration is determined by the formula [11]:

$$a_i(\ell) = Cv_i^{\beta}(\ell)\frac{(v_{i+1}(\ell - d) - v_i(\ell - d))}{(x_{i+1}(\ell - d) - x_i(\ell - d))^{\gamma}} \quad (4)$$

where C, β and γ are parameters of the model, and d is the delay of the driver.

(1 – Assume that T_{react} – reaction time, which typically has a value of 1-1.2s, is an integer multiple of simulation time step Tsim. So, $T_{react} = \sigma T_{sim}$ where σ – Integer.

2 – It is assumed that T_{delay} usually has a value of from 1-1.2 s, and is an integer multiple of T_{sim}. Thus $T_{delay} = dT_{sim}$, where d – Integer).

4.3. Models for intelligent vehicles

Intelligent Vehicle (IA) used adaptive cruise control (ACC) and intelligent speed adaptation (ISA) when driving in the part of the group of vehicles. Consider the model for calculating the acceleration of the head of the groups of vehicles and other vehicles in the group.

1) model for the head of the group of vehicles: the calculation of the acceleration is made on the basis of the expression:

$$a_i(\ell) = K_1(v_{ISA}(\ell) - v_i(\ell)) \quad (5)$$

where K_1 is – the constant of proportionality, v_{IAS} – initial rate value, which is measured by the roadside controller.

2) model for other vehicles: in this case, the acceleration is calculated based on:

$$a_i(\ell) = K_2(h_{init,i}(\ell) - (x_{i+1}(\ell) - x_i(\ell))) + K_3(v_{i+1}(\ell) - v_i(\ell)) \quad (6)$$

where K_2 and K_3 – constants and $h_{init,i}$ – distance to advance the starting of the car (i). The controller calculates a safe distance forward as follows:

$$h_{init,i}(\ell) = S_0 + v_i(\ell)T_{ford,i} + L_i \quad (7)$$

where S_0 – the minimum safety distance to be maintained at zero speed. $T_{ford,i}$ – Time to move forward for the vehicle (*i*) and L_i – the length of the vehicle (*i*).

4.4. Model for the Group of IV

On a more general level, one can also consider a group of vehicles, as a single entity without regard to the detailed description of the interaction between the individual vehicles in the group. So essentially, we consider a platoon as one vehicle with a length that is a function of the speed of the platoon (due to the dependence of the intervehicle spacing managed by the ACC on the speed and the number and length of vehicles in the group). Consider p group and assume for simplicity that the vehicle group are numbered from 1 (the last car group), 2 (the penultimate group of vehicles), ..., n_p (group leader). The speed depends on the length of the group:

$$L_{group,p} = (n_p - 1)(S_0 + S_1 v_{n_p}(\ell)) + \sum_{i=1}^{n_p} L_i \quad (8)$$

where $S_0 + S_1\, v_{n_p}(\ell)$ – the speed depends on the distance between the vehicle in the group, the $\boldsymbol{S_1}$ constant, and v_{n_p} is the speed of cars (leader).

When merging the groups of vehicles can use the group model, if the merger will not be lead to a collision at the following times intervals. If both conditions are satisfied, the group of the vehicles is joined to the main flow (at a rate, which is determined by roadside controller).

For individual vehicles not controlled by the roadside controller can use the similar model, i.e., the vehicle joins the mainstream line provided that there is a large enough distance between the groups, and that collision will not occur. The vehicle speed can be taken equal to the speed of the vehicle in front or a value not exceeding the maximum permitted speed.

5. Example simulation

To illustrate the operation of IVHS, consider the segment of the road length of 13 km. At a distance of 7.5 km, is provided a branch from the beginning of this section (Figure 4).

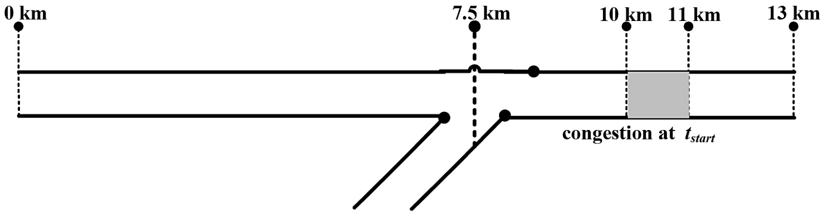


Fig. 4. Fragment of the road

Let us consider the motion of vehicles without IVHS, with speed (ISA) and the movement of intellectual adaptation of IA system. For simplicity, all the vehicles are considered to be of the same length (L_i = 4 m). During the simulation, we believe that the ISA limits the speed of the vehicle and that drivers may not exceed the imposed speed limit. In the IV-based case the groups of vehicles. Suppose that all the IVs equipped with all necessary facilities (computers, sensors, and ACC and ISA controllers on board).

Modeling a period of 9 minutes starting from the time t_{start} = 7 hours, ending at time t_{end} = 7 h 9 mins. The intensity of the movement of vehicles assumed to be constant during the simulation period, and 1365 veh/h for non-automated vehicles, and 404 veh/h for the agency.

In the present state of the initial state of the simulation scenario is described as follows. There is congestion of vehicles on the segment from x = 10 km. to x = 11 km. at time t_{start}. In congested area there are 100 vehicles at a speed of 0 km/h. The area has not overloaded vehicles 70 (uniformly distributed) at a speed of 120 km/h. After time t_{start}, the traffic congestion in the area returns slowly to its normal value.

For the research model was developed in the Matlab environment, simulated and compared the results obtained for this scenario in the normal driving mode and using the IVHS. Model used to model vehicle (2)–(3) with the relative acceleration. To calculate the relative acceleration during normal driving of the equation (4). For groups of cars with the ISA – the equations (5)–(7). For the head of the car in the group C = 1,55, β = 1,08 and γ = 1,65 to accelerate, and C = 2,55, β = -1,67 and γ = -0,89 for braking. Moreover, selected σ = 1, d = 1, K = 0.01

and K_1 = 0,4. For all vehicles in the group we have K_2 = 0,6, K_3 = 1.2, S_0 = 3 and T_{ford}= 0.5. For a group of vehicles in a model (8) is chosen S_1 = 0.5. Furthermore, $a_{\text{acc,max}}$ = 3 and $a_{\text{dec,max}}$ = -3 for all models. Time step simulation made T_{sim}= 1s.

The purpose of traffic management is to increase the traffic performance, i.e. minimizing the total time spent (TTS) for all vehicles using dynamic speed limits:

$$J_{TTS,sim} = \sum_{\ell=1}^{N_{sim}} \left(n_{veh}(\ell)\right) + q_{highway}(\ell) + q_{on-ramp}(\ell) T_{sim}, \quad (9)$$

where N_{sim} = 540, the total number of simulation steps (length *Tsim* = 1s) during the entire period of simulation 9 minutes n_{veh} (ℓ) is the number of vehicles that are present in the network at time $t = t_{start} + \ell\, T_{sim}$, $q_{highway}(\ell)$ is the number of cars in the queue for travel on the highway during $t = t_{start} + \ell T_{sim}$ and $q_{on\text{-}ramp}(\ell)$ – the number of vehicles present in the queue at time $t = t_{start} + \ell T_{sim}$.

The corresponding function efficiency $J_{perf}(k)$*,* when used in the MPC step approach to control is then given,

$$J_{perf}(k) = \sum_{\ell=kK+1}^{(k+N_p)K} (n_{veh}(\ell) + q_{highway}(\ell) + q_{on-ramp}(\ell)) T_{sim}, \quad (10)$$

with $K = \dfrac{T_{ctrl}}{T_{sim}}$. The total target MPC functions are also included, the term fine α = 0,01. For a control of the human situation, the ISA Management measures applied (with a speed limit for each section of 1 km between the position of x = 0 km and the position x = 10 km). So, u for the MPC control signal of the control task to step k includes ISA speed limit for the first 10 sections and measuring speeds (expressed as a number between 0 and 1) control step k to $k + N_c - 1$ (i.e., $11N_c$ variables in total).

If P_k amount present in the network vehicle groups at the control point k, and if Q_k is the number of cars groups which could enter into the network during the time interval from $t = kT_{ctrl}$ to $t = (k + N_p)\, T_{ctrl}$, the total number of variables is determined $P_k N_c + Q_k$ in total.

Consider a maximum speed of 120 km/h. Roadside controller must ensure the maintenance of a safe distance between cars in the group, and between groups of cars. In particular, the minimum safe distance between the group cars p_1 and following the same lane in front of a group of p_2 cars is set $S_{0,group} + T_{ford,group} v_{gruop,p1}$ where $v_{gruop,p1}$ has a cars group speed p_1. For the case study $S_{0,group}$ = 20 m and $T_{ford,group}$ = 2 s.

The access time T_{ctrl} control is set to 1 min. For prediction horizon N_p was made a value that matches 7 min, and is set to control horizon N_c, which corresponds to 3 minutes in order to limit the number of variables.

6. Results

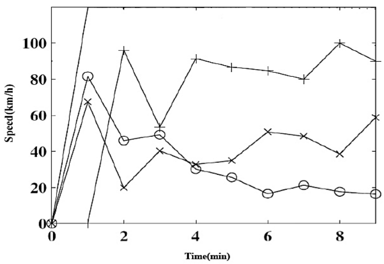
The simulation results showed a significant reduction in the total time spent (TTS) in the case of the control groups of vehicles. Compared to the uncontrolled movement of the improvement was more than 24% (Table 1).

Table 1.

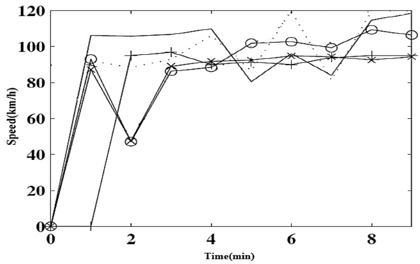
Values of the total time spent on the network during the simulation period

Case	TTS(veh/h)	Relative improvement
Uncontrolled case	27.44	0%
Controlled (human drivers)	24.72	9.91%
Controlled (car groups)	20.67	24.67%

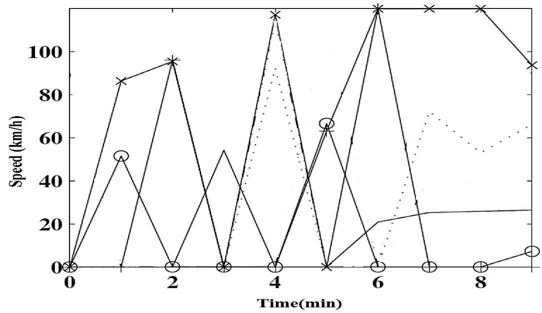
These results can be explained as follows. In the uncontrolled case, when there are no vehicle in front of the driver or, if there is enough space between vehicles, drivers retain their desired speed. But when the driver is faced with traffic jams, he has to brake to avoid a collision, and he had to wait until this incident will cleared. Moreover, there are no mechanisms that can delay or prevent the flow of additional vehicles from entering the highway. All this results leads to a lot of time spent in the network for the vehicle, and thus also a higher value TTS (total time spent).



(a) simulation for uncontrolled case



(b) simulation for controlled (human drivers)



(c) simulation for controlled (car groups)

Fig. 5. Simulation graphs of results

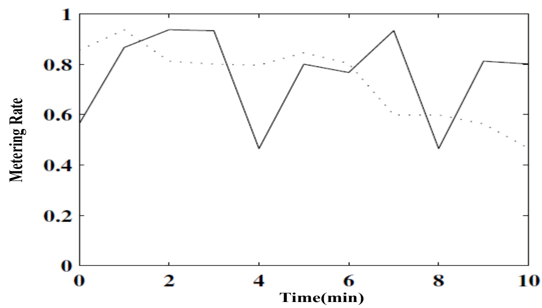


Fig. 6. The speed limits and ramp metering rates for controlled case

The MPC approach can predict the presence of congestion and prevent it or reduce its negative effects due to the deceleration of vehicles (using the speed limit), or delayed vehicles before they reach the congested area.

When controlling group of vehicles by the full automation, able to maintain a small distance between the vehicles, which leads to the decrease in TTS.

7. Conclusion

It is showed that the model predictive control (MPC) can be used to determine the optimal speed of group of vehicles within the IVHS. The proposed approach was illustrated by practical examples based on modeling with the establishment of dynamic speed limits as control measures. These results show the potential benefits and the possibility of improvement that can be obtained using an intelligent control for MPC in IVHS.

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ALGORITHMS FOR TRAFFIC MANAGEMENT IN THE INTELLIGENT TRANSPORT SYSTEMS

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Traffic jams interfere with the drivers and cost billions of dollars per year and lead to a substantial increase in fuel consumption. In order to avoid such problems the paper describes the algorithms for traffic management in intelligent transportation system, which collects traffic information in real time and is able to detect and manage congestion on the basis of this information. The results show that the proposed algorithms reduce the average travel time, emissions and fuel consumption. In particular, travel time has decreased by about 23%, the average fuel consumption of 9%, and the average emission of 10%.

Keywords: *traffic jams; intelligent transport systems; detection and control of congested roads; automated control system; control; simulation; algorithm.*

Introduction

Traffic jams are a major problem in large urban centers and directly impact on the economy due to increase fuel consumption. In addition, it affects the productivity of society as congestion dramatically increase travel time from one point to another and causing irreparable damage to the environment due to the increase of the emission of polluting gases. According to statistics, 85% is associated with time wasted in traffic, 13% due to the increase in fuel consumption and 2% can be attributed to an increase in emissions of polluting gases [1, 2].

To prevent congestion and improve the efficiency of transport systems, there is an active implementation of intelligent transport systems (ITS). Intelligent transport systems use advances in techonology in the area of processing, sensing and communication in order to monitor traffic conditions in a particular region to manage traffic and reduce congestion as well as reduce the number of road accidents. In addition, they can be used to provide information and entertainment services to drivers and passengers in order to make their journey a more pleasant process [2, 3]. A Vehicular Network is an important component in an ITS. In this network, vehicles are equipped with processors, sensors and wireless communication interfaces so that they can communicate with one another and with the elements in the network infrastructure (RSU – Road Side Unit), thus creating an ad hoc network while vehicles move through roads. Thus, when driving vehicles on the roads equipped with ITS, it created a special network (4, 7, 10).

Some researchers [8, 9] proposed the architecture for the design of ITS, which range from centralized solutions to distributed decision making solutions. These solutions use both the information provided by vehicles and the characteristics of the infrastructure of the roads to detect and control congestion. Thus, after detecting a congested area or road, a rerouting mechanism is applied to the vehicles to prevent more vehicles from entering the affected area, which results in a more efficient traffic. Thus, this work is aimed at the implementation of a distributed ITS to detect congestion and traffic management.

The proposed system consists of a set of roadside controllers. Each controller is responsible for roadside vehicles management and congestion detection only within the coverage area of its range. Moreover, the system includes a congestion control mechanism that periodically performs routing of all vehicles so they do not pass through congested areas. The system is divided into four stages, the distribution of the roadside unit RSU collection and transmission of data, congestion detection and congestion control [5].

The algorithm of placing of roadside controllers (RSU) on the map

Allocation of road side controller (RSU) is uniform depending on their radius and size of the map. Thus, the larger the range, the smaller the number of roadside controllers is used to cover the map. In algorithm 1, when placing roadside controllers are taken into account: Width – the total width of the card, Length – total length of the card and Radius – range roadside communication controller. Algorithm 1 based on the size of geographic area and radius roadside communication controller (line 3) calculates the number of roadside controllers that are needed to cover the entire map. Then the coordinates of the placement of roadside controllers in relation to the map.

The algorithm of placing of roadside controllers (RSU) on the map

```
Input:   Width // Total width of the map
         1 Length // Total length of the map
         2 Radius // Operating range of RSU
Output: Coordinates of the points of each RSU
         // returns the amount of RSUS to cover the entire map
3 rsus ← getNumberOfRSUs(Width; Length; Radius);
4 foreach γ ∈ rsus do
         // returns the coordinates (x; y) for each RSU
5 Rsus_coordinates.add(getCoordinates(r));
6 end
```

Communication range of roadside controllers influences the cost of implementing the system, i.e, the smaller the radius of the connection, the greater the number of roadside controllers required to cover the entire map.

Algorithm to collect and transmit data in the RSU

This algorithm provides data collection from RSU to obtain information about the events taking place within their communication range, as well as information about the behavior of the vehicle in their coverage area. In which vehicles periodically send information about the position, speed, distance covered, time and direction of travel movement in the near RSU. This information is transmitted via the long-range communication (LTE or 3G).

Algorithm 2 describes a process in which each vehicle sends the information to the nearest RSU. The algorithm takes as input the set of vehicles and a set of coordinates of each RSU, which are respectively represented N and RSUs-Coordinates. Thus, each vehicle collects information and identifies the nearest RSU in relation to its position (Line 4). Moreover, each vehicles create messages containing the collected information and sends it to the nearest RSU (Lines 5–6). After collecting and transmitting data to the RSU, it is necessary its analysis and interpretation. Each roadside controller creates a graph G = (V, A), where the vertices V – a set of transitions within the reach of roadside controller (representing the top) and the arc A – is a set of roads that connect the top. Each road (edge) of graph G has a weight defined by the average speed with which the vehicles travel it and the maximum speed allowed on it. This weight is inversely proportional to the speed at which the vehicle moves along the road. This weight is inversely proportional to the speed at which the vehicle moves along the road. Thus, the closer to the speed of movement of the vehicle with speed limited, the lower the weight of the road. Conversely, the lower the speed of the vehicle relative to the maximum speed, the higher the weight.

Алгоритм of Collecting and sending data to the nearest RSU

```
Input:  N // Set of vehicles on the network
        1 RSUs_Coordinates // Set with the coordinates
        of each RSU
2 foreach υ ∈ N do
        // returns information about vehicle V
3       status v.getInformations();
        // returns the nearest RSU to vehicleV
4       nearestRsu RSUs_Coordinates.getNearstRSU(v.getPosition());
        // creates a message with the information of vehicle v and sends
it to the nearest RSU
5       message ← CreateMessage(status);
6       message.sendTo(nearestRsu);
7 end
```

The algorithm of alternative routing of vehicle

The change of route of vehicle movement occurs periodically depending on the current traffic. Each roadside controller is responsible for the selection of a new route within its range. The distortion depends on the intensity of vehicle movement and the weight of the road. When an overload vehicle are forwarded to another route to avoid congested areas. As the base routing algorithm is used to find the shortest route in time. However, the set of K shortest paths is calculated as alternative ways in which K can be easily adjusted to adapt better to the behavior in the network. Of these alternative routes, the only way is selected by using the probability distribution of Boltzmann.

Algorithm 3 describes the process of alternative routing of the vehicle. The algorithm takes as input a set of vehicles within a radius of communication of each RSU (N). The graph is created with the appropriate functions described previously (represented in the algorithm as G, and the variable K, which represents the number of shortest routes that must be calculated). Thus, the RSU computes the path of each vehicle and its current coordinates (lines 4–5). Then, the RSU calculates the destination vehicle V is located within its coverage area (the last part of the vehicle ways within the RSU). After the detection of the last section of the path within the RSU, k shortest paths are calculated starting from the current point to the final vehicle In the path (line 7). From the K shortest past, a new path is selected based on the probability distribution of Boltzmann (line 8).

Algorithm of alternative routing of vehicles

input: N // a Set of vehicles in range of each RSU
1 G // the Graph is created for each RSU
2 K // Number of alternative ways
3 For $\upsilon \in N$ do
// sets of edges that make up the route of vehicles V
4 route v.getRoute();
// returns the current coordinates of the vehicle and the distance to the last segment of the path V, contained in the graph G for a given RSU
5 source ← **v.getPosition**();
6 lastEdge ← **G.getLastEdge**(route);
// calculates K shortest paths from the starting point to the last point of movement of the vehicle

```
alternativeRoutes ← G.getKShortestPaths (source; lastEdge;K);
// select a path from a set of alternative paths
newRoute ← boltzmann(alternativeRoutes;G);
if lastEdge! = route.getDestination() then
// returns the remaining part of the route of vehicle V from the last section
remaningEdges ← route.split(lastEdge);
newRoute.add(remaningEdges);
v.setRoute (newRoute);
end
else
v.setRoute(newRoute);
end
end
```

Select the path among *K* shortest routes is based on the calculation of weights, defined as the sum of the weights of all segments of the path included in the route. For load balancing across shortest routes uses a lot of R_j. For route determination uses the following rules:

J = set of vehicles on the map
Wj= set of paths of the vehicle *j* ($j \in j$)
γ_J^I = path *i* of vehicle j ($j \in j$) and ($\gamma_J^I \in R_j$)
ω_J^I = weight of path γ_J^I
$M(\omega_J^I)$ = normalized value of ω_J^I $\left(\omega_j^i \in [0,1]\right)$ defined by Equation. 1:

$$M(\omega_J^I) = \frac{P(\gamma_J^I)}{\max\{ R(\gamma_J^i) \mid \forall \in Wj \}} \qquad (1)$$

The H_J^I is the Boltzmann constant of vehicle *j* for temperature *T*, according to equation 2:

$$H_j^i = \sum_{i \in R_j} e^{-(U(\omega_j^i)/T)} \qquad (2)$$

P_J^I is the probability of choosing path *i* of vehicle *j* with the parameter of temperature T,

$$P_T^j(\gamma_j^i) = \frac{1}{K_N^j} e^{-(U(\omega_j^i)/T)} \quad (3)$$

where: $T \longrightarrow \infty$ all candidate paths have the same probability of being chosen, i.e., the process approaches a uniform random distribution. When T ! 0, the path with less weight has a high probability of being chosen.

$F(R_j)$ is the path chosen ($F(R_j \in R_j)$, the choice is made according to equation 4:

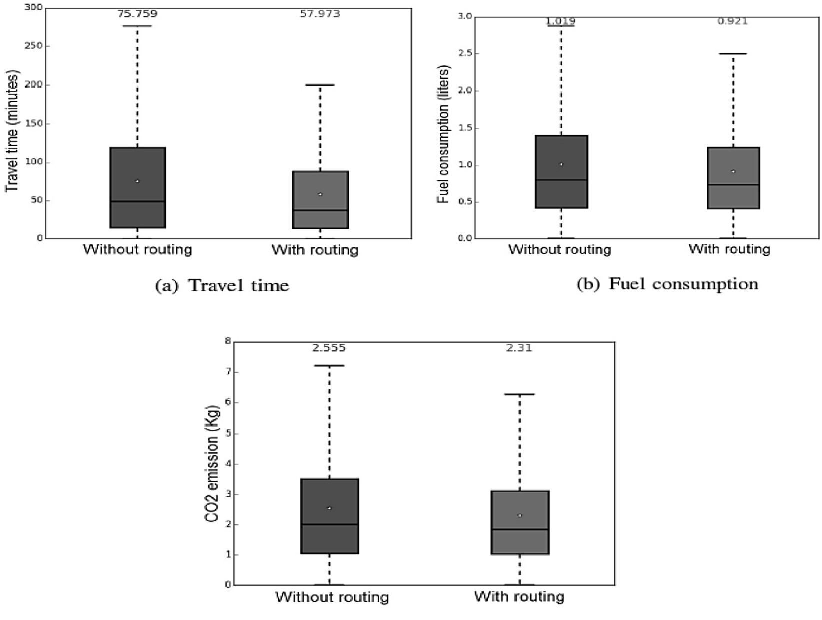
$$(F(R_j) = \max\{X \times Q_j^i(\gamma_j^i) \mid \forall \gamma_j^i \in R_{j,} X \approx \cup([0,1])\} \quad (4)$$

After chosing the path, it is checked whether the last segment of the path the vehicle V is in range of the roadside controller is its ultimate destination (line 9). If it is not like thet, then this is the last segment of the path in the area of that RSU (line 10). The remaining stretches of road are added to the new Vehicle (lines 11–12). However, if the last segment of the path the vehicle V in the range of the RSU is the ultimate destination, then it is the end of the route (line 15).

Results

This section presents the results of using the proposed system compared to the traditional approach where TC is not automated and does not interact with RSU, but the system does not have an alternate routing. In Fig. 1 shows the results obtained by the system. As can be seen from the figure, the proposed system reduces the effects, caused by congestion (increased travel time, fuel consumption and emissions O_2). Figure 1 (a) shows that the proposed system reduces the travel time by 23% in comparison with the traditional approach. This confirms the efficiency of the algorithm of alternative routing. Figure 1(b) shows that the proposed system reduces fuel consumption by 9% compared to the traditional approach. This reduction is due to the fact that the proposed system detects and eliminates congestion by using alternative paths to avoid congested areas. The proposed mechanism for congestion control that contributes to more effective and continuous movement that leads to a reduction in fuel consumption. In addition, it reduces braking and acceleration, which also contributes to increased fuel consumption.

Consuming less fuel, less O_2 is emitted, as we can observe in figure 1 (C). The proposed system introduces a reduction of up to approximately 10% in emissions compared to the traditional approach.



(a) Travel time

(b) Fuel consumption

(c) CO2 emission

Fig. 1. The results of modelling

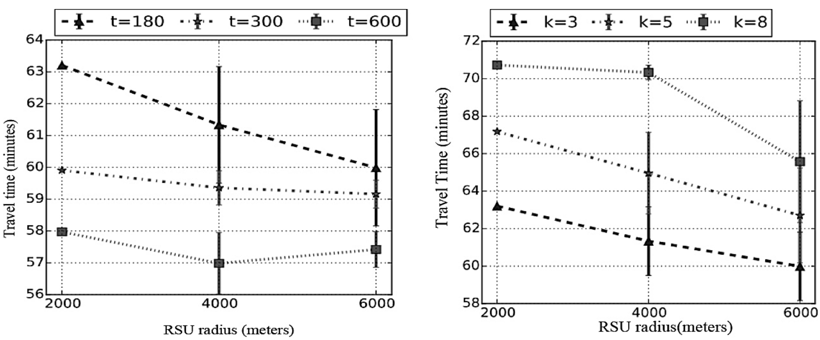


Fig. 2. Diagram of the results of travel time with the change of radius of communication RSU

Figure 2 shows the average travel time when changing the radius of communication in RSU (2, 4 and 6 km), the path to the shortest (3, 5 and 8) and the frequency of re-routing (180, 360 and 600 seconds). Figure 2 (a) shows the results of the K shortest paths with a fixed frequency of re-route in 180 seconds and varying the communication range of RSU from 2; 4 and 6 km. As we can observe, the higher communication range of RSUs, the larger the reduction in travel time. This is because RSUs have a greater knowledge of the area of the map and the calculated path is better from the standpoint of the time when calculated for a smaller area of the map. In addition, we can observe that the number of K shortest paths has an impact on the results obtained using the proposed system. For varying K, we can note that K = 3 has better performance compared to other values for K, thus , the result will be reduced to 9% against k = 8 and the reduction to 4% to = 5. Figure 2 (b) shows the results with frequency of re-routing 180; 360 and 600 seconds, and K shortest paths recorded in 3 (higher performance shown in the comparison figure 2 (a)) and the different range of communication from RSUs 2; 4 and 6 km. As we can observe, the frequency of re-routing has a positive effect on reducing the average travel time in the proposed system. The results show that the more the frequency of re-routing, the greater the reduction in the average time of passage for the proposed system. Figure 3 shows the fuel consumption of the proposed system by changing the communication range of RSU in (2, 4 and 6 km), K shortest paths (3, 5 and 8), and the frequency of re-routing (180; 360 and 600 seconds). Figure 3 (a) shows the results of the K shortest paths (3; 5 and 8) with the frequency of re-route fixed in 180 seconds and varying the communication range of RSUs from 2, 4 and 6 km. As we can observe, the higher communication range of the RSU, the greater the reduction in fuel consumption. This is because the RSU have a greater knowledge of the area maps and design way better when calculated for the smaller area of the map. In addition, it is possible to notice that the value of K shortest paths has an impact on the results obtained using the proposed system. The results show the difference in the amount of up to 7% for the evaluated configurations.

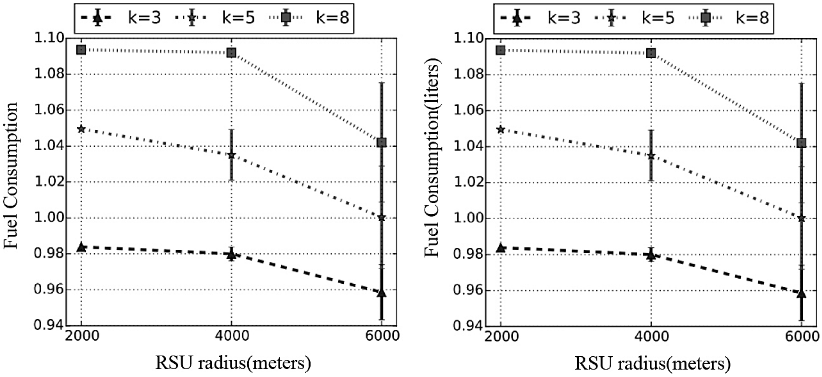


Fig. 3. Diagram of the results of fuel consumption

Consuming less fuel, the vehicle produces less emissions, which is shown in figure 3. The proposed system provides a reduction of approximately 10% of emissions compared to the traditional approach. Figure 3 (b) shows the results with frequency of rerouting 180, 360 and 600 seconds in the presence of K shortest paths (figure 3 (a)) and the different range of communication from RSU 2, 4 and 6 km (figure 3(b)). As we can observe, the range of re-routing positively contributes to reducing fuel consumption in the proposed system. The results show a difference of up to 4% in relation to the intervals of re-routing from 180 to 600 seconds. The results are presented in figures 2, 3 and 4 show that the higher the communication range of RSUs, the larger the reduction in travel time, fuel consumption and O_2 emissions. The obtained results allow to conclude that the smaller the number K shortest paths, the smaller the effect caused by congestion management.We note that large values of K also directly affect travel time, fuel consumption and O_2 emissions. Another important factor is the frequency of re-routing: the longer the interval, the more reduced travel time, fuel consumption and O_2 emissions. In this case, the vehicle does not need to make unnecessary changes of the path, thereby causing unnecessary braking and acceleration, because of high frequency of re-routing contributes to a more efficient and continuous movement, as you can see in figures 2 (b), 3 (b) and 4 (b).

The results obtained using the proposed system for O_2 emissions presented in figure 4, when changing the communication range of RSU (2,4 and 6 km), in the presence of K shortest routes (3,5 and 8) and the frequency of re-routing (180,360 and 600 seconds). Emissions associated with fuel consumption are shown in figures 4 (a) and 4 (b) are the result of fuel consumption. Emissions associated with fuel consumption are shown in figures 4 (a) and 4 (b) are the result of fuel consumption, graphs of which are depicted in figures 3 (a) and 3 (b). The results are presented in figures 2, 3 and 4 show that the higher the communication range of RSUs, the larger the reduction in travel time, fuel consumption and O_2 emissions.

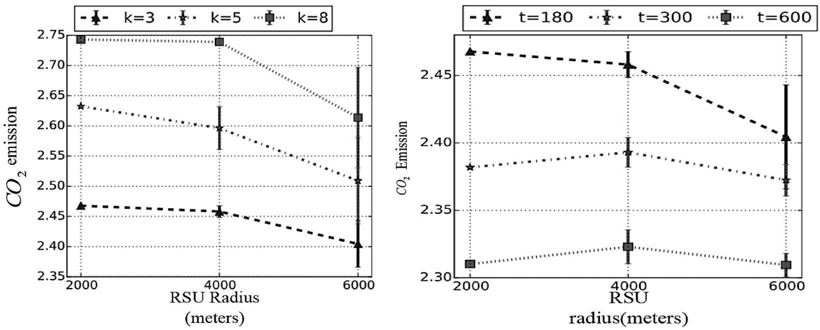


Fig. 4. Diagram of the results of O_2 emission

Conclusion

In this work, the algorithms for traffic management in intelligent transportation system for use in metropolitan areas. The proposed algorithms allow to reduce travel time, fuel consumption and emissions. The results show that the proposed system can significantly reduce average travel time, fuel consumption and emissions .

This work is aimed at implementing a distributed intelligent transport system for detection and control of overloads. For this purpose , RSUs are distributed throughout the city to provide full coverage of the region. In addition, each RSU is responsible for managing congestion only in the area covered by its range. Thus, the vehicle can interact with a number of shares of the way to reducing the harmful impact of an overload, such as increased travel time, fuel consumption and O_2 emissions.

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ANALYTICAL AND SIMULATION PLANNING MODEL OF URBAN PASSENGER TRANSPORT

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The article described the structure of the analytical and simulation models to make informed decisions in the planning of urban passenger transport. Designed UML diagram that describes the relationship of classes of the proposed model. A description of the main agents of the model developed in the simulation AnyLogic. Designed user interface integration with GIS map. Also provides simulation results that allow concluding about her health and the possibility of its use in solving planning problems of urban passenger transport.

Keywords: *simulation; traffic simulation; AnyLogic; urban public transport; passenger transportation; transport route; transport system.*

1. Introduction

Now there is the problem of the movement of land transport in megacities. It appears, because there are different factors: different rate of passenger arrival, non-uniform loading of transport. [1]. Important tasks are to determine the number of units of rolling stock for passenger service and analyze the quality of passenger service [2].

To solve these problems, to effectively use tool of analytical and simulation modeling. In the general case, simulation can solve many problems: analyze and predict different situations, to adjust characteristics. Any simulation model can make a variety of experiments, even if it is impossible to realize them in reality [3, 12, 13].

The actuality is that that before the project implementation, analytical and simulation modeling makes it easier to make decisions in the planning and management of urban passenger transport [16].

2. The description of the objects for designing models

In the task of planning urban passenger transport, there are the following objects: passengers, public transport, bus stops, transport fleet [14]. These objects have the following parameters: the estimated rate of arrival passengers, the number of transport, seating capacity, the interval of departure of transport. The result of solving the problem of planning of urban passenger transport by land, defines the routes and the headways of vehicles. We also consider the beginning and end time of traffic on a specified route, the actual number of available transport mean in the fleet. In addition, we consider the duration of the transport, which returned to the transport fleet after the working shift.

There is a sequence of bus stops for a specific route. The route has two directions: forward and reverse. The transport mean leaves from the fleet at regular intervals of time. It makes boarding and alighting of passengers at each bus stop. The rate of arrival passengers at bus stop depends on the time of day. All passengers out of the transport at bus stop before it moves to the fleet. Then transport mean going to the fleet without passenger.

3. UML diagram project

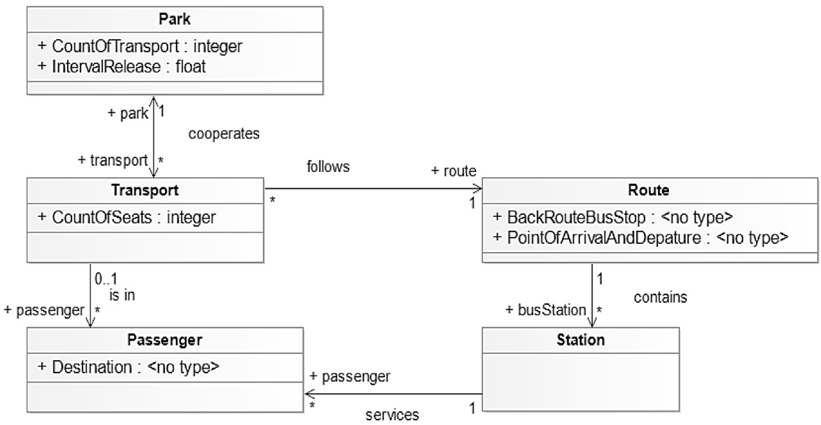

Fig. 1. UML Diagram

We should to represent each object in a visual form. The most convenient and illustrative tool is view class diagrams (UML diagrams) [4–6].

In the following, a description of the function of each class show in Table 1.

Table 1.

Class description

Class name	Summary
Park	It simulates transport departure from the fleet and his arrival to him. Interval departure means the period of time, when transport leaves the park and begins work.
Transport	It is moving on the specified route. Transport serves passengers at bus stops: boarding and alighting.
Route	There is a sequence of stopping points
Passenger	It simulates awaiting the arrival of transport, boarding and alighting from it.
Station	It is mean bus stop. Tfhis is the arrival of passengers, arrival and departure of transport.

Figure 1 shows the class diagram. There is a connection between classes.

4. Implementation Analytical and Simulation Model

We use the software AnyLogic 7 to implement this task. AnyLogic is Multimethod Simulation Software, which supports many ways to create simulation models [7–8]:

- Discrete Event Simulation Modeling
- System Dynamic Simulation
- Agent Based Modeling.

This tool allows combining different methods.

In our case, we consider two methods to simulation: Agent Based Modeling and Discrete Event Simulation Modeling.

This model consists of different types of agents. We list them:

1. Park.
2. Passenger.

3. Station. (It is mean bus stop).
4. Transport.

Each type of agent to do various functions. In addition to this model is the main module, which performs the simulation.

The **Figure 2** shows the types of agents, implemented in the AnyLogic.

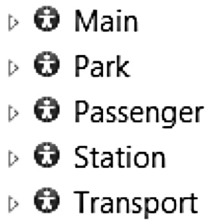

Fig. 2. Implemented agents

This article describes the types of agents that have peculiar properties for implementation [9–10].

4.1. Agent "Park"

The **Figure 3** shows the elements that simulate the following processes: seize of resource and departure from the fleet, arrival to the fleet and release of resource. In this case, the resource is a transport.

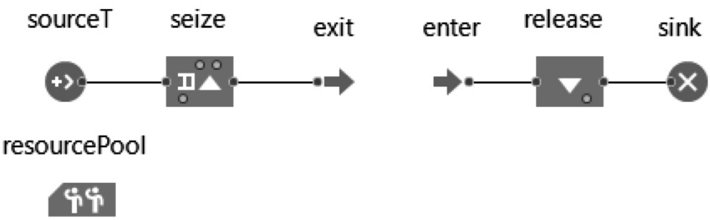

Fig. 3. Elements for modeling work in the fleet

4.2. Agent "Station"

This type agent allows simulating bus stop. It can simulate the arrival of passengers to the waiting place. In addition, bus stop allows simulating the arrival of transport, the boarding and alighting of passengers.

There are also elements that simulate the various processes: arrival waiting passengers to the point, the arrival transport to the point, the boarding and alighting of passengers, departure passengers from point, the output of the transport from the point.

The **Figure 4** shows the diagram elements.

4.3. Agent "Transport"

This type of agent simulates the traffic. He departures from the fleet and arrives to him, arrives at a bus stop and departure from it, makes boarding and alighting of passengers [17–19].

To simulate a composite process [20], we have developed the state diagram. The **Figure 5** shows the state diagram.

The left is a diagram of the states of the operating mode of transport. The initial state is "work". It is a normal operating mode. When the working time comes to end, it goes into the state "goingToPark". This condition means that the transport should be follow to the park at the end of work.

On the right is a diagram of transport operation states. First, there are preparatory stages. After that, the cycle of actions begins. They are movements (go) and stops (stop). The cycle will continue until the transport will not follow the park (goToPark) after the stop.

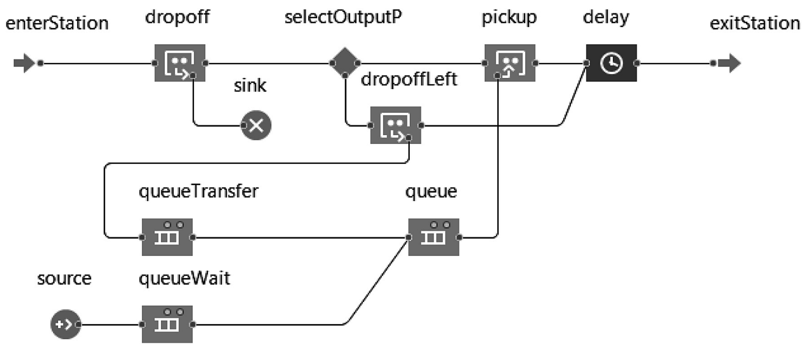

Fig. 4. Diagram elements for simulation of processes at bus stops

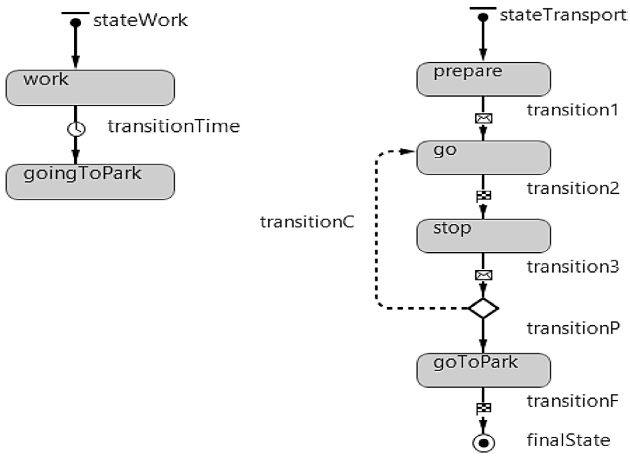

Fig. 5. State charts

4.4. The implementation of the main model module

The main module of the analytical-simulation model includes a set of objects. The main element that plays a big role is the GIS map. The **Figure 6** shows an example of a GIS map. Many objects are associated with it: more information is available with its help. The main module performs general analytical and simulation modeling. With the GIS-map [15], we can observe visual animation modeling – the operation process of transport, the location of the bus stop and the fleet.

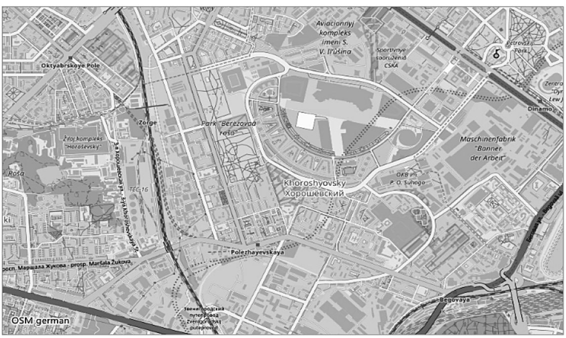

Fig. 6. GIS-map

5. Developing a user interface model

After the development of the entire model, a user interface has been designed (**Figure 7**). Interface type is “Experiment”. The initial data are the route, the rate of arrival of passengers, the coordinates of the fleet and the coordinates of the bus stops of the route, the number of transport means in the park, the working time, passenger capacity and the interval of departure from the park [11].

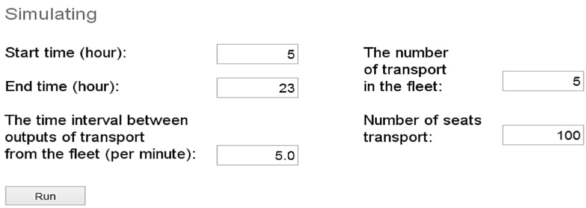

Fig. 7. Interface “Experiment”

The **Figure 8** shows the results of visualizing the route on the GIS map. It shows the traffic along the specified route and various buses stop.

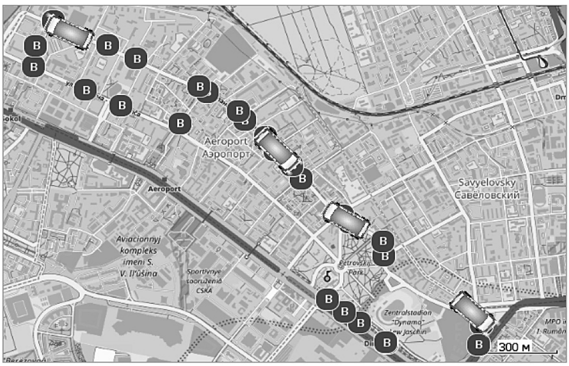

Fig. 8. Visualization of the route on the GIS-map

6. Simulation results

The developed model can to get various results. The **Figure 9** shows the column diagrams of the number of waiting passengers at the buses stop at time.

The **Figure 10** shows the time plot of waiting passengers at the bus stop.

The **Figure 11** shows the time plot of the number of filled seats in the transport mean.

Based on the analysis of the graphs presented in **Figures 10–11**, it can be assumed that for this route system is not overloaded, the traffic flow copes.

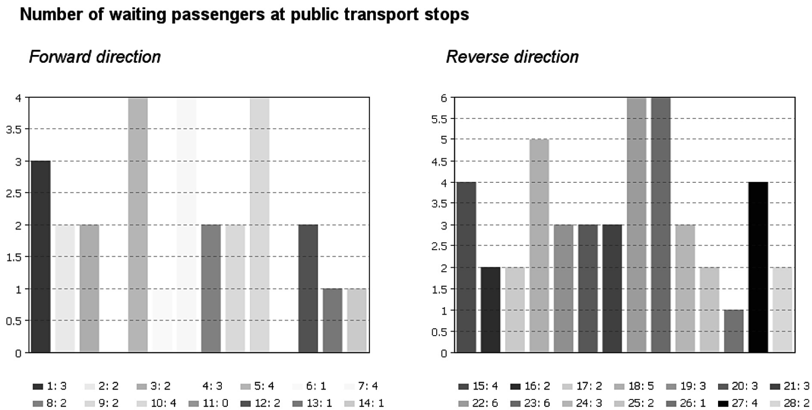

Fig. 9. The column diagrams

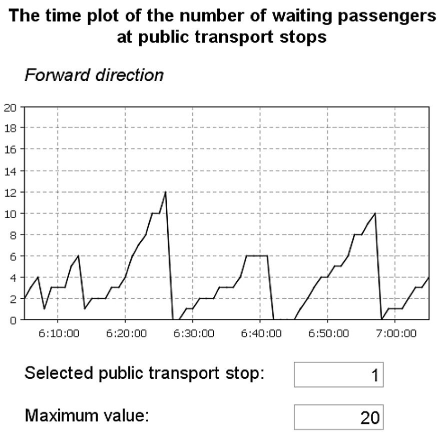

Fig. 10. Time plot of waiting passengers at the bus stop

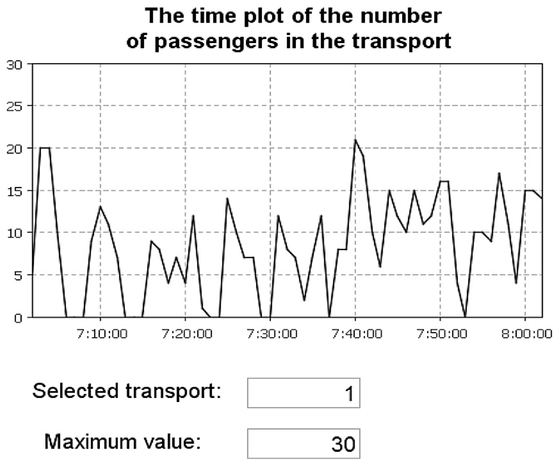

Fig. 11. The time plot of the number of filled seats in the transport mean

We selectively analyze the detailed result of the simulation, i.e. during the whole simulation.

The **Figure 12** is a simulated plot of the number of passengers in the transport during the whole simulation. Model time is given in hours.

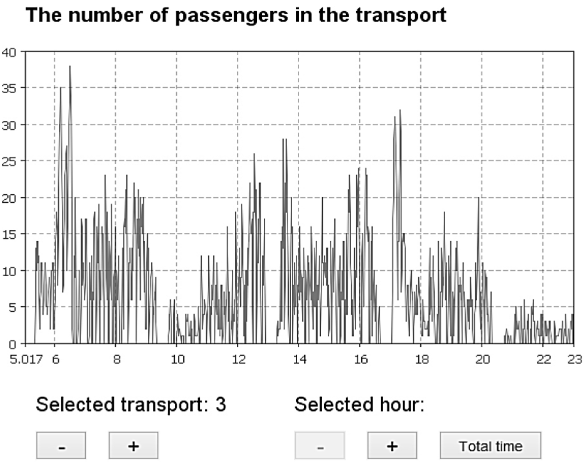

Fig. 12. Simulated plot of the number of passengers in the transport

Based on the **figure 12**, we can assume that the capacity of the transport is sufficient. The transport system copes even in peak loads.

For the analysis of the average rate arrival of passengers **Figures 13–14** show plots of waiting passengers at the buses stop. One of them in two directions is randomly selected.

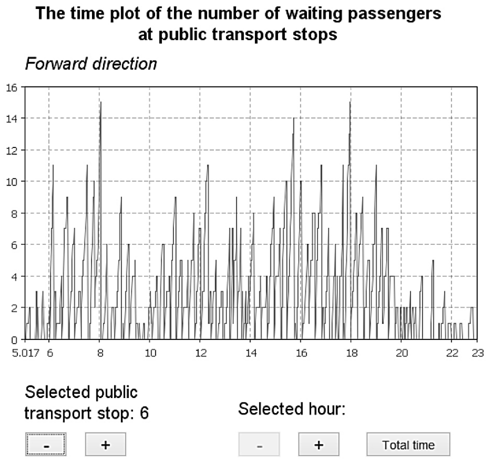

Fig. 13. Simulated plot of waiting passengers at the bus stop (forward direction)

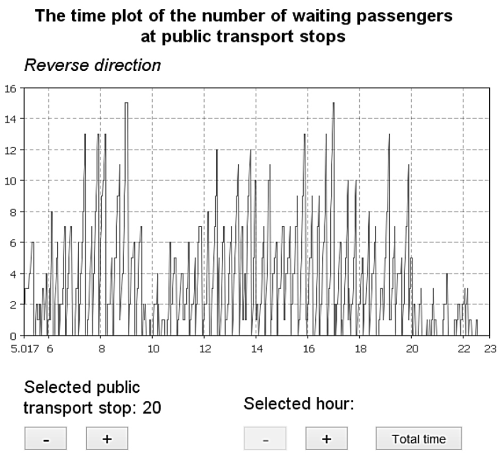

Fig. 14. Simulated plot of waiting passengers at the bus stop (reverse direction)

Based on the result, it can be concluded that the transport has time to discuss passengers. The time interval in this case is acceptable.

The **Figure 15** summarizes the results of simulated plots. It shows the average simulation result for the whole work.

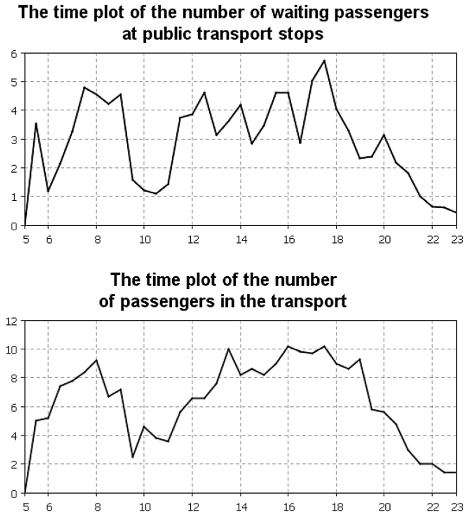

Fig. 15. General simulated plots

The simulation results for this route is seen that the plots are highly correlated with each other.

5. Conclusions

The article proposed and studied a model of surface passenger transport. It can be applied in research organisations, dealing with transport problems. Because of design, it is possible to solve some problems of traffic flow. Application AnyLogic 7 provides simulation modelling with GIS maps and get the necessary results.

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