TOWARDS A METAMODEL FOR AIRPORT MODELING AND SIMULATION

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ABSTRACT
Simulation is an effective method to reflect real life situations as well as possible future solutions. Airport modeling and simulation provides great benefits to decision makers to identify potential bottlenecks and operational constraints of an airport via simulating a model of the airport. This work will present a metamodel which will help airport designers to develop airport plans and evaluate alternative options prior to implementation. The metamodel will be used to draw airport design models, and to transform these models into discrete event simulation models automatically. This work will initiate the research on model driven development of airport simulation models.

Keywords: metamodeling, airport modeling, airport simulation, discrete event simulation

1. INTRODUCTION

Modeling and simulation is an effective method for analyzing and designing systems and it is of interest to scientists and engineers from all disciplines. Airport modeling and simulation is the activity of developing either the current or the future model of an airport and simulating the model over time in order to identify potential bottlenecks and operational constraints of an airport. Processes in an airport involve many moving objects, and require a good performance that can be measured in several different performance indicators (Verbreack and Valentin 2002). For example, the discrete event simulation of passenger or baggage flows at airport terminals is a very common example in this field (Takakuwa 2003).

Airport modeling and simulation does not only provide benefits to decision makers but also support airport designers, airport engineers, aircraft manufacturers, etc. For example, aircraft manufacturers can utilize simulation to analyze and optimize the relationships between aircrafts and the airport system. Airport design is an important and widely studied research topic. There are various organizations and research groups which are dedicated on this subject. For example, the Airport Design Studio at the University of California, Berkeley provides a diverse group of researchers, students, and faculty with a unique facility dedicated to accommodating research in contemporary design, planning and management for airport and aviation systems (Airport Design Studio, 2014). A consortium of 8 universities contracted by the Federal Aviation Administration to provide research support for a wide variety of aviation issues is another example. The consortium was awarded the NEXTOR II contract in 2011, and builds upon the success of the original NEXTOR consortium. For example, short courses about airport systems planning and design are conducted for many years.

This work will present a metamodel and a model driven approach which will help airport designers to develop airport models and evaluate alternative options prior to implementation. Analyzing the performance of existing or planned facilities in an airport and assessing the layout of the airport prior to implementation can potentially reduce the implementation costs and increase the chance of successful airport systems.

In the latest global passenger survey conducted by IATA (International Air Transport Association) in June/July 2013, it is reported that %55 of respondents had experienced travel disruptions in the past 12 months (Behan, 2013). Besides, three out of four (%77) experienced severe delays of more than 2 hours. Delays occur with parking, checking in, security screening, passenger identification, limited luggage weight control, safety procedures at boarding, etc. Although passengers acknowledge the need for increased security, delayed boarding, cancelled flights, long waiting times have created an environment of passenger dissatisfaction (Guizzi, Murino and Romano, 2009). Therefore operational efficiency at an airport can have a direct impact on user and customer satisfaction. We believe that modeling and simulation can help to analyze the existing systems to understand the current problems, as well as to evaluate the future airport designs.

The proposed metamodel will be used to draw airport design models, and to transform these models into discrete event simulation models automatically. This work is the initial part of a research project about model driven development of airport simulation models. Following two sections provide more information about airport systems and model driven development respectively. Section 4 presents the metamodel and Section 5 illustrates how the metamodel will be used. Section 6 presents the future work and conclusions.

2. AN AIRPORT SYSTEM

An airport system consists of many integrated components to provide facilities and services for air transportation. Each of these components and operations need to be carefully considered during the design of an airport. An airport basically consists of terminals, runways, taxiway, apron, access roads, parking facilities, hangar, fire station and emergency services, etc. For example, Figure 1 shows a simple airport layout with a single terminal. Planning the airport layout, deciding the positions and connections of each component is a very important design problem.

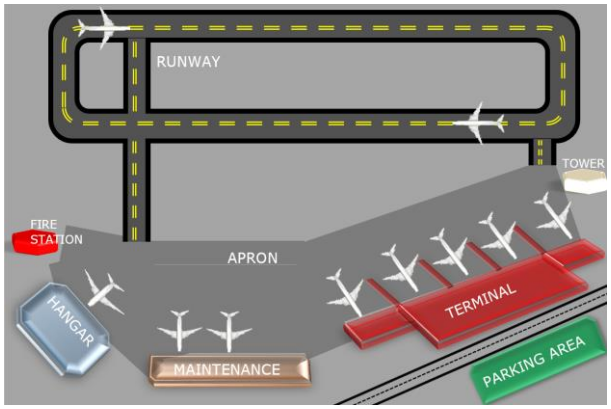

Figure 1: An example airport layout.

For example, the length of runway, the position of parking facilities, the location of the tower, wind analysis for the runway, etc. are very important and the design should conform to the national and international standards such as the airport design guidelines of Federal Aviation Administration of U.S. Department of Transportation (FAA, 2014), or standards by ICAO (International Civil Aviation Organization). Each airport needs to include different means of inland transport (such as road and rail system) and provide various services to passengers (Guizzi, Murino and Romano, 2009). As stated in the previous section, the overall experience of a passenger at an airport can be time consuming. Hence, a systems thinking approach for airport systems can provide an in-depth knowledge of airport structure and operations.

The number of airports in Turkey, as in many countries, has increased in the last decade. While 33 airports were actively used in 2001, there are 52 airports in Turkey as of 2014. Figure 2 shows the increase in number of passengers for Turkish air transportation. The number of passengers increased %233 in 10 years (DHMİ, 2014).

Today, due to the increase in aircraft and passenger traffic, improving the efficiency of airport operations and passenger satisfaction has become very important. Therefore, some requirements need to be taken into account when building airports such as reliability, safety, flexibility, comfort and high-quality. Airport modeling is an effective method for airport analysis and design to satisfy these requirements.

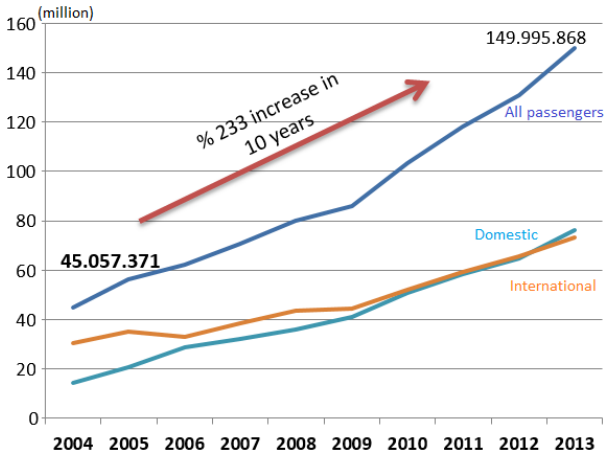

Figure 2: Passenger traffic in Turkish airports.

2.1. Passenger Terminals

Due to the fact that passengers spend most of their time before boarding at the terminals, airport terminal modeling has been widely studied in the literature to optimize passenger flows (Takakuwa 2003; Guizzi, Murino and Romano, 2009). An example airport terminal layout is given in Figure 3. A typical terminal includes check-in counters, gates, security check points, shops, restaurants, baggage claim, customs office, etc. Similar to the overall airport design, terminal design is also very important and each of these components and operations need to be carefully planned.

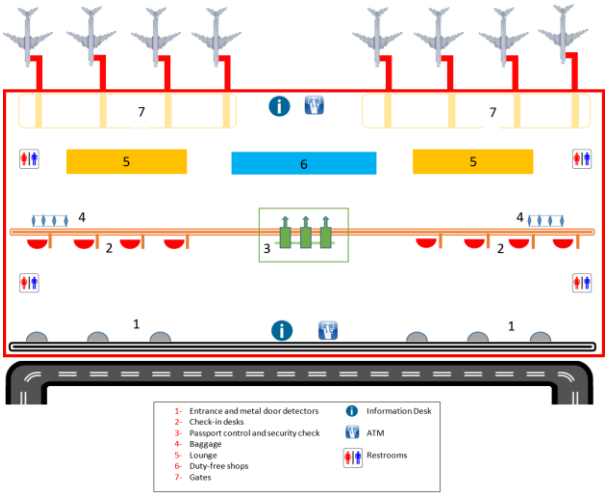

Figure 3: A sample airport terminal layout.

The aviation organizations define the standards and minimum requirements for efficient and safe terminal applications. For example, IATA (International Air Transport Association) defines industry norms for various components and services such as walking distances of passengers, aided or unaided. Similarly, airport passenger terminal planning and design guidebook of the Airport Cooperative Research Program presents the requirements and the guidelines for terminal design (ACRP, 2010). Any airport design and implementation should take care of these kind of regulations.

During the first stage of the project, the focus of the metamodel is currently on airport terminal modeling due to fact that the available knowledge and the simulation models in the literature can provide a sound basis. In the later stages, a comprehensive metamodel for airport modeling will be developed.

2.2. Airport Modeling and Simulation

Today, with the emerging computer technologies and simulation research, major airport developments are conducted with the use at some level of airport modeling and simulation and GIS techniques. Especially, to comply with the more stringent security measures at airports airport terminal simulation became essential and critical (Ashford, Mumayiz, and Wright, 2011). Airport simulations generally address and analyze the following problems and features: airport-airspace capacity studies, airport impacts on the environment, airport's functions and services, landside simulation, vehicle and people movements, baggage flows, etc. In the future, the demand for air transportation of passengers is expected to increase. This means that airport design and engineering discipline will need more tools and methods to optimize the processes and functions at the airports.

There are various tools to support airport design and to perform airport simulations such as SIMMOD and TAAM (Total Airspace and Airport Modeller). In order to achieve reasonable outputs various input data is required such as flight schedules, number of passengers, passenger characteristics, security control service rates, and so on.

Recently, more formal approaches in airport modeling and simulation have emerged. For example, Skorupski (2013) presents the concept of airport traffic modelling using coloured, timed, stochastic Petri nets. By the example of an airport with one runway and simultaneous takeoff and landing operations, the applicability of such models in analysis of air traffic processes is shown. Davidrajuh and Lin (2011) presents a similar effort as well. They show how to explore airport traffic capability using a Petri net based model.

In this work, the metamodel for airport modeling can be transformed into formal models such as Petri Nets or DEVS (Discrete Event System Specification). The formal models and formalism based simulation is explained in (Zeigler, Praehofer and Kim, 2000) and (Mittal and Risco-Martin, 2013).

3. APPLYING MDD4MS

Model driven development (MDD) approaches have been commonly used in the last decade in the simulation field. Çetinkaya, Verbraeck and Seck (2011a, 2011b) propose a general MDD framework for modeling and simulation (MDD4MS). The MDD4MS framework presents an integrated approach to bridge the gaps between different steps of a simulation study by using metamodeling and model transformations.

Metamodeling, in MDD context, is the process of complete and precise specification of a modeling language in the form of a metamodel. A model transformation is the process of converting one or more source models into one or more target models according to a set of transformation rules. The MDD4MS framework defines three metamodels for conceptual modeling, simulation model specification, and simulation model implementation. Metamodel based model transformations provide the continuity throughout the M&S life cycle.

Applying MDD4MS in airport terminal modeling and simulation will provide new design mechanisms for airport planning. This study brings Software Engineering, Systems Engineering and Aeronautics disciplines together. The relationships between these three disciplines are shown in Figure 4. In particular, this work combines model driven development and airport modeling and simulation. Although there are some research in MDD literature that uses air transportation or airports as application domains or for illustrative purposes (Oetsch, 2011; Shaw, 2013), to the best of our knowledge, there are no metamodeling and MDD research proposed for airport modeling and simulation.

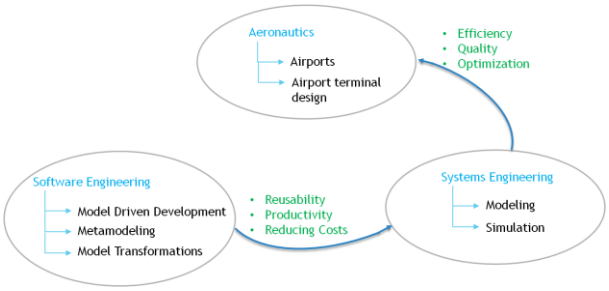

Figure 4: Interdisciplinary research on airport modeling and simulation.

Although simulation modeling is commonly used in this field, in most cases the development of a simulation model for an airport is expensive and takes time. However, with MDD approach the model generation can be automatic and simulation models can be developed more quickly.

In other words, once a conceptual model of the existing or proposed airport is developed, it can be transformed to a platform independent simulation model. The remaining steps can be automatic for a specific simulation platform. In this study, the proposed metamodel for airport conceptual modeling will provide means to determine some parameters for discrete event simulation. In this way, the airport design models can be transformed into simulation models easily.

Figure 5 shows the application of MDD4MS for airport modeling and simulation. There will be two model-to-model transformations and one model-to-code transformation. In case of transforming into a simulation language which is supported by a visual tool, such as the simulation programs like Arena or Simio, the model-to-code transformation is not needed. Our research will focus on transforming models into a simulation language instead of a general programming language.

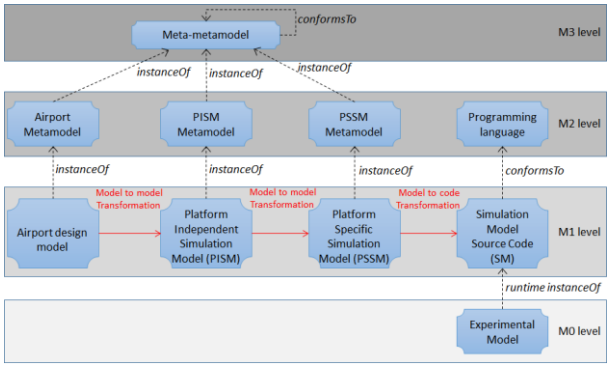

Figure 5: MDD4MS based airport modeling and simulation.

4. METAMODEL FOR AIRPORT MODELING

In this section, we present a metamodel for airport modeling and simulation. The high level view of the metamodel is given in Figure 6. The metamodel is developed in GME (Generic Modeling Environment) version 14.

GME is a free and open source meta programming tool developed by Vanderbilt University. In GME, metamodels are defined as modeling paradigms. Upon loading a modeling paradigm, the MetaGME (the meta-metamodel) interpreter automatically creates an environment for model development in the specified modeling language. GME has a decorator facility for nicer visualization of the models. It is also possible to define some constraints on the metamodel with OCL.

Passengers, airlines and flights are modeled separate from the airport. All other components are modeled as part of an airport. Basically, an airport can have:

- Terminal
- Runway
- Apron
- Hangar
- ARFF (Airport rescue and firefighting station)
- Parking area
- Taxiway

As well as, a terminal can have:

- Entry point (metal door detectors)
- Passport control
- Security check
- Check-in
- Customs office
- Information desk
- Luggage conveyor
- Lift
- Other airport services
    - Car rental company
    - Change office
    - Shop
    - Restaurant
    - ATM
    - Ticket office
    - Restrooms

The metamodel includes two aspects, one for structural representation and one for activity modeling. Both diagrams form an airport design model. As an example, the diagram in Figure 7 shows passenger flow in an international departure terminal. Once an airport design model is ready, it can be transformed to a simulation model.

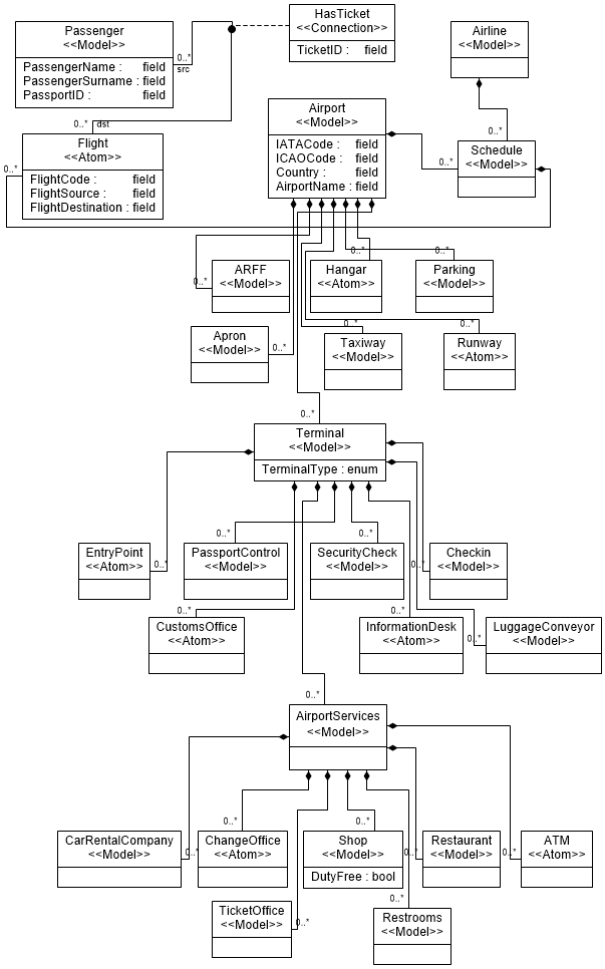

Figure 6: High level view of the airport metamodel.

In order to verify the feasibility and the correctness of the metamodel, the official airport planning and design documents of the Directorate General of Civil Aviation in Turkey will be used (SHGM, 2014). These documents provide the requirements and the constraints for airports, similar to Airport Development Reference Manual by IATA. As a practical case, the metamodel is aimed to be used to model and analyze the activities in one of the Turkish airports. The planned case study will help to evaluate and validate the metamodel.

5. FUTURE WORK

The project has started with terminal modeling and it will continue with the other components and functions of an airport. Our research is going on for developing the metamodel and generating the modeling editor. Model transformation rules will be written next. Currently, the simulation platform is chosen as one of the commercial discrete event simulation tools.

However, in the later stages of the project, the airport design models will be transformed into a more common formalism such as DEVS to provide platform independence.

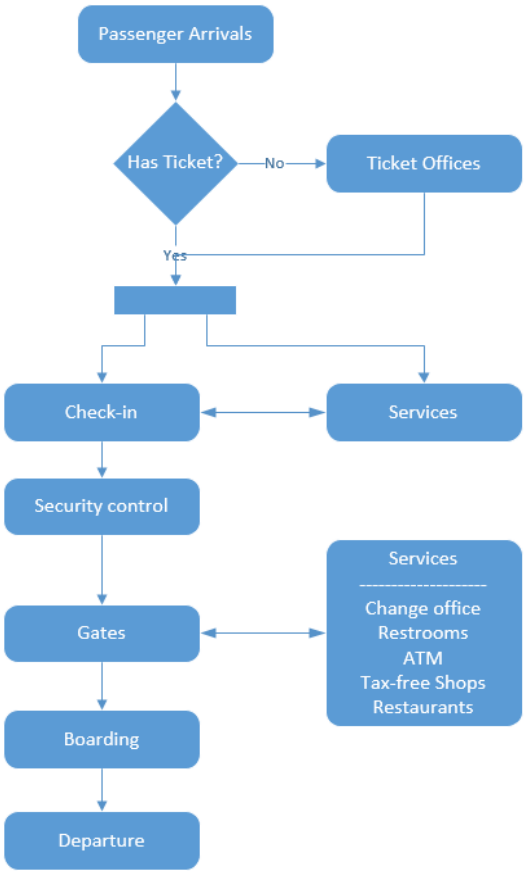

Figure 7: Passenger flow in an international departure terminal.

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