Telematic Transport System Model

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Abstract

The present model contains vehicles traffic simulation at specified highway sector equipped with telematic infrastructure. In section 2, inside the transport system two subsystems are specified: the subsystem of transport processes as highway vehicles traffic and the subsystem of telematic tools affecting on transport processes. In section 3 there is presented modelling in Simulink module by library elements. Inside state diagrams, earlier defined objects represent model elements: highway sectors, vehicles, telematic tools. Inside section 4, the simulation of vehicle traffic in model is described as well as telematic tools interaction with these vehicles traffic. The effect of present work is the base to real time modeling methodology addressed to multimodal transport systems, especially railway transport usage.

Keywords: transport, modelling, telematic

1. Introduction

The paper is a result of model analysis within the confines of work [19] in research team, and then other papers of team emerge. At definition of telematic tools fix-up about sources of work [19], however, inspiration for processed foundation of model operations was method [15] of telematic functions representation in models of transport systems. This method gives the model parameterized as:

$T = < TST, RT >$, where:

$TST = < G, K >$ and $RT \subseteq K \times M$

TST is the telematic tools network

RT is the telematic relation based on cartesian product "x"

G is the graf of network structure on the package of knots and arches

K is the package of telematic means

M is the package of telematic methods

This model of road traffic under automatized control, simply explained later in chapter 4: "Model simulation", may be the contribution to the theory and reality of the anticipatory systems. Drawings of representative traffic conditions base on help system of Matlab – Simulink tool.

Problems presented in paper were analyzed in earliest publications many times. In work [5], it analyzes tasks of monitoring systems of cities in wide systems of safeties. In work [9], it presents specificity of advanced telematic applications in chosen European metropolises. Position [8] says about methods of vehicles traffic modeling and it serves exemplary results of new models - deterministic and stochastic. It research in elaboration [7] capacity of collective communication network elements. For characteristic and representative element of communication network accept intermodal section closed bilaterally with illuminating signaling apparatus crossroads. Maximum capacity analyze, possible to obtainment at optimal match of parameter characterizing vehicle traffic. It defines variability range of traffic parameter through local measurements and influence of this variability on capacity behind assistance of research on models. Two models of traffic were designed in analyzed element of network: deterministic and stochastic. Other authors solved similar problems. In work [1], it constructs and accustoms the model of vehicle traffic simulator for requirements of advanced telematic applications of road transport. In position [2], it processes the real time control system model based on Unified Modeling Language notation. Position [6] says about modeling concepts of telematic tools influences on road traffic. In work [16], it makes application of intelligent transport model. In elaboration [17], it employs modern communication means for advanced telematic application.

Fact deserves underlining that suggested solution has certain features, which existing elaborations do not contain. During conference discussion [10] it emphasize capabilities of utilization the Unified Modeling Language notation in Matlab Simulink tool for design the simulation telematic models of transport process. Idea of elaboration and used techniques result from many years experiences gotten during works [11], [12], [14] over modeling in real time and from employment of personal concepts [13] of person - computer cooperation system modeling. Knowledge in elaboration is partly based on positions [4] and [18] and it was dried from experiences in work [3] gotten at Unified Modeling Language designing.

The model already runs and it is going to involve in near future. The model is going to be applied in several transportation cases. Now the model is being prepared to the intelligent telematic highway system.

2. Model definition

Model concerns the vehicle traffic simulation on specified highway section furnished with telematic infrastructure. Model consists of two parts – subsystem of vehicle traffic and telematic tools subsystem. Objects defined in model are sections of highways divided on strips of traffic with vehicles in vehicle traffic subsystem and telematic tools in second subsystem. Individual telematic tools like navigation, detection of movement, detection of presence, supplying, weather, road conditions, traffic signs, road tables, broadcasting information, alarm, radio stations, monitoring - define on vehicle traffic to manner in farthest detailed definitions. Model of highway section is presented on Figure 2 in the form of class diagram. Model takes a stand here with names, attributes, and methods of classes in the form served on Figure 1.

class
attributes
methods

Fig. 1. Form of objects classes presentation in class diagram.

Each described class owns attributes as its unique feature or as identifiers. Common identifiers for different classes represent associated connections among classes of objects. Lines of junction classes present associations. Lack of symbol means numerical force „one" at association, however, symbol „*" means numerical force „ many" at association, it signifies be integer from package <0, N>, where N means admissible number of object of given class in model (like vehicles or telematic tools). Individual telematic tools are jointed through association with objects of vehicle traffic subsystem and they interact with them through transmitting and getting back of signals.

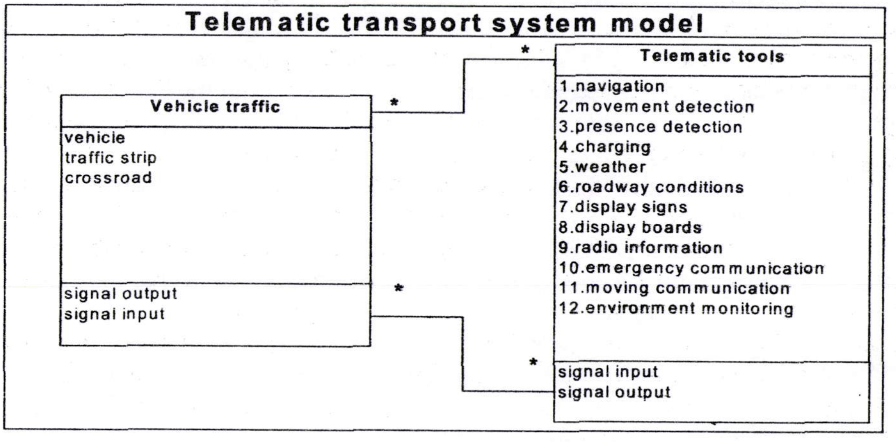

Fig. 2. Telematic transport system model as class diagram.

2.1. Vehicles traffic definition in model

Presented model of highway section has to grant following tasks:

- Foundation for modelling:
  - Vehicles move monotonous movement
  - Choice of vehicle speed is with limitation 40 for 100 units
  - Each vehicle is autonomous
  - Vehicle traffic proceeds on two strips in each direction of movement
  - Vehicle can change strip of movement, if second strip is available
  - Vehicle can outstrip other vehicles, if it ride faster, or dismiss
  - Outstripping can be after right strip of movement
- Characteristic of vehicle:
  - *Vehicle receives following data input:*
    - *From environment of simulation (fate generator):*
      - Speed
      - Strip of movement
    - *From decision element:*
      - Signal of necessity of vehicle speed reduction (at lack of capability to outstripping)

- Value of speed after reduction = value of previous vehicle speed (when vehicle does not have capability to outstrip)
- Signal of traffic strip change necessity
- Value of speed after limitation as result of telematic objects functioning

➢ *Vehicle output data:*

- Value of vehicle speed
- Distance from initial point of simulation process
- Current number of traffic strip, which vehicle moves after
- Value of vehicle speed after limitation as result of telematic objects functioning

❖ Decision element

- *Inputs:*
  - ◆ Information from vehicle about current traffic strip
  - ◆ Distance of vehicle from start of simulation process
  - ◆ Current speed of enclosed vehicles, i.e. previous vehicle, closest vehicle beside reference vehicle and closest vehicle beside previous vehicle
- Vehicles of enclosing are identified on base:
  - ◆ Distance of vehicles from start of simulation process
  - ◆ Information of current traffic strip
- *Outputs* (Outputs go out only to vehicle steered by decision element)*:*
  - ◆ Keeping or change of traffic strip
  - ◆ Keeping or change of speed

Figure 3 presents drawing with four vehicles in one direction after two strips of highway.

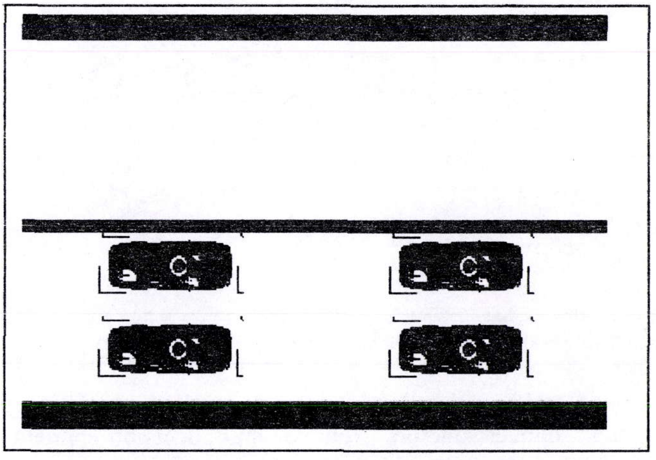

Fig. 3. Vehicles position on the start of model simulation.

Four values of vehicles sites are in treated highway section:

S -distance among reference vehicle P_x but start of highway section

S_1 -distance among vehicle P_1 as previous for P_x but start of highway section

S_2 -distance among vehicle P_2 as previous for P_3 (P_3 is closest vehicle beside P_x) but start of highway section

S_3 -distance among vehicle P_3 (P_3 is closest vehicle beside P_x) but start of highway section

There are four variables, of which binary values define behavior of vehicle on the road:

- $|S - S_1| \geq 65 \quad \in \{0,1\}$
- $|S - S_2| \geq 65 \quad \in \{0,1\}$
- $|S - S_3| \geq 65 \quad \in \{0,1\}$

  (variable accept: value 0, if condition has not been granted
  value 1, if condition has been granted)
- $P \in \{0,1\}$

  (variable accept: value 0, if vehicle P_x rides after left traffic strip
  value 1, if vehicle P_x rides after right traffic strip)

2.1.1. Use case diagrams

The criteria presented in use case diagrams, has to grant the model of highway section and criteria of vehicles traffic – including, outstripping, stopping, tasks in the form of actors and use cases cooperation. Actors in diagram on Figure 4 are objects of traffic subsystem as well as connections with telematic tools subsystem.

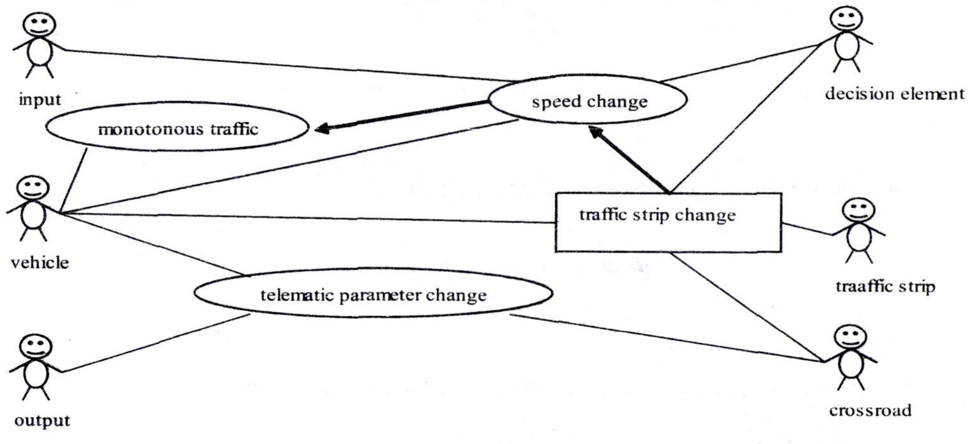

Fig. 4. Exemplary use cases of vehicles on highway section in *use case* diagram.

Communication proceeds among traffic strips through use case called „traffic strip change". Use case „ change speed " concerns actors „vehicle" and „decision element" and expands other use case called „monotonous traffic". Use case „telematic parameter change" exists in vehicle traffic subsystem too as element interacting with telematic tools, for example road table before crossroad with other way.

Theme *Case Studies* has been taken advantage in use case construction from help system of Matlab-Simulink tool.

2.1.2. Class diagrams

Diagrams of class concern individual models objects like: traffic strips, crossroads, vehicles, as well as coherence between objects inside vehicle traffic class as well as with telematic tools class objects.

The following theme from Matlab-Simulink tool has been taken advantage in construction of class:

-The Class Constructor Method
- Class Diagrams for the Link for Code Composer Studio
- Some Object-Oriented Programming Terms
- About the Relationships Between Objects
- Designing User Classes in MATLAB
- Function Objects--Their Methods and Properties
- Classes and Objects: An Overview

Class diagram "Vehicles traffic" is presented on Figure 5.

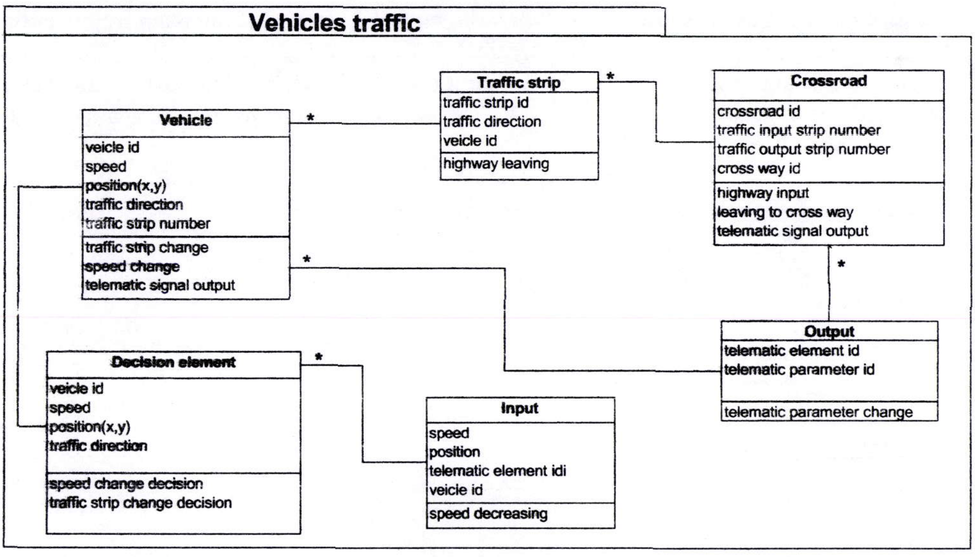

Fig. 5. Vehicles traffic presented as class diagram.

There are the following elements in each class description:

Name and short class description

Identifier of class: main attribute of class

Identifiers of associated classes: class attributes jointed by associations

Other attributes inside the class: the rest of class attributes

Methods of the class: elements of class dynamics

There are detailed classes of objects in vehicle traffic subsystem: vehicle, decision element, traffic strip, crossroad, input, and output. This is *vehicle* class description:

Vehicle is the vehicle driving on the highway.

Identifier of class:

Vehicle id: Vehicle identity number

Identifiers of associated classes:

Velocity: The present velocity of vehicle

Position(x,y): Distance of vehicle from start of simulation process

Traffic direction: Direction of vehicle movement

Traffic strip number: Variable y of vehicle position

Services of the class:

Traffic strip change: Traffic strip change – change variable y of vehicle position

Speed change: Vehicle speed increasing or decreasing

Telematic signal output: Vehicle traffic information output

The vehicle class description can be compared with classes presented on Fig.5.

2.1.3. Sequence diagrams

Diagrams of sequences are given as two dimensions: vertical dimension representing time and horizontal dimension representing different objects. Exemplary diagram of sequence on Figure 6 presents traffic condition, in which vehicle dismisses before approach for crossroad , and it turns back next and accelerate (for simplification traffic strip represents all strips on highway).

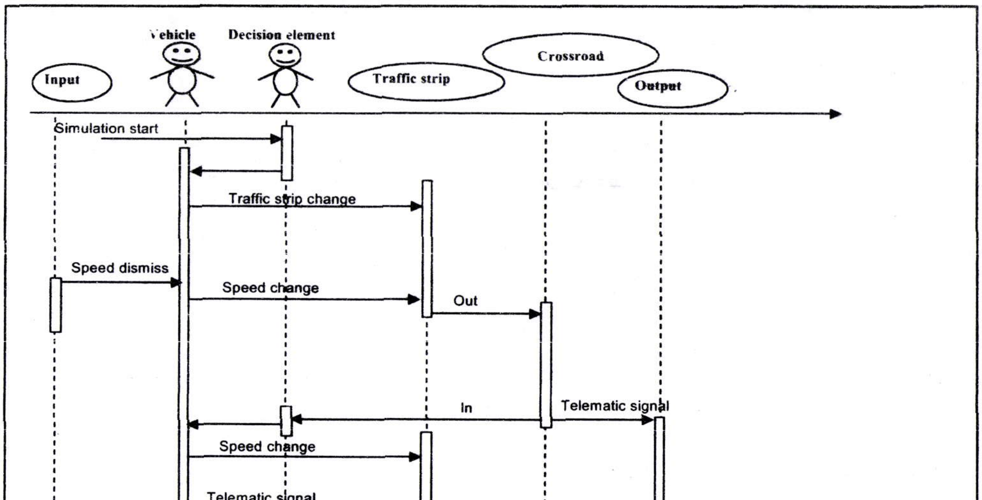

Fig. 6. Exemplary traffic condition as diagram of sequence

2.1.4. Diagram of activity

Diagram of activity (action) is focused on logic description of vehicle traffic process, in which objects of vehicle traffic subsystem participate as well as objects of telematic tools subsystem. Diagram of activity is very good instrument, when we want to present concrete cooperation of objects within the transport process. Each vehicle on way can speed up, dismiss, or change traffic strip.

Diagram of activity describes action driver executes in time of relocation on highway section. Driver comes on modeled highway section and achieves driver speed, it ride next monotonous movement till it meet highway leaving point or some barriers on way, it executes proper actions for concrete variant, for example limitations of speed. Diagram is finished in indicated model point of highway or in leaving point from highway through crossroad approaching.

Example introduced on Figure 7 pictures algorithm of vehicle outstripping and simultaneous change of traffic strip on highway.

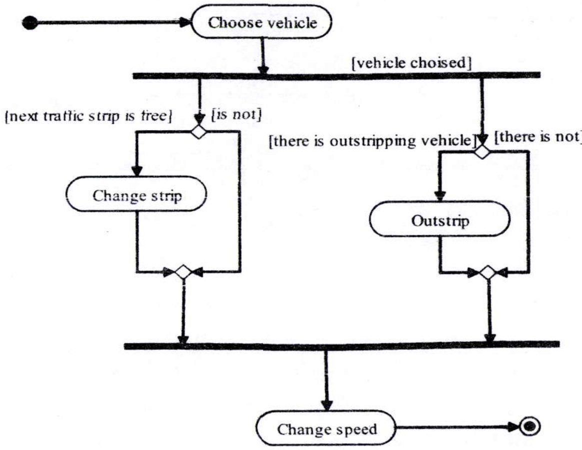

Fig. 7. Exemplary vehicles traffic algorithm as sequence diagram.

2.1.5. State diagrams

Scheme presents the states of object at vehicle class inside vehicle traffic subsystem during riding and meeting the other vehicle riding in the same direction on highway. The pass through states of stops and monotonous riding on the same strip is performed through indirect states of speeding up of movement still and dismissing.

For example, riding with incremental speed on data traffic strip will cause catching up the vehicle before vehicle riding, and change of traffic strip will be necessary in consequence, it means the change of state. States of vehicle are showed here in movement on highway in moment of meeting the second vehicle.

We have deal able here with two indirect states: speeding up and braking, due to which vehicle can proceed from state of stop to riding with constant speed and vice versa. Vehicle can change traffic strip in the course of monotonous movement riding.

When other vehicle rides on the same strip, it has to catch up it, change traffic strip of and outstrip.

Figure 8 presents states of objects of class *vehicle* inside vehicle traffic subsystem during movement after highway.

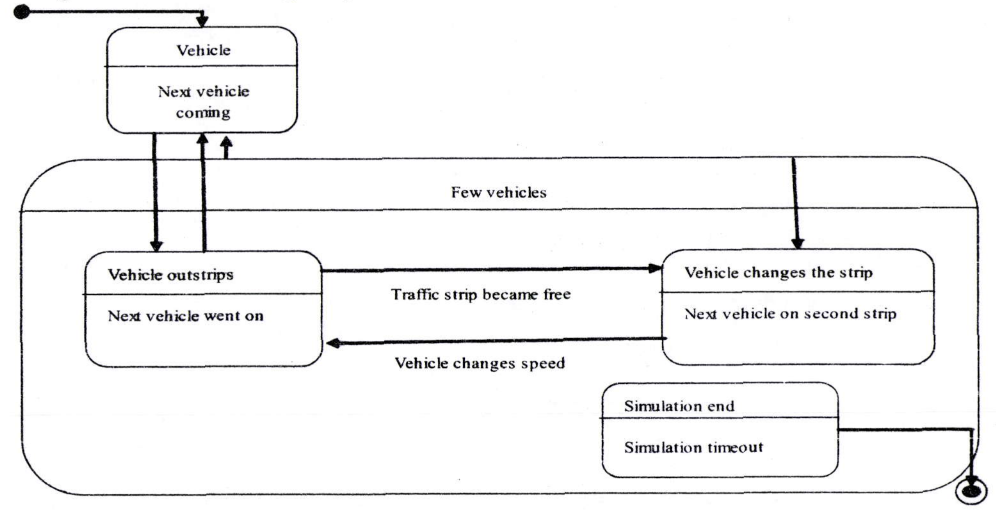

Fig. 8. Exemplary vehicles traffic state as state diagram.

2.2. Telematic tools definition

2.2.1. Use case diagrams

It present in diagrams of use cases criteria of vehicle traffic cooperation with telematic tools as: navigation, detection of movement (traffic), detection of presence, supplying, weather, road conditions, traffic signs, road tables, broadcasting information, alarm, radio stations, monitoring. It takes advantage *Case Studies* themes from Matlab-Simulink. They are presented on Figure 9 (in use case diagram) exemplary use cases on

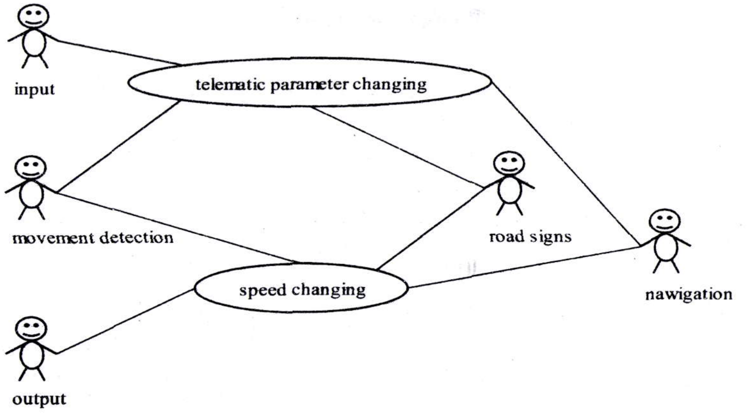

Fig. 9. Exemplary use cases of telematic tools on highway section in *use case* diagram.

highway section. Foundation is definition of telematic tools, tools interact the model, which simulate vehicle traffic riding among highway indicated points. For example, driver of car seeing table about traffic organization can change the traffic organization or remain on strip. He changes traffic strip to right and goes on the next road through crossroad, or he remains on strip and go on the next road through crossroad. Otherwise, he can change traffic strip to left and ride straight further, or he can remain on strip and ride straight further.

2.2.2. Class diagrams

Diagrams of classes in telematic tools subsystem concern individual objects of model like: navigation, detection of movement (traffic), detection of presence, supplying, weather, road conditions, traffic signs, road tables, broadcasting information, alarm, radio stations, monitoring, as well as coherence between objects inside of class of telematic tools and with objects of vehicles traffic class.

Vehicle can be informed or warned by telematic tools, for example, traffic signs, illuminating signs, tools informing of speed. Diagram of class is presented on Figure 10 "Telematic tools".

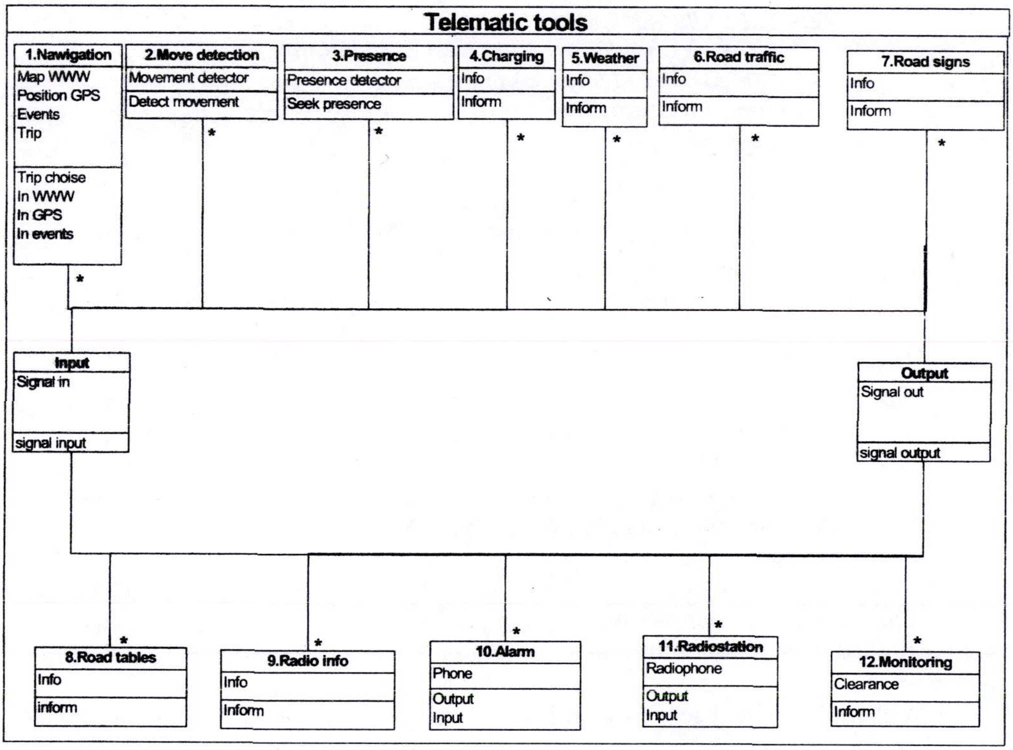

Fig. 10. Telematic tools presented as class diagram.

It takes advantage the following themes in diagrams of classes from Matlab-Simulink tool:

- ✓ The Class Constructor Method
- ✓ Class Diagrams for the Link for Code Composer Studio
- ✓ Some Object-Oriented Programming Terms
- ✓ About the Relationships Between Objects
- ✓ Designing User Classes in MATLAB
- ✓ Function Objects--Their Methods and Properties
- ✓ Classes and Objects: An Overview

It present positions of class *vehicles traffic* in each description of class just the same as in part 2.1.2. Classes of objects are detailed in telematic tools subsystem: navigation acts, detection of movement (traffic), detection of presence, supplying, weather, road conditions, traffic signs, road tables, broadcasting information, alarm, radio stations, monitoring. This is *navigation* class description:

Navigation is the telematic tool to vehicle intelligent road navigation
Identifier of class:
Trip: Sensor informing of vehicle trip choice
Identifiers of associated classes:
Map WWW: Activator taking map from Internet
Position GPS: Activator taking signal of GPS position
Events: Activator taking information of road events
Services of the class:
Trip choice: Vehicle trip choice
In WWW: Taking map from Internet
In GPS: Taking signal of GPS position
In events: Taking information of road events

The navigation class description can be compared with classes presented on Fig.10.

2.2.3. Diagrams of sequences

Traffic signs and illuminating tool are located on the highway and interact on vehicles traffic (decrease of vehicle speed at limitation of speed, change of traffic strip and other). In addition, information of weather affects vehicle behavior, mainly causing speed limitation. Vehicle can be informed or it is warned by telematic tools, for example, which can be traffic sign or illuminating tool.

Sequence diagram of telematic tools shows in detail how transport processes are executing influenced by operation of telematic objects - which message be sent and when. Time expires during moving to bottom of part. Objects involved to cooperation are mentioned from left part to right according to it, when they take part in sequence of messages.

Exemplary diagram of sequence on Figure 11 presents cooperation of telematic tools changing vehicle traffic.

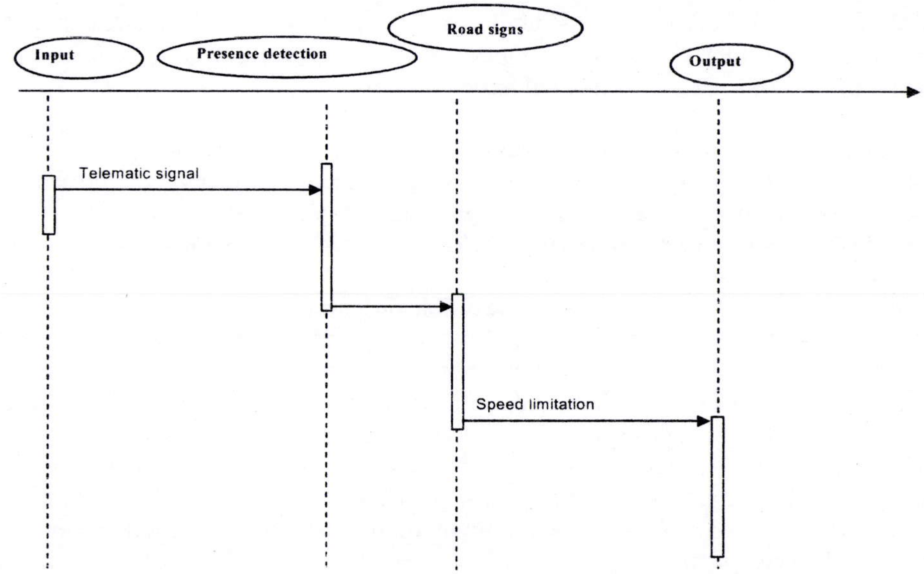

Fig. 11. Exemplary telematic tools activity shown as sequence diagram.

3. Model description as Simulink module

Record of Simulink model includes two subsystems in the form of unit - transport process subsystem and telematic tools subsystem - jointed through input-output signals, presented on Figure 12 .

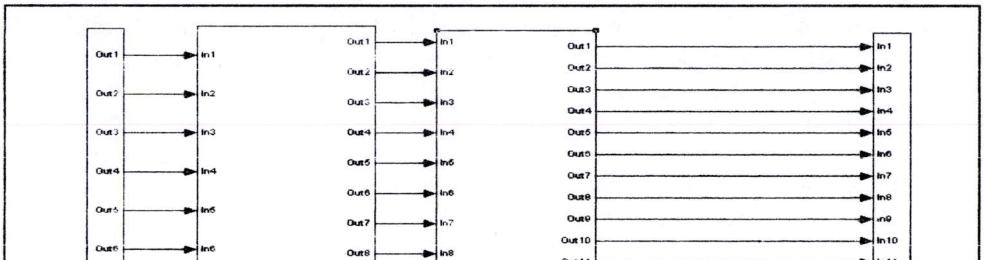

Fig. 12. Model main construction as Simulink module.

Vehicle traffic is based on construction of transport process subsystem and it includes units of vehicles and other objects of this subsystem, which perform the simulation of road traffic on the specified highway sector.

Telematic tools subsystem is the construction of units representing individual telematic tools like navigation, detection of movement, detection of presence, supplying, weather, road conditions, traffic signs, road tables, broadcasting information, alarm, radio stations, monitoring. All of telematic tools have optionally capability getting back signals from transport process, as well as interactions on vehicles traffic on highway. It has elastic modifying of construction on purpose during development of research over model as the most.

Library elements of Matlab, Simulink and virtual reality are employed in model construction, in *Library Browser* available. Simulink units allow elastic construction of individual unit in whole transport system and cooperation with telematic tools. Units of virtual reality VR implicate the simulation stages image created in VR editor, showing road situation from the outside observer point of view as well as leading vehicle observer of telematic tools.

Vehicles move in model according to criteria defined in point 2.1. in construction presented on Figure 13.

Model acts in Simulink system after start-up of animation in real time. Individual elements of model are represented by earlier defined objects: highway sections, vehicles, telematic tools. Objects of models are recorded in the form of state diagrams. Model recorded as Simulink module generates in real time the vehicle traffic and operation of telematic tools, at utilization of animation. Foundation of model operation is capability of vehicle introduction for traffic so, to observe capacity of highway section in time of vehicle traffic simulation.

Telematic tools interact on vehicle traffic according to criteria defined in point 2.2 in construction presented on Figure 14.

Diagrams of states (*State flow Diagram Objects)* present sequence of processes in model and represent in their construction individual telematic tools: navigation, detection of movement, detection of presence, supplying, weather, road conditions, traffic signs, road tables, broadcasting information, alarm, radio stations, monitoring.

In Simulink unit in part representing telematic tools, wide capability of model construction elastic development exists, based on optional connection all of tools with vehicle traffic.

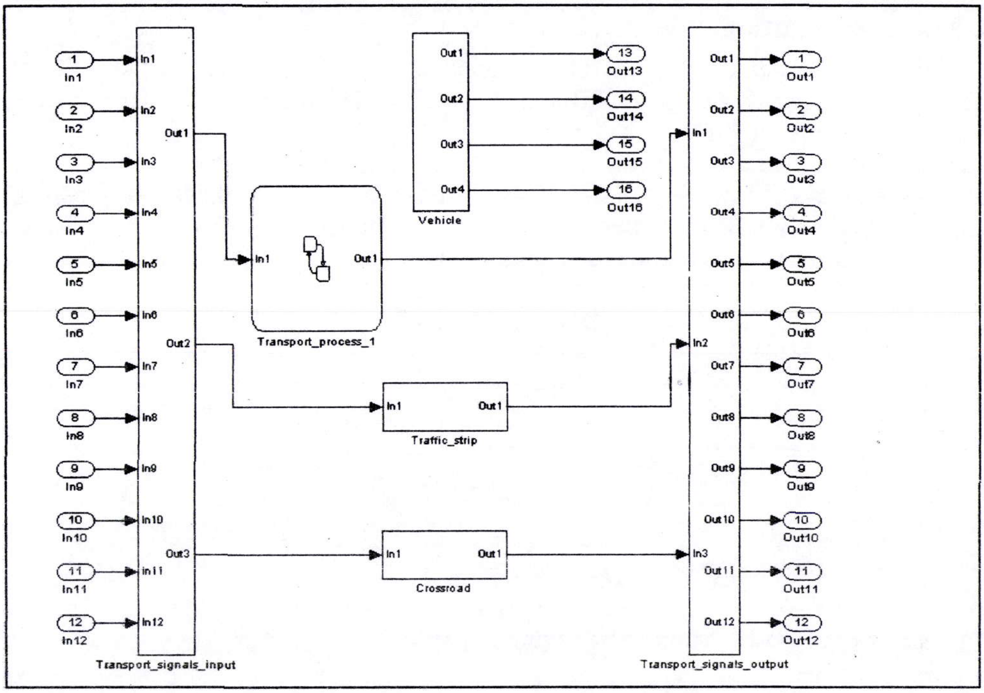

Fig. 13. Construction of vehicle traffic in model in the form of Simulink units.

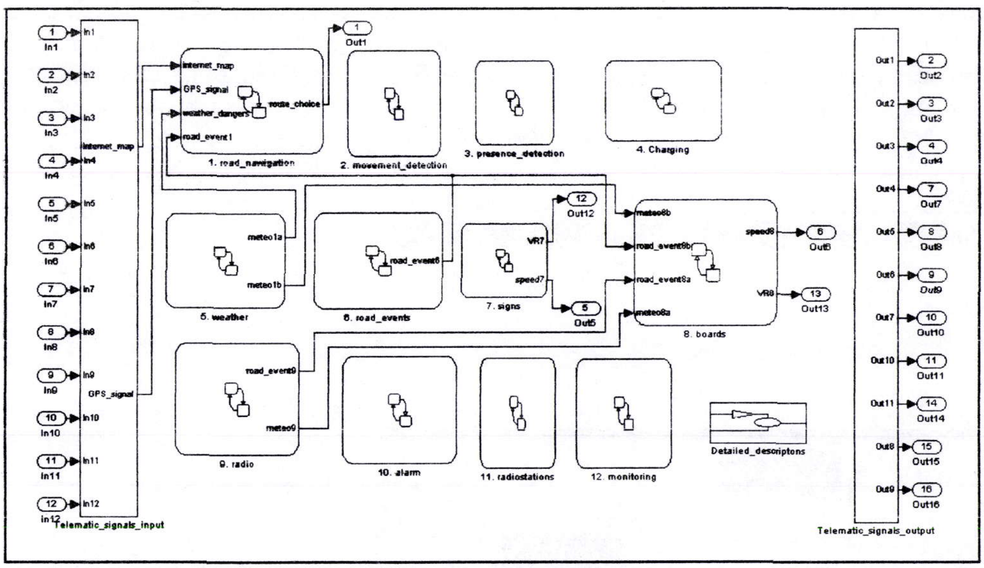

Fig. 14. Telematic tools construction as Simulink module.

4. Model simulation

Malingering scheme of model is presented on Figure 16. Faked section AC of highway is divided on two parts AB and BC with different groups of telematic tools interacting. Tools in group „ telematic tools 1" effect vehicle traffic as objects independent on traffic condition, for example, weather conditions or information of rally on other way, however, tools in group „ telematic tools 2" belong to group of objects related with traffic condition on highway section BC, for example, information of traffic condensing or limitation of visibility.

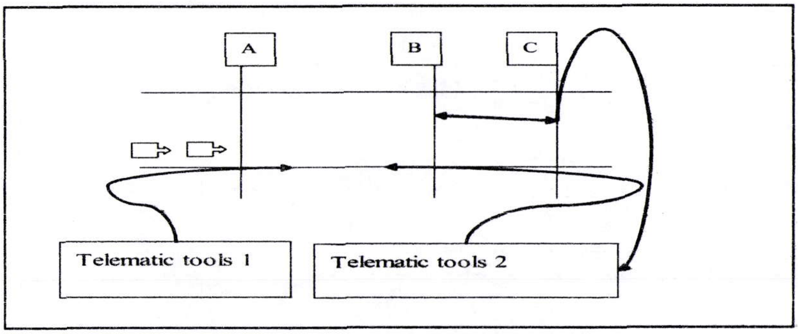

Fig.16. Figure of model simulation at highway part AC.

4.1. Vehicles traffic simulation

Vehicles in model move in view presented on Figure 17 after indicated highway section, for example, AB, react to operation of telematic tools. Then traffic condition on section BC effects the changes in operation of telematic tools. Project and simulation of virtual image of vehicles going on highway is realized in foothold about unit VR Sink (*Creating a Sphere in a Virtual World*), at utilization of virtual reality editor *vrbuild2.exe* in folder ***<matlab root>\toolbox\vr\vrealm\program\..***

Vehicles view on highway section from top on Figure 17 is stage in match XY.

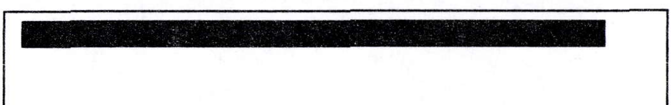

Fig. 17. Vehicles traffic virtual reality scene – up side view.

4.2. Telematic tools simulation

Image of stage enabling observation of telematic tools on the road is presented on Figure 18, for example, signs and road tables or telematic tools possibly finding inside of vehicle, for example, map of vehicle route.

Telematic tools like navigation, detection of traffic, detection of presence, supplying, weather, road conditions, traffic signs, road tables, broadcasting information, alarm, radio stations, monitoring, they are visible by road traffic users and they inform of reaction requirement of user of road traffic.

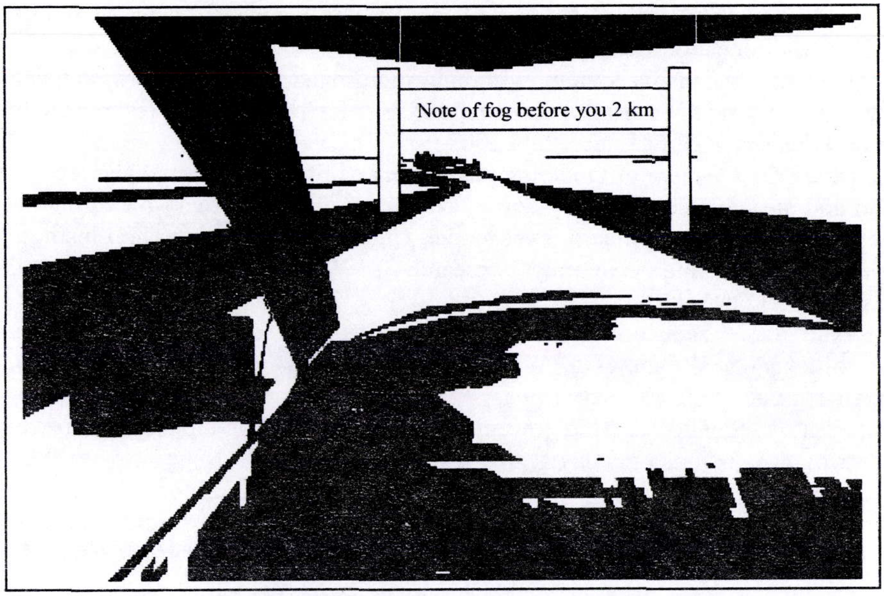

Fig. 18. Telematic tools scene – vehicle inside view.

5. Conclusion

In the paper there is used Unified Modeling Language notation for transport processes simulation description and designing. They determine telematic tools operation. There were introduced: use-case diagrams, class diagrams, sequence diagrams, activity diagrams and state diagrams, they allow to create clear and one-valued construction of model and start-up of simulation in real time. They allow simulating from concept through analysis of operation to presentation of virtual reality.

The paper presents example of Matlab Simulink tool employment in transport process modeling basing on new method of virtual reality modeling, the method is under research. Elements of Unified Modeling Language in Matlab Simulink allow to use it for start-up of computer simulation of vehicle traffic in real time, and to display this situation.

Results of work can be of service for analysis of transport processes in aspect of telematic tools interaction in multimodal transport.

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