Enterprise Dynamics Business Case

Developing the Philips Stadium model

INCONTROL

Simulation Solutions

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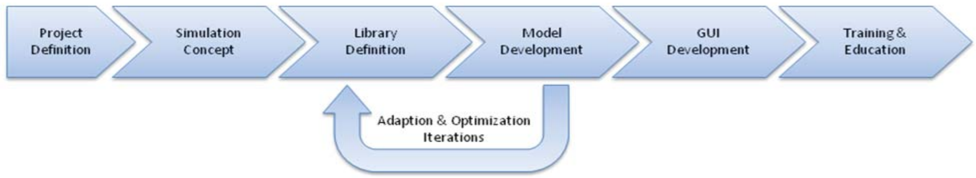
Contents

1. Introduction

In this article a business case of INCONTROL Simulation Solutions is discussed. The business case concerns the development of a user-friendly simulation model that represents the pedestrian movements of visitors at a soccer stadium. In order to simulate the proper behavior of the visitors and available facilities some additional library atoms with specific functionality were created that are used in the model. In the following chapters the process of model/application development with all relevant design steps and decisions are discussed.

2. Project phases

In the following figure the main phases of the project are shown.



The development project will be discussed according these phases. In every project some general considerations have to be made dependant on the situation that is simulated. Each phase having its own considerations and corresponding decisions before taking the next step in the process. In the following chapters each phase will be discussed on a general level and based on the business case examples of these considerations are given. In the end, one will have a clear view on simulation projects and the phased decision making that is necessary in these projects.

2.1 Project definition

2.1.1 Introduction

In the orientation phase of the project it is important to define the functionality and level of detail that will be modeled/developed. Secondly it is important to define the user of the application or model. Dependant on the user and the desired functionality of the resulting simulation, the developer can decide to build an application with specific library atoms that contain the desired functionality. On the other hand the developer can select to build a simulation model with the standard library atoms that are available through the Enterprise Dynamics platform and the Suites.

2.1.2 Business case

The project concerns the simulation of pedestrian flows through the soccer stadium of a Dutch soccer team called PSV. The capacity of the stadium is 35.000 people. The following reasons where stated for the use of simulation in analyzing these pedestrian flows:

- Scale of figures. The analysis of normal game situations and evacuation scenarios were the main focus of PSV. Since it is difficult (impossible) to perform a real-time evacuation with 35.000 people, the company was searching for alternative solutions to create insight in the impact of changing evacuation and normal game protocols.

- Complexity of monitoring. Since the soccer stadium covers a surface of 40.000 m2 and has 6 levels of different height, it is complex to monitor and analyse these pedestrian flows in realtime.

- Communication. In every game about 300 stewards are used to manage the visitor flow. By using the visualization of the model and output parameters of, for instance a new evacuation protocol, the simulation model firstly supported the security managers in communicating this protocol and secondly convincing the stewards of the effectiveness of the protocol.

Based on these reasons PSV realized the added value of simulation and the project was started.

The security managers of the PSV stadium where defined as the end-user of the simulation model. With the simulation model the security manager should be able to:

- analyze people flow in and around the stadium under different circumstances
- develop and analyze evacuation scenarios
- determine capacity of staffing and processes
- analyze infrastructural changes in and around the stadium

In order to fulfill these goals the project purpose was stated as “the development of a customized user-friendly simulation model”. In the following chapters there is discussed how INCONTROL performed the project in such way that the purpose was fulfilled.

2.2 Simulation concept

2.2.1 Introduction

The second step is to translate the definition of the project into clear functional properties with the right level of detail. Since the resulting simulation entity will be a model of reality, the developer has to consider which behaviour is relevant enough and so taken into account in the simulation model.

2.2.2 Business case

In the PSV stadium project the following functionalities where taken into account, to perform analysis on the right level of detail:

- The user is able to perform a simulation run of a normal game scenario which is characterized by a start up, first half, break, second half and end of game. Also the user should be able to execute an evacuation on an arbitrary moment during the game.

- The visitor has a specified identity. Since every visitor has its own properties (e.g. walking speed, route selection method) each visitors is simulated as a unique entity that will select the proper route to reach the desired destinations within the stadium.

- The stadium infrastructure is developed as a network that represents all the possible routes that a visitor can use. In this network several infrastructural entities (e.g. doors, stairs, elevators, entrance gates) with corresponding properties (e.g. throughput capacity) are built to simulate the infrastructural capacity of the stadium. The user will also have the possibility to open or close doors and gates at a certain moment during the simulation run to analyze the effect of this change in infrastructure and routing.

- Facilities inside the stadium are taken into account. These facilities are toilets, bars, coin-sale machines. Each facility has unique capacity and throughput properties.

- Crowd behavior. In order to simulate the proper crowd behavior the following functional properties are available; Gender, walking speed, toilet usage, bar usage, coin sale usage.

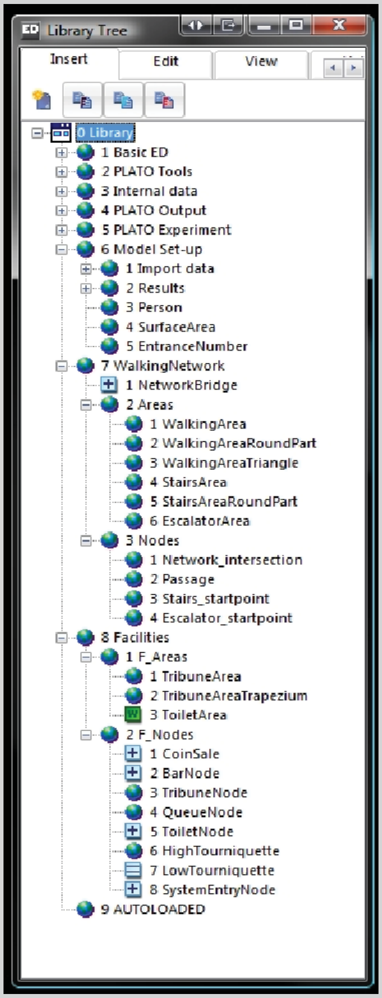
- Arrival & ticket settings. The user is able to analyze the effect of different arrival patterns of the visitors by defining the intervals and the percentage of people arriving in this interval. Also the user can define the amount of visitors that will enter the stadium per section (total of 52 tribune sections).

- The model needs to support all CAD drawings of the different layers of the stadium.

- The model will be visualized in both 2D as 3D

- The user can customize/personalize the model to the real situation by changing the names of the relevant facilities, doors and passages.

In the following chapters there is discussed which library is used and adapted to create the desired functionality as discussed above.



2.3 Library definition

2.3.1 Introduction

After the desired functionality is defined, the developer decided which library to use for the development of the model. The available suites constructed by INCONTROL offer many flexible atoms with a pre-defined functionality. Next to the pre-defined atoms, the developer also has the possibility to create an own library with self-developed atoms. An important decision that the developer has to make is where the functionality with corresponding properties is kept. This can either be in the library or in the model. If the functionality is kept in the library, these atoms can also be used in other models. The question that arises however is whether the functionality is generic enough to be used in other models. Otherwise the functionality is better kept in the model. Some examples of these considerations are given in the following part on the business case.

2.3.2 Business Case

The basis for the pedestrian flow simulation projects lies with the simulation product PLATO. PLATO stands for Pedestrian Logistics Analysis Tool. For the analysis of pedestrian flows nowadays simulation is a common used tool. Three main approaches are distinguished in the modeling of pedestrian flows namely macroscopic, microscopic and mesoscopic. A macroscopic approach describes the flow of pedestrians as a fluid through space. The main subject of this approach lies with the behavior of the combined pedestrians in a group. In a microscopic approach, on the other hand, the pedestrians are modeled as individual entities with a unique behavior. Also the mutual behavior of pedestrians, like collision avoidance, is taken into account. The microscopic models can be described in two main approaches, either continue (e.g. social force) or discrete (e.g. cellular automata). The mesoscopic approach combines parts of the functionality of both the macroscopic and microscopic approach. Individuals are stated as a unique entity in the model, but have no mutual behavior. Like in the macroscopic approach, the effect of different characteristics of the flow in the environment is applied to the individual pedestrian. For example, as the density (stated as the amount of person/m2) in a certain area increases the individual walking speed of pedestrian will be adapted according to a pre-defined density formula. This formula is defined by microscopic research of pedestrian flows.

INCONTROL Simulation Solutions uses this mesoscopic approach to analyze the pedestrian flows in a wide range of designs for buildings and other infrastructures such as airports, train stations, city planning, musea & exhibitions, theme parks and stadiums. The main purpose lies with the analysis of the quality and the safety of transfer between several functional activities. Based on the functionality of the infrastructure and the pedestrian properties, an individual will have a sequence of processes that it needs to undergo within the infrastructure. Based on the individual characteristics of the environment the pedestrian will follow (and adapt) his route to perform this sequence of functional processes.

The quality of the transfer between these functional processes is based on the situation that is modeled. In general this quality is stated as the comfort (m2/pp) and speed of the transfer, but also the properties of the processes are important. This quality is therefore influenced by the environment, for instance the density in certain areas, but also the physical design of the infrastructure and processes with corresponding capacity.

An important issue that concerns the safety is evacuation capacity of an infrastructure. The effect of physical infrastructure, amount of pedestrians and pedestrian behavior (e.g. route selection) is analyzed in evacuation models. As stated before, the properties and performance of the model is dependant of the situation and purpose of the project.

The PLATO library was used as basis for the model that was built in the business case. This library includes the movement of the pedestrians and use of walking networks to route the pedestrians through the different processes that a pedestrian undergoes (e.g. entrance, toilet and tribune seat). These processes however were not yet available in the basic library. Since the scale of usage of these process is high (e.g. 300 toilet in the stadium) and the chance of usage in a potential other stadium project was high, the developer decided to add some functional specific atoms to the library. The following atoms where added:

- SurfaceArea, to visualize CAD drawings, but also easily switch between levels and these CAD drawings.
- HighTourniquette, an high entrance gate which a visitors takes before entering the stadium
- LowTourniquette, a low entrance gate which a visitors takes before entering the stadium
- TribuneArea, the area where the visitors stays while watching the game
- TribuneNode, the connection node for the tribune area to the walking network
- ToiletArea, the area where people use the toilet
- ToiletNode, the connection node for the toilet area to the walking network,
- CoinSale, the node where the visitors goes when he wants to buy a coins
- BarNode, the node where the visitor goes when he want visit a bar

In the list above, the atoms with corresponding functionality that were added to the library are discussed. This decision was made based on the generic properties of these atoms. For the remaining functionality there was decided to build this in the model. The main reason was the specificity of these functionalities to business case. The following functionalities were developed in the model:

- Arrival of visitors
- Setting up a game scenario and evacuation scenario
- Routing of visitors to facilities, doors, entrance gates and tribunes
- Crowd settings

In the following chapter about the model development these functionalities are discussed in more detail.

2.4 Model development

2.4.1 Introduction

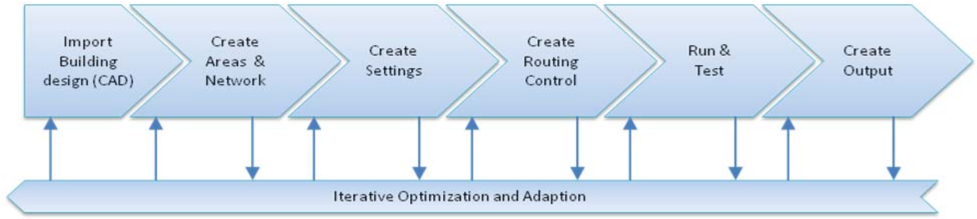
The simulation model that will be developed will be a model of situation/system that represents the proper behavior on the right level of detail. Since the selected library will contain many pre-defined functionalities modeling with Enterprise Dynamics is made easy. Nevertheless as the complexity of the situation/system increases, model developers will also have to create unique situation-dependant functionality to achieve final model. Enterprise Dynamics supports this desired flexibility by a clear event based scripting code. Next to the modeling of the defined functionality also other aspects can be important when developing a model:

- Input/import of data
- Output/export of data
- Visualization of performance indicators
- Visualization of the situation (2D of 3D)
- Use and level of detail of Graphical User Interface to control the model
- Experimentation

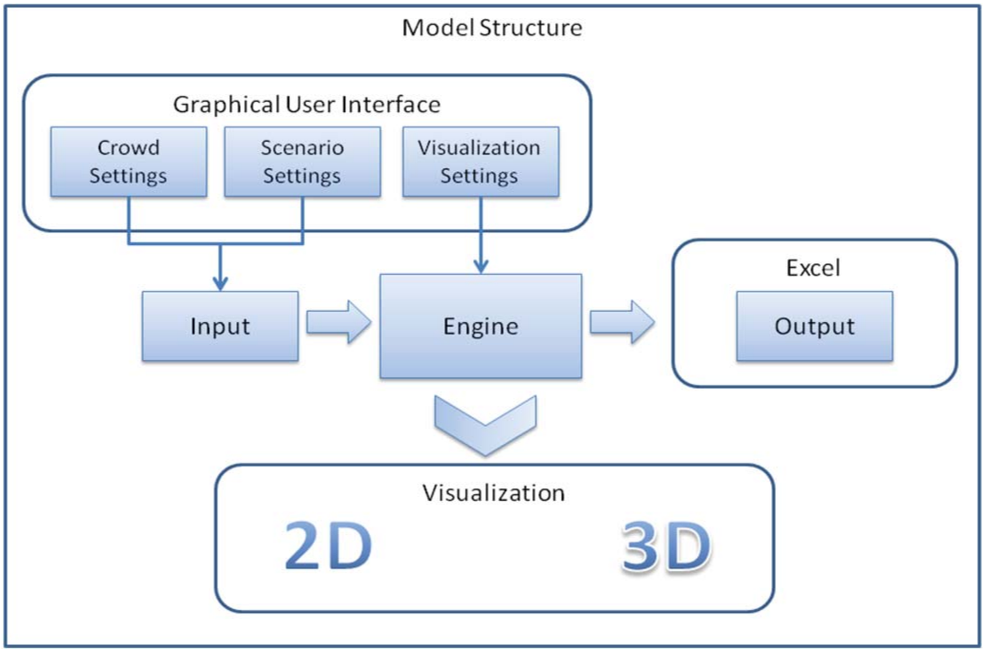
In the next part there is discussed how all these aspects are threaded in the model of the business case.

2.4.2 Business case

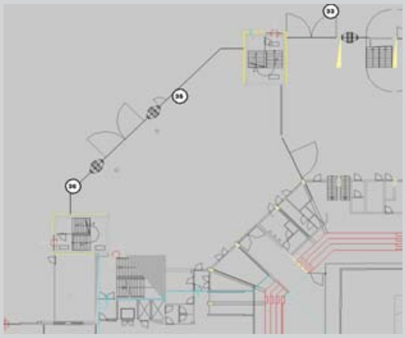
In the case of the PSV stadium the following development steps were taken (see figure). These model development steps are typical for the creation of a pedestrian model.



The model structure is defined as follows:



In the following parts the model development will be discussed according the step defined in the figure.



Number of Attributes: 32 Set

No.	Name	Attribute
1	EntryPercentageNorthWest	25
2	EntryPercentageNorthEast	25
3	EntryPercentageSouthWest	25
4	EntryPercentageSouthEast	25
5	NormalWalkingSpeed	=Uniform(0.9, 1.7)
6	EvacuationWalkingSpeed	=Uniform(1.3, 2.0)
7	PercentageMale	90
8	SimulationStart	0
9	GameStart	7200
10	FirstHalfLength	=hr(0.75)
11	SecondHalfLength	=hr(0.75)
12	BreakLength	=hr(0.25)
13	ClockStart	64800
14	ClockGameStart	=hr(20)
15	GameStatus	Pending...
16	CoinStartPercentage	7
17	CoinBreakPercentage	1
18	MaleToiletStartPercentage	10
19	FeMaleToiletStartPercentage	30
20	MaleToiletBreakPercentage	20

Dimensions
Rows: 52 Columns: 7 Set

	Name	AreaCode	Number	NodeNumber	Network	PTV	level
1	TrN_4_379_LowerRing	*N	11	379	4	80905172	1
2	TrN_4_381_LowerRing	R	12	381	4	216693324	1
3	TrN_4_384_LowerRing	S	13	384	4	233252192	1
4	TrN_4_387_LowerRing	T	14	387	4	242848676	1
5	TrN_4_390_LowerRing	U	16	390	4	249682724	1
6	TrN_3_427_LowerRing	V	51	427	3	260041612	1
7	TrN_3_430_LowerRing	W	17	430	3	263752160	1
8	TrN_3_433_LowerRing	X	19	433	3	261944860	1
9	TrN_3_436_LowerRing	Y	21	436	3	258421768	1
10	TrN_2_354_LowerRing	A	25	354	2	244897404	1
11	TrN_2_359_LowerRing	B	26	359	2	279104940	1

2.4.2.1 Import building design CAD

Enterprise Dynamics offers the possibility to import CAD drawings (format .dxf). This CAD drawing is can be visualized in the model. The advantage of this method is that the imported CAD drawing represents the correct scale of the building. In this way the areas and walking network entities can be easily set on the correct location. Before importing a CAD drawing it is important to select a proper drawing that represents the building at the right level of detail. All relevant walking, staying and process areas should be visible and also all doors, gates, stairs and process entities should be visible. By using the SurfaceArea atom each CAD layer of the building can be place on the correct location and be turned on and off if necessary.

2.4.2.2 Create Area & Network

Based on the imported CAD design all relevant areas, processes and network nodes can be created and located. When creating the areas it is important to define the proper size of the area. Based on the situation and form of the space, an area visible in the CAD drawing can be defined by one or more walking areas. Since every walking area is stated as a separate entity, this is also dependant on the level of detail of the desired output monitoring in this CAD area. Within the walking area the user creates nodes. By connecting these nodes the available walking network is created. Based on the Dijkstra Algorithm al connections, distances and shortest route between these nodes can be calculated. The different processes, gates and doors, stairs etc. are all nodes within the walking area. By creating the proper connections between these nodes all possible connections and routes of the building are defined. Every node in the network gets a unique node number. By giving the pedestrian a node as a destination, the pedestrian will automatically follow a selected route (e.g. shortest, less crowded) to reach its end destination.

2.4.2.3 Create settings

Before the visitors can be routed to different location within the stadium, several settings and properties need to available in the model. These settings can either be available through tables or attributes on model atoms. When these settings are available they can be referred to by other atoms. An atom VisitorCreator can create visitors based on the interarrival pattern defined in the table InterArrivalTimes. When a visitor is created, the initial properties can be set. For instance the desired walking speed of the visitor can be set based on the value of attribute “NormalWalkingSpeed” set in the atom VisitorProperties.

Next to these settings also the relevant model information needs to be registered, for instance in order to create routing algorithms. For the registration of important data of the model also tables or attributes are used. If for instance a visitor needs to travel to a tribune area, the corresponding node number of this tribune needs to be set on the visitor, therefore a table can be available that states all the tribunes with corresponding node numbers.

Based on the desired model functionality the user needs to define settings and model information that will be used during the dynamic run of the simulation. In the following part there is discussed how this information can be used to achieve the designed system behaviour.

2.4.2.4 Create routing control

As stated above the PLATO library offers automatic movement and routing of the pedestrians to a defined location in the network. However the developer of the model still has to decide the number and locations of the route-steps a pedestrian will make. So a controlling layer has to be developed to model the desired behaviour. If for instance the visitors that will go to tribune area Y can only enter the stadium through entrance X this relation has to be defined but also executed. So before sending the visitor to his end-destination (the tribune node) it first has to go to a sub destination (the entrance gate). Since all these nodes have node numbers the control of the pedestrian routes has to define the correct node-destination on the visitor in the right sequence and moment. So in this case when entering the model, the visitor first needs to have the nodenumber of entrance X as destination. After the visitors exited entrance X the destination number of the visitor should be equal to the tribune area Y. In order to achieve this functionality for example the onexit trigger of the entrance gate-node can be used to set the new destination on the visitor. Another example is given by a visitor that needs to use the toilet during the break. When the break event is executed people that need to use the toilet (based on a set property) will leave the tribune and go to the closest toilet. This information needs be available, so the closest toilet to the tribune node needs to be defined. When the break event arises this toilet node number is set as a sub-destination of the visitor. When the visitor has finished the toilet process, for example the onexit event of the toilet can set the destination of his visitor back to the tribune area.

Another functionality that is available is to change the state of the walking network on an event. For instance, opening an emergency exit during an evacuation. When opening this emergency exit and re-optimizing the walking network, the pedestrians will adapt their route in order create another optimal route selection.
By managing the events during a run and control the destination, all visitors can get the proper behaviour and so a valid model of the real situation can be created. For the creation of such a controlling layer in these pedestrian models moderate developer skills are necessary. Each model will have a unique behaviour concerning these routes and processes. This is also the reason why this functionality is hard to capture into a generic library atom.

2.4.2.5 Run & test

After the model settings and routing control is defined the model is “ready to run”. To test if the model performs the right behaviour several options can be used.

- Visualization. The PLATO library offers a 2D visualization of the pedestrian and all processes in the walking network. By just following pedestrian and checking their properties and routes the functionality of the routing control can be evaluated

- By using logs. By logging each step of a pedestrian with all relevant parameters the functionality of the routing control can be evaluated by analysing this log report of all relevant routing decision.

Mainly in this phase, iterations will be made to optimize and advance the behaviour of the model. These iterations can happen in different phases of the model developer. A user can for instance adapt the walking network of the building but also for instance optimize routings for e certain group of pedestrians.

2.4.2.6 Create output

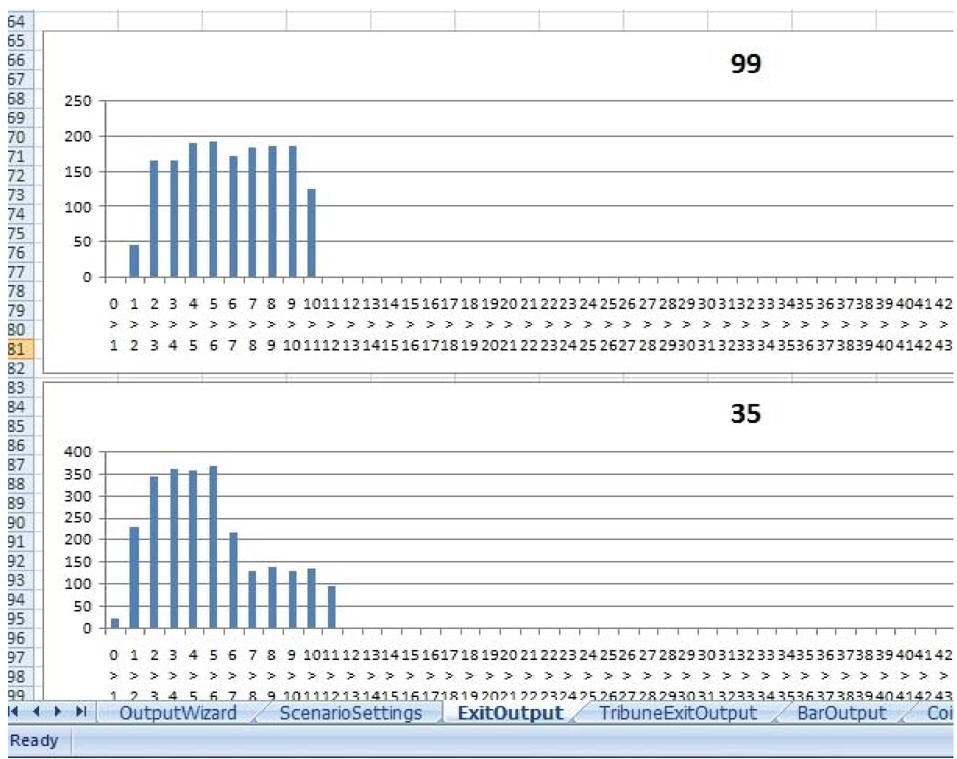
Based on the defined performance indicators of the situation output can be created in order to analyse the state and performance of the modelled situation. Based on the desired level of detail several options can be used to do this analysis:

- Output monitors during the run. Showing the real-time values of the indicators in the model visualization
- Create output tables. In these output tables all necessary output data is saved. In addition the developer can also decide to export this data tables to another application (e.g. excel, access)

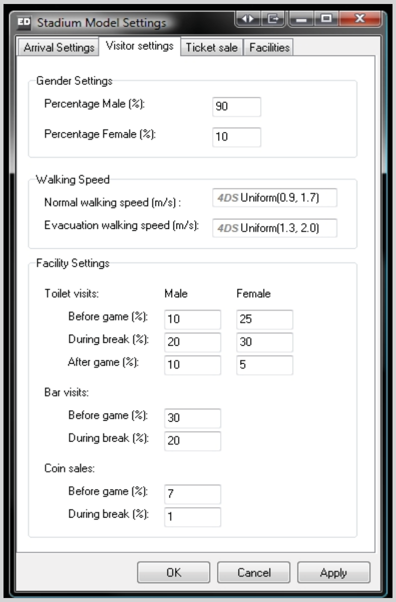
For the model created in the business case all relevant data was exported to excel at the end of run. The following data was available for analysis.

- Travel times (e.g. to exit or emergency exit) per exit and per area.
- Waiting times (e.g. for entrance gates or toilet).
- Process usage (e.g. number of people using a bar) defined per interval.
- Summary of the scenario that executed.

Now that the model works according the defined functionality some additional steps were made to improve the user interface and user friendliness of the model. The reason for this step is the software experience of the security managers at PSV. This experience level was low. GUI's were built so that the user could easily change and set all the relevant settings. In the next chapter these GUI's are discussed.



2.5 GUI development



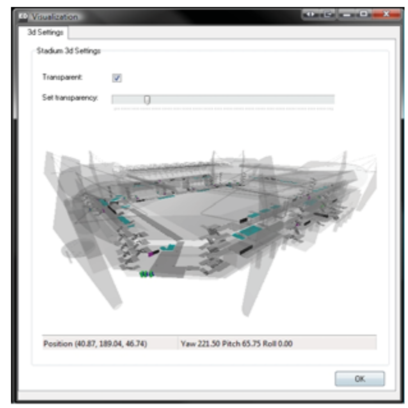
2.5.1 Introduction

The graphical user interfaces are used to improve user friendliness of the simulation model. All atoms available in the standardized libraries have an own GUI which provides the user an easy way of setting the atom properties. Also Enterprise Dynamics offers a GUI builder which allows the developer to built customized GUI's for both library as model atoms. In the business case there will be explained how all relevant settings where made easy to access using GUI's.

2.5.2 Business case

In the developed stadium model all settings where available in several tables and atom attributes. In order to change a parameter these value had to be set using the model tree or by editing the table. Since the user at PSV were not familiar with Enterprise Dynamics all these settings where combined in four GUI's:

- Model settings. This GUI covered the most settings. With the use of tabs these relevant setting could be combined to groups in order to create a clear view.
- Output settings. For selecting the run scenario (game/evacuation) and selecting the output parameters
- 3D Visualization settings. Selecting which layer/level of the stadium is shown.
- 2D visualization settings. Selecting which layer/level of the stadium is shown.



By using the GUI builder all relevant setting from different tables and attributes can be imported into one GUI screen, in this way the user does have to open these different atoms to do these settings. When the user applies the settings in the GUI the values will be written to correct location (table/attribute) of the parameter.

The use and development of GUI's is dependent on the desired level of user friendliness. Where an advanced developer is can easily control a model using tables a less experienced user will possibly need more help controlling the model. GUI's provide are useful method to improve the usability of the software and models.

2.6 Training & Education

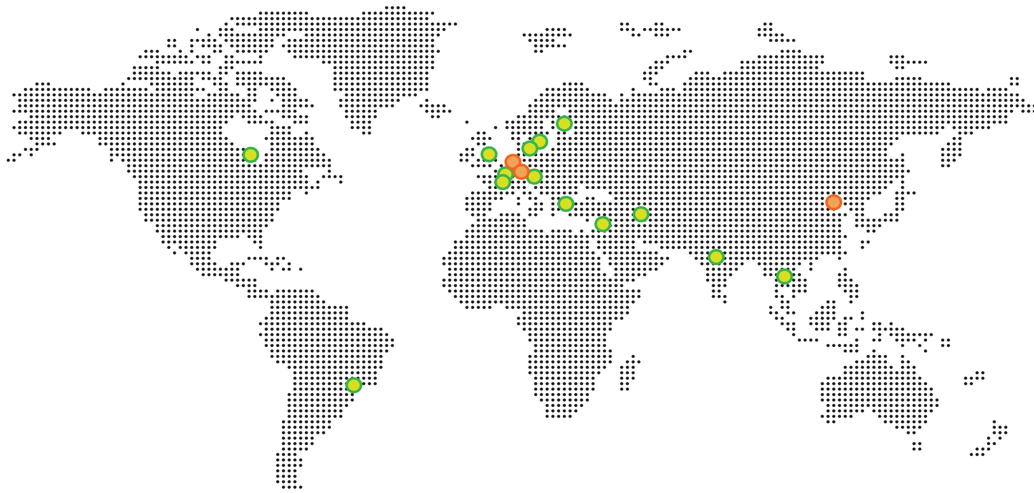
2.6.1 Introduction

If the model/application is to be used by external users the functionality and user interface needs to be clear to this external user. The external user in this case will be trained/educated to use the model/application.

2.6.2 Business case

In the case of the PSV stadium the security managers of the stadium where stated as the users. A session was planned to train these security managers in using the model and setting up user-defined scenarios. A test phase was initiated and INCONTROL supported the users if they had questions or remarks about the tool. Based on these remarks some adaptions where made to the model and PSV is now using simulation to create and evaluate protocols for optimal crowd management in and outside their stadium.

Contact



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