Ambulance Car Logistics using Shortest Path Achievement Tree in Plant Simulation

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Keywords: Discrete Event Systems, Object Oriented Modelling, Simulation, Logistics, Graph, Shortest Path, Achievement Tree, Tecnomatix Plant Simulation, Resource Statistics, In Memory Database, SQlite, Data Retrieval.

Abstract: Tecnomatix Plant Simulation software based on discrete-event modelling and simulation provides all the necessary equipment to operational modelling of real-world systems. Models created in it can be useful in different ways. Running long time simulation of some model, the user can retrieve a sufficiently big amount of information and data, in adequate degree similar to real world data because of wide range possibilities to use random parameters in the model. These data retrieved from simulation can be further used to analysis and test of new design, control, or decision strategies. Model of a simple tracks network with an ambulance car serving patients from houses along the tracks is used as a test case. The motion of the car is controlled using a shortest path achievement tree, prepared in an Excel file and read into the Plant Simulation model. Part of the data received from the model simulation is stored in SQLite in-memory database to be exported for further analysis.

1 INTRODUCTION

Discrete event modelling and simulation of dynamic systems present a wide range of research effort for many years. For example, heuristic scheduling of a production process using a statecharts model was described in (Kurdel & Sebestyénová, 2011). Creation of a distributed flexible manufacturing system's model with logistics requires data exchange and intensive communication between distributed places. In earlier works of the authors, workflow for a multi-agent system with voice user interfaces in a changing environment was described in (Sebestyénová & Kurdel, 2014a) and multimodal aspects of communication was given in (Sebestyénová & Kurdel, 2014b).

All the necessary equipment to operational modelling of real-world systems is prepared in Plant Simulation software based on discrete-event modelling and simulation (Bangsow, 2015). Dealing with just substantial aspects, it can simulate long-lasting manufacturing plant operation in seconds.

To reflect the natural hierarchy of systems to be simulated requires a well-structured simulation models. To this purpose, Plant Simulation offers a basic object Frame which can be put into the RootFrame (the main object of the model) or in another Frame. In this way, complex tasks can be broken down into manageable parts, using object-oriented modular design and programming.

Smith (2013) presents a review on the usage of simulation for construction and functioning of manufacturing systems. Blaga et al. (2018) compares modelling based on Petri nets to Tecnomatix Plant Simulation for management of manufacturing process. Vavrík, Gregor & Grznár (2017) described Computer simulation as an instrument for the optimisation of logistics using automated guided vehicles.

In the paper, an extension of the authors' work (Sebestyénová & Kurdel, 2019) is presented. Model of a simple tracks network with an ambulance car serving patients from houses along the tracks, partially inspired by (Mes, 2017, pp. 91-92) will be used as a test case. Part of the data received from the model simulation will be stored in SQLite in-memory

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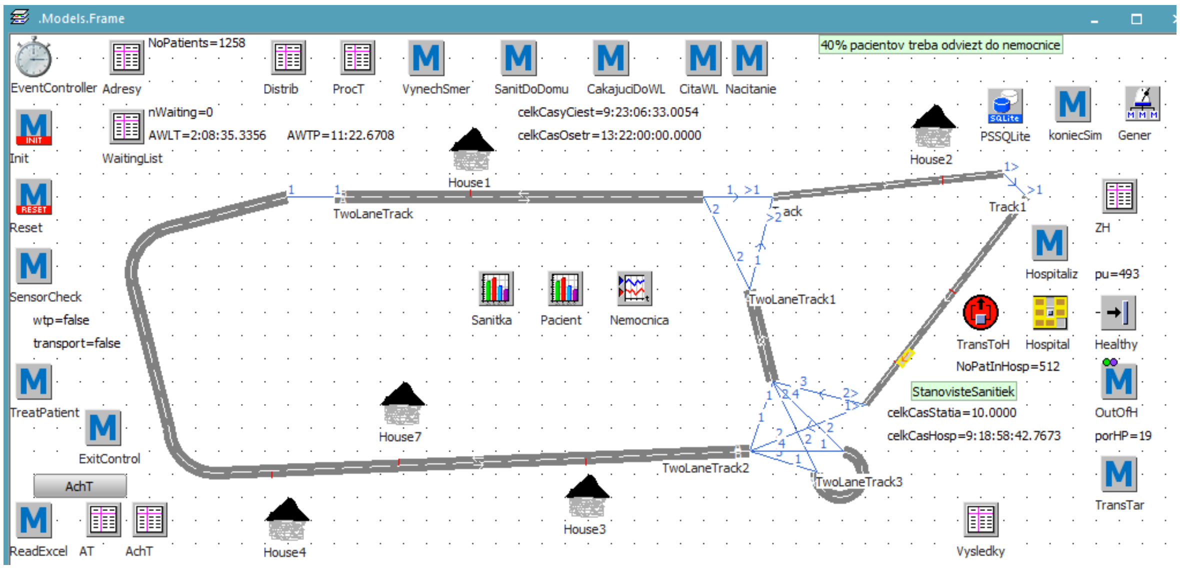
Sebestyénová, J. and Kurdel, P.
Ambulance Car Logistics using Shortest Path Achievement Tree in Plant Simulation.
DOI: 10.5220/0008493402140220
In *Proceedings of the 3rd International Conference on Computer-Human Interaction Research and Applications (CHIRA 2019)*, pages 214-220
ISBN: 978-989-758-376-6



NoPatients=1258
nWaiting=0
AWLT=2:08:35.3356
AWTP=11:22.6708
celkCasyCiest=9:23:06:33.0054
celkCasOsetr=13:22:00:00.0000
wtp=false
transport=false
pu=493
NoPatInHosp=512
celkCasStatia=10.0000
celkCasHosp=9:18:58:42.7673
porHP=19

Figure 1: Model's main frame in Plant Simulation with 2 one-way tracks and 4 two-lane tracks at end of simulation.

database to be exported for further analysis, which can be done in the model as well as outside of it.

2 MODEL OF A TRACKS NETWORK WITH AN AMBULANCE CAR

The tracks network considered in the paper consists of 4 two-lane tracks where cars can move in two directions and 2 one-way tracks with two crossroads. Connectors between two-lane tracks work for both traffic directions, but connectors connecting one-lane tracks distinguish the traffic directions. The TwoLaneTrack3 is only used to change the moving direction of the car, if needed. Along the routes there are 5 houses where patients turn up at some random time and one hospital where some of the patients need to be transported after a short treatment at home.

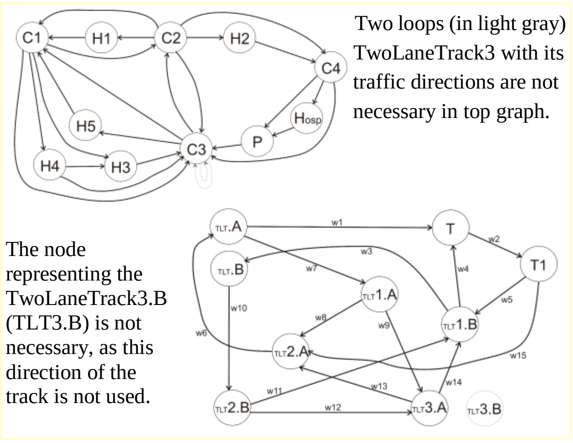
In commercial applications, animation and visualisation of results are often used to communication with the user. In research works, it is adequate to concentrate on functional aspects and use animation only during debugging. This enables to run long time simulation retrieving sufficiently big amount of data. The Interpreter executes the source code written in programming language SimTalk entered into any Method object. SimTalk 2.0 is used in the model. In the proposed model's main frame, the most important objects are the routes of a tracks network, as can be seen in Fig. 1.

The model contains one ambulance car (AC) derived from a Transporter type mobile unit from the Plant Simulation Class library (corresponding class is named CarGP, meaning a general practitioner in the car). It is created by Init method, at the start of the simulation. The AC waits at parking place near the hospital until an order appears, and it also moves to this place if no more patients are waiting for treatment.

The parking place, the hospital, as well as all of the houses have assigned its position sensor on the track which indicates a stop position of the car serving this place. In case of two-lane tracks, the sensor is assigned only to one half of the track with proper traffic direction. Each time the car approaches the sensor, SensorCheck method starts to control further simulation run.

2.1 Shortest Path Achievement Tree

Shortest path problem between vertices in the weighted directed graph, shortest path tree, bidirectional search etc. are widely described in the literature (Wikipedia, 2009). Dijkstra's Shortest Path algorithm enables to find the shortest paths between nodes in a graph, which may a.o. stand for road network. It was published in the year 1959. The problem is defined for simple graphs without cycles, negative weights, multigraphs, or loops. For problems similar to the described one, the negative weights are not needed, but the other properties will occur with high probability. The structure of Bellman Ford's algorithm and Dijkstra's algorithm is very



Two loops (in light gray) TwoLaneTrack3 with its traffic directions are not necessary in top graph.

The node representing the TwoLaneTrack3.B (TLT3.B) is not necessary, as this direction of the track is not used.

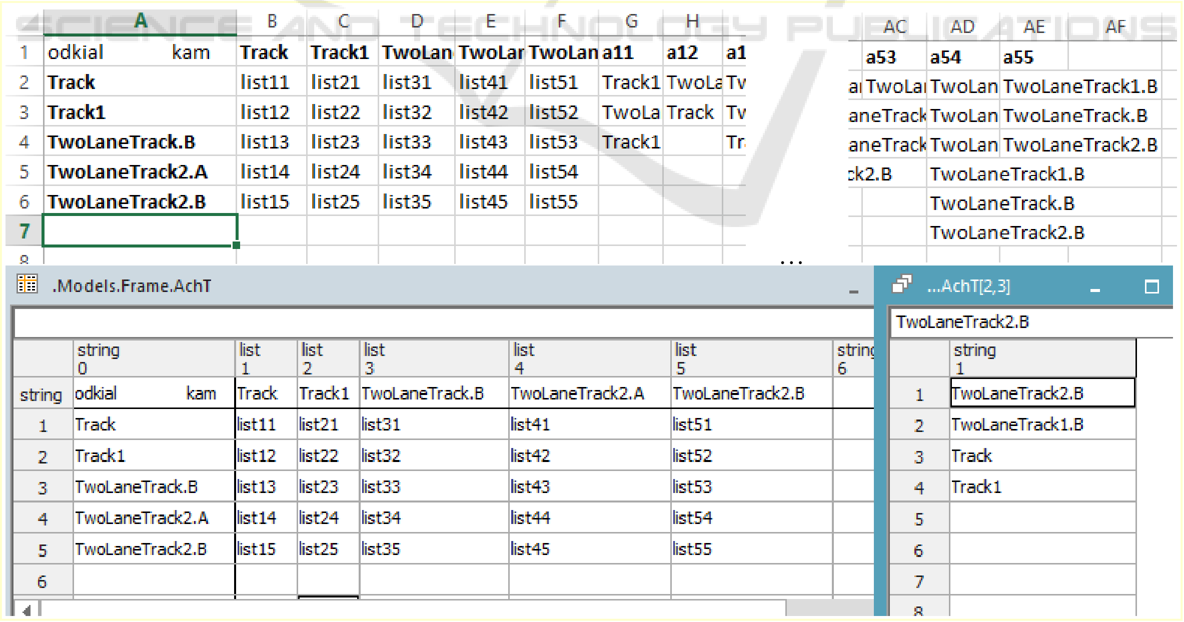
Figure 2: Two graphs created according to the model of the tracks network.

similar. While Dijkstra takes into account only the immediate neighbours of a node (breadth first), Bellman looks into each edge in every iteration (depth first search). Many different, enriched algorithms are available for graphs with widened properties.

Given a graph G = (V, E) and a source vertex u, the shortest distance from u to every other vertex v in V could be found e.g. by Dijkstra's algorithm, but in the test case some tracks need to enable move in both traffic directions. For this reason, creation of the graph from the model's routes network must take it into consideration, as can be seen in the top part of Fig. 2. The nodes consist of the position sensors near the houses, the parking place and the hospital, and of connectors of the routes. The edges represent the routes with directions. The routes length are specified during creation of the model. Positions of the houses on the routes are specified in the TableFile Adresy, which enables to compute the routes parts lengths.

One can prepare the shortest path achievement tree from any place on the route specified by a sensor to any other place. Another possibility (as can be seen in the bottom part of Fig. 2) is to create the graph in which nodes represent the tracks. The paper suggests that the shortest path achievement tree (based on the route length) received from the graph is prepared in an Excel file. The creation of the tree is out of the scope of the paper, but e.g. Kurdel & Sebestyénová (2013) described routing optimization for ATM cash replenishment for ATM's places received from Google maps of town Bratislava and its surroundings. To illustrate the achievement tree of the presented model, a part of it is given in the top part of Fig. 3, where rows specify starting tracks and columns specify destination tracks.

Using a method ReadExcel, this data is imported into Plant Simulation table and lists, as can be seen in the bottom part of Fig. 3. The table at the left contains lists representing branches of the tree, and an example list at the right contains tracks names and traffic



	A	B	C	D	E	F	G	H	
1	odkial kam	Track	Track1	TwoLan	TwoLar	TwoLan	a11	a12	a1
2	Track	list11	list21	list31	list41	list51	Track1	TwoLa	Tv
3	Track1	list12	list22	list32	list42	list52	TwoLa	Track	Tv
4	TwoLaneTrack.B	list13	list23	list33	list43	list53	Track1		Tr
5	TwoLaneTrack2.A	list14	list24	list34	list44	list54			
6	TwoLaneTrack2.B	list15	list25	list35	list45	list55			
7									
8									

…

AC	AD	AE	AF
a53	a54	a55	
aı TwoLaı	TwoLan	TwoLaneTrack1.B	
aneTrack	TwoLan	TwoLaneTrack.B	
aneTrack	TwoLan	TwoLaneTrack2.B	
ck2.B	TwoLaneTrack1.B		
	TwoLaneTrack.B		
	TwoLaneTrack2.B		

.Models.Frame.AchT

	string 0	list 1	list 2	list 3	list 4	list 5	string 6
string	odkial kam	Track	Track1	TwoLaneTrack.B	TwoLaneTrack2.A	TwoLaneTrack2.B	
1	Track	list11	list21	list31	list41	list51	
2	Track1	list12	list22	list32	list42	list52	
3	TwoLaneTrack.B	list13	list23	list33	list43	list53	
4	TwoLaneTrack2.A	list14	list24	list34	list44	list54	
5	TwoLaneTrack2.B	list15	list25	list35	list45	list55	
6							

...AchT[2,3]

TwoLaneTrack2.B

	string 1
1	TwoLaneTrack2.B
2	TwoLaneTrack1.B
3	Track
4	Track1
5	
6	
7	
8	

Figure 3: Shortest path achievement tree: at the top, in Excel file (as input file to the model); at the bottom, after being read into Plant Simulation table and lists (list23 is one branch of the tree - from TwoLaneTrack.B to Track1).

directions (A/B). These lists will be used to control the car driving to its destination (which may be one of the houses / the hospital / the parking place) during the simulation.

3 PATIENTS REQUIREMENTS, TREATMENT AND HOSPITALISATION

The Patient class is derived from Entity type mobile unit (MU) from the Class library. The house instances are derived from the House class created in UserObjects category in Plant Simulation Class library. As both classes and instances are named objects in Plant Simulation software, the users must take care to properly distinguish between them.

The model works with two sub-classes of patients. While some of them can be served by care at home (sub-class Pat), another part needs to be transported to the hospital, after a short treatment at home (sub-class PatHosp). Distribution of instances of the sub-classes is specified in Distrib TableFile of the main frame of the model; in the simulated case about 40% of the patients need transport to the hospital.

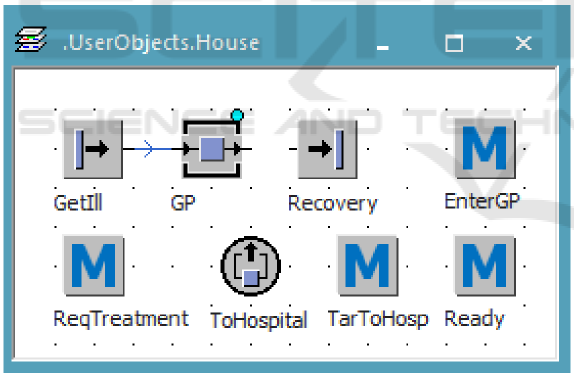


Figure 4: Sub-frame of one of the houses where patients emerge (the class of the House, from which 5 instances will be derived).

Fig. 4 presents a sub-frame of one of the houses where sometimes someone gets ill, which is represented by a Source type icon called GetIll. If someone gets ill in the house, ReqTreatmet method starts the AC moving to the house if the AC is free. If the AC is not free, e.g. moving to another patient or waiting to the end of the treatment provided to the patient by the GP, etc., the new requirement data is stored in a WaitingList TableFile. The next patient to be served will be read from the WaitingList file in FIFO order, after finishing the previous patient treatment, or after the transport of the patient to the hospital.

When the AC stops at the house, the patient in the house frame moves from the source to a station entitled GP, which represents the general practitioner‘s work in the house. If the treatment at home is sufficient, after some random treatment time the patient (Pat) moves to a drain icon entitled Recovery and ceases to exist in the model. If the patient needs further hospitalization, the AC will transport him/her (PatHosp) to the hospital. To accomplish this, the patient moves to a TransferStation entitled ToHospital after a short random treatment time. The TransferStation ToHospital enables boarding the patient on the AC. In both cases, the movement of the patient out of the GP station starts a Ready method in the House frame. The method writes some statistics data into an in-memory database (will be described latter).

Another TransferStation entitled TransToH in the model’s main frame enables transport of the patient from the AC to the hospital. The hospital is created as a Store type object from the Plant Simulation Class library. A random hospitalization time is specified for arriving patient. After this time, the patient moves from the hospital to a Drain type object entitled Healthy by means of the method OutOfH in the model’s main frame and ceases to exist in the model. This method also writes some data into the database.

4 DATABASE

Tecnomatix Plant Simulation object ODBC enables to import data from an ODBC database on a server, e.g. to read parameters of the model to be created and re-export the changed data back into the database. Data exchange with an SQL database is also enabled using SQLite object from the Class library. The object SQLite uses a database which can be stored in a file on the local hard disc, but also in main memory. In that case, a string “:in memory:“ is specified instead of the file pathname. In Plant Simulation software, writing/reading data into/from in-memory SQLite database is faster than writing/reading them into/from the TableFile object.

As previously mentioned, some of the methods write data into the SQLite database. The presented use-case works with only one DB table entitled Pacienti with 4 columns: MUType, MUName, StartTime, and EndTime. The first two are texts, the last two are reals. MUType is a primary key.

After the elapse of 1 month simulation time (specified in EventController as 31:00:00:00

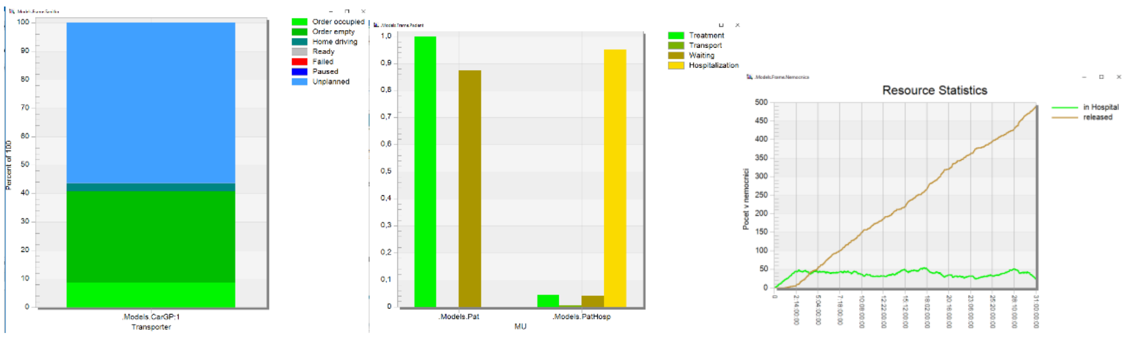


Figure 5: The ambulance car statistics (left), the patients statistics (centre), the hospital statistics (right).

[dd:hh:mm:ss]), a method koniecSim reads the data from the DB into a TableFile Vysl and subsequently writes the data into an Excel file for further analysis. The next lines present a part from the code of the method reading data from SQLite:

```
var sql,sql2:string
var r:integer
sql  :=  "CREATE  TABLE  IF  NOT  EXISTS
Pacienti   (MUType  TEXT  PRIMARY  KEY,
MUName  TEXT,  StartTime  REAL,  EndTime
REAL)"
sql2 := "SELECT * FROM Pacienti"
PSSQLite.open
PSSQLite.exec(sql)
PSSQLite.prepare(sql2)
r := 1
while PSSQLite.step
 Vysl[1,r]:=PSSQLite.getColumnString(0)
 Vysl[2,r]:=PSSQLite.getColumnString(1)
 Vysl[3,r]  := PSSQLite.getColumnReal(2)
 Vysl[4,r]  := PSSQLite.getColumnReal(3)
 r += 1
end
PSSQLite.close
Vysl.writeExcelFile("E:\PlantSim\Pacien
ti.xls")
```

Last line instruction writes data into an Excel file.

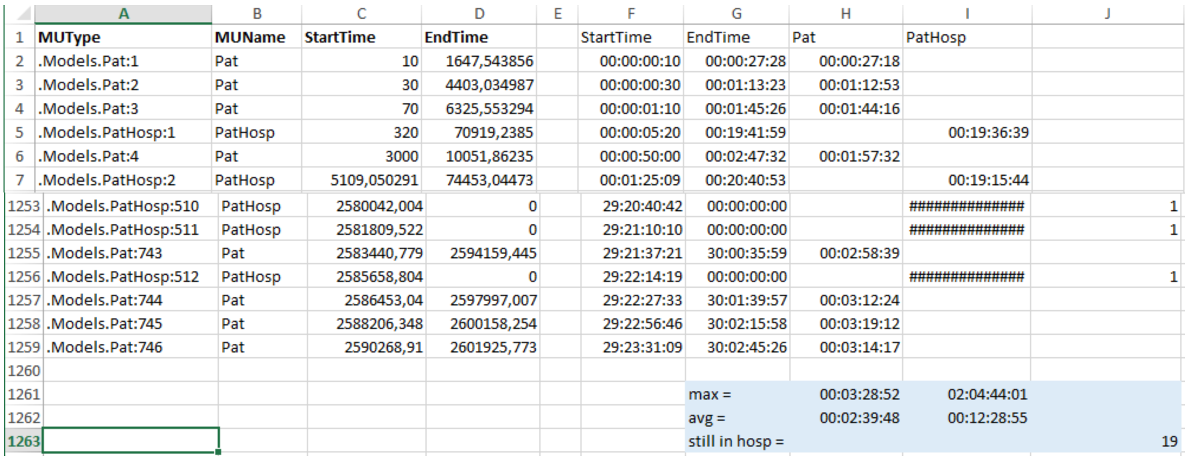
4.1 Resource Statistics

The AC statistics can be seen at the left side of Fig. 5. The instance name of AC object in the model is CarGP:1, as only one AC is used in the use-case. The AC‘s whole time of existence (1 month) is divided to coloured parts of column chart according to: *Order empty* part of time (representing the driving part of time of AC without any patient), *Order occupied* part of time (representing the driving part of time of AC with any patient transported to the hospital), *Unplanned* part of time (used to represent treatment part of time, when the AC is waiting near the house), *Home driving* and *Ready* parts of time, when the AC actually has no order, i.e. no patient is waiting for treatment (the AC then drives to the parking place near the hospital and waits for an order, being ready to serve).

The Patient statistics are represented in the central part of Fig. 5. Two sub-classes of the Patient class are used in the use-case, so statistics of the time usage are given for the patients from the class Pat (needing only treatment at home) and for patients from the class PatHosp (that also need to be transported to the hospital).

In case of the patients needing hospitalization, the biggest part of existence time of these patients in the model is the hospitalization part of the time. Treatment and Waiting time of these patients are smaller. The smallest part of the time is the transport time of these patients. This is influenced also by the fact that the shortest paths to the hospital are in most of the cases shorter in presented use-case than the shortest paths from any house to another house, where often the change of the traffic direction is needed, although houses may be on the same track. The presented very simple tracks network was used to show the usefulness of similar models, that could also be created e.g. for optimisation of logistics between manufacturers, sub-providers, warehouses, and customers. For the patients cared for only at home, there are only two slopes in the graph representing the waiting and treatment time of these patients.

Resource statistics for the hospital can be seen at the right side of Fig. 5. The number of the patients in the hospital from start to end of simulation is represented by the curve named *inHospital*. The second curve named *released* gives the growing number of released patients from the hospital during the month.



	A	B	C	D	E	F	G	H	I	J
1	**MUType**	**MUName**	**StartTime**	**EndTime**		StartTime	EndTime	Pat	PatHosp	
2	.Models.Pat:1	Pat	10	1647,543856		00:00:00:10	00:00:27:28	00:00:27:18		
3	.Models.Pat:2	Pat	30	4403,034987		00:00:00:30	00:01:13:23	00:01:12:53		
4	.Models.Pat:3	Pat	70	6325,553294		00:00:01:10	00:01:45:26	00:01:44:16		
5	.Models.PatHosp:1	PatHosp	320	70919,2385		00:00:05:20	00:19:41:59		00:19:36:39	
6	.Models.Pat:4	Pat	3000	10051,86235		00:00:50:00	00:02:47:32	00:01:57:32		
7	.Models.PatHosp:2	PatHosp	5109,050291	74453,04473		00:01:25:09	00:20:40:53		00:19:15:44	
1253	.Models.PatHosp:510	PatHosp	2580042,004	0		29:20:40:42	00:00:00:00		##############	1
1254	.Models.PatHosp:511	PatHosp	2581809,522	0		29:21:10:10	00:00:00:00		##############	1
1255	.Models.Pat:743	Pat	2583440,779	2594159,445		29:21:37:21	30:00:35:59	00:02:58:39		
1256	.Models.PatHosp:512	PatHosp	2585658,804	0		29:22:14:19	00:00:00:00		##############	1
1257	.Models.Pat:744	Pat	2586453,04	2597997,007		29:22:27:33	30:01:39:57	00:03:12:24		
1258	.Models.Pat:745	Pat	2588206,348	2600158,254		29:22:56:46	30:02:15:58	00:03:19:12		
1259	.Models.Pat:746	Pat	2590268,91	2601925,773		29:23:31:09	30:02:45:26	00:03:14:17		
1260										
1261							max =	00:03:28:52	02:04:44:01	
1262							avg =	00:02:39:48	00:12:28:55	
1263							still in hosp =			19

Figure 6: The time of existence of two types of patients in the model exported from SQLite to Excel file for further analysis of retrieved data.

5 DATA ANALYSIS

The time of existence of two types of patients in the model exported from SQLite to Excel file to further analysis of data are given in Fig. 6. DB table columns (two of type string, and two of type real) mentioned in section 4 represent for each patient its instance name, class name, and start/end times of his/her appearance/disappearance in the model.

In many cases, it is better to transform time data given in real format to time data given in time format [dd:hh:mm:ss], which can be done by division by 86400. The existence time of the patient in the model can be received by subtraction operation (EndTime - StartTime). At the end of the simulation some of the patients (instances of the PatHosp class) are still in the hospital. The end time data for them equals to zero (initial value), so a result of the subtraction is negative. This can be used e.g. to obtain the number of the patients still in the hospital (by a simple count). In presented use-case there are 19 patients in the hospital at the end of the simulation.

Table 1: Results from data analysis in the Excel file exported from SQLite.

	Pat	PatHosp	No
Max time	00:03:28:52	02:04:44:01	
Avg time	00:02:39:48	00:12:28:55	
Still in hospital at end			19

The existence time of each patient consists of the waiting, treatment, transport, and hospitalization time. For illustration, maximum/average existence time calculated for two categories of the patients are given in Table 1.

6 CONCLUSIONS

Plant Simulation software and models created in it can be useful in different ways. Running long time simulation of some model, the user can retrieve a sufficiently big amount of information and data, in adequate degree similar to real world data because of wide range possibilities to use random parameters in the model. These data retrieved from simulation can be further used to analysis and test of new design, control, or decision strategies. Model of a simple tracks network with an ambulance car is presented. Some of the data received from the model simulation is stored in SQLite in-memory database to be exported for further analysis.

The model contains one ambulance car (AC) waiting at parking place near the hospital until an order for treatment appears and returning to this place if there are no more patients waiting for treatment. Shortest path achievement tree from any place on the routes network to any other place is prepared before the start of simulation run in a form of an Excel file. This data is imported into Plant Simulation table and lists and is then used to control the car moving over to the destination during the simulation. Some of the methods write data into SQLite database. After the elapse of 1 month simulation time (running approximately 12 s for this simple test case), the data from the DB is read into a TableFile and subsequently written into an Excel file for further analysis.

Results presented in the paper can be seen as part of the project research. Creation of the routes network model in Plant Simulation is planned (to be done in future) using Google maps and GPS coordinates of some important places. Influence of Blockchain on the transportation industry is described in (Robinson, 2019). In further work, the authors plan to create a distributed flexible manufacturing system model with logistics. In such a task, intensive data exchange and communication between distributed places will be needed. BlockChain distributed database (Zigurat, 2019) connected to Plant Simulation model will contain data on products, sub-parts, manufacturers, sub-producers, customers, orders, etc. and this data will become the subject of further sophisticated analysis.

ACKNOWLEDGEMENTS

The authors are grateful to Scientific Grant Agency of Slovak Republic and Slovak Academy of Sciences for partial support of this work by projects VEGA 2/0167/16 and VEGA 2/0155/19.

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