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SIMULATION OF STREETCAR AND BUS TRAFFIC

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ABSTRACT

This paper describes the design and application of a SIMAN-model of a streetcar and traffic system. The model includes an animation of the traffic process. It will be discussed different approaches for modeling a traffic network. The animation systems CINEMA and Proof Animation were used for the animation. The model has been used for an enterprise for streetcars and buses in Magdeburg, Germany.

1 INTRODUCTION

This paper describes different approaches for modeling streetcar and bus traffic systems. Models have been applied to analyze schedules of streetcars and busses, change time for passengers between different streetcar lines, change time between streetcars and busses depending on the time of day (morning, evening and night) and consequences of new routes.

It will be discussed model objectives, input data requirements, different modeling approaches with SIMAN, model output and animation with different systems. Some features of model architecture are discussed in detail. Finally it will be discussed the model's application to the Magdeburger Verkehrsbetriebe AG (MVB), the enterprise for streetcar and bus systems in Magdeburg, Germany.

2 MODELING

2.1 Restriction for model development

The different models were developed at the University of Magdeburg, where the simulation language SIMAN is sometimes used in courses for discrete simulation. We used SIMAN to model the traffic system. For animation, we used CINEMA, a special animation system for SIMAN, and Proof Animation a general post-processing animation system.

For our simulation studies we developed three different modeling approaches:

- Modeling with elementary SIMAN-elements and animating with CINEMA
- Modeling with SIMAN guided transporter features and animating with CINEMA
- Modeling with elementary SIMAN-elements and animating with Proof Animation.

Prototypes were developed and tested for each approach. One approach was selected as best after testing.

2.2 Model objectives

The simulation model gives the MVB management and engineers the capability to
- use a realistic model of the streetcar and bus traffic network, including all stations, switches and yards
- simulate traffic throughout the entire day
- visualize traffic in a network,
- compute special traffic system parameters.

2.3 Model Input

The model inputs can be divided into two classes :
- network information and
- route information.

Network information contains all lanes, yards, terminals, stations and tracks with switches for streetcars.

Up to 13 routes for streetcars and up to 18 routes for busses exist in the Magdeburg traffic system. Different cars or busses going on a given route are called trains. One rout consists of two terminals and some stations. The logical structure of a route is presented in Figure 1.

Time tables exist for every route with departures times from the terminals. Table 1 gives an example for a time table.

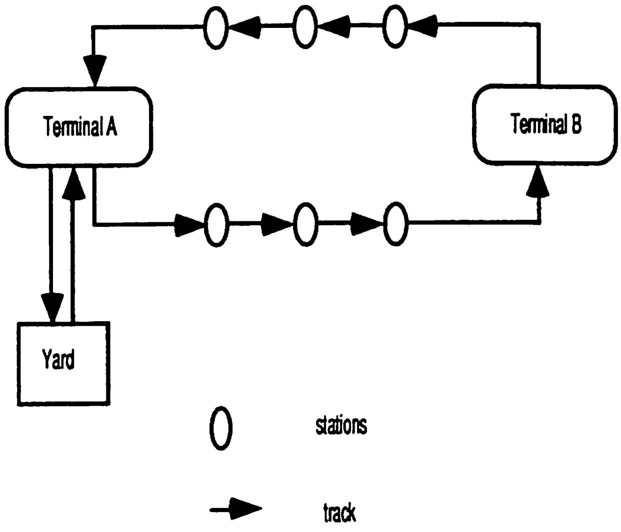

Figure 1: Logical structure of a route

Table 1: Excerpt from a time table for route 1

Terminal	train 1	train 2	train 3
Sudenburg	4:33	4:53	5:03
Neustadt	5:14	5:34	5:44
Sudenburg	6:04	6:24	6:34
Neustadt	6:45	7:05	7:15

Tables exist for the travel times between the stations too. Table 2 shows travel time between some stations for course 1.

Table 2: Excerpt from a table of travel times

station	length	travel time
Sudenburg		
Jordanstr.	0.4	2.10
Nikolaistr.	0.6	2.30

3. MODELING WITH ELEMENTARY SIMAN-ELEMENTS

The following section describes the modeling of the traffic system with elementary SIMAN-Elements without animation.

Routes consist physically of three elements :

- **station** (passenger get out or get in ; terminal can be modeled like station)
- **track** (busses or cars travel on these elements which connect stations with other stations and with switches)
- **switch** (busses or cars can use switches to switch to another track)

SIMAN SEQUENCES elements are used to model the chronological order and travel time in routes. Every station, track and switch for one route are described in SEQUENCES elements. Here is an example of such a SEQUENCES

```
SEQUENCES: 1,
                    Sudenb834&
                    Jordan835,2.1&
                    Nikolai836,2.3&
                    ...
```

A station is modeled as a resource with a capacity of 1 or 2. Switches can be used by only one train at time. So switches are modeled as resources with a capacity of one. Tracks have different lengths. They are modeled as resources too. Track resource capacities vary, depending on track length.

Trains are modeled as entities with numerous attributes like route number and train number. Figure 2 shows a cycle used to model the movement of a train.

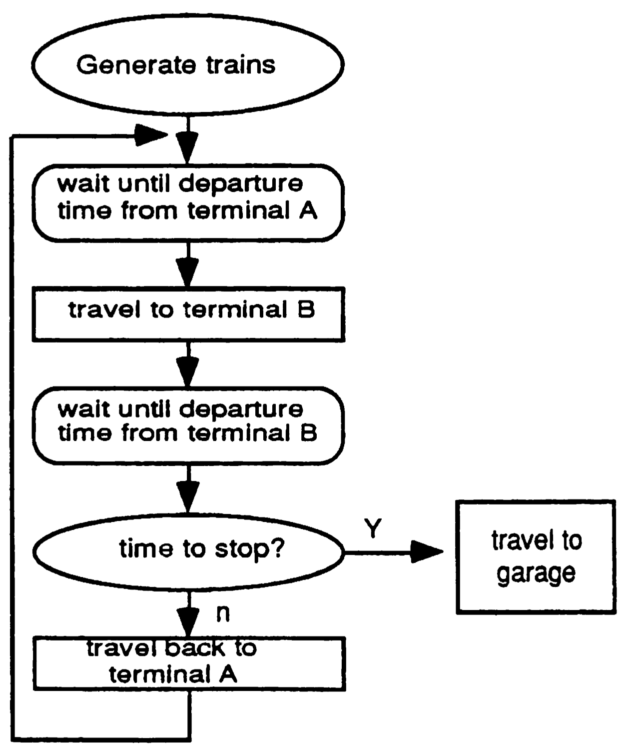

Figure 2: Cycle of a train movement

A typical sequence for a train, shown in figure 3, consists of the following elements :

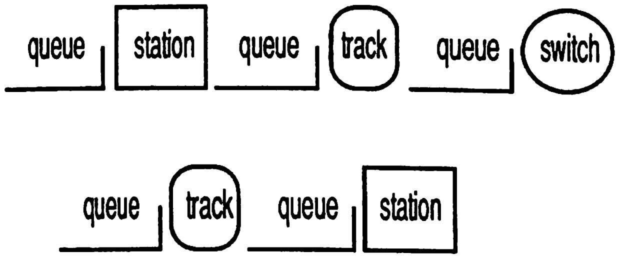

Figure 3: Sequence for a train

Using SIMAN-STATIONS submodels reduces the model size. We developed STATIONS submodels for stations, switches and tracks. The submodel for stations and switches consists of the following statements, for example.

```
STATION,    BU832 - BU1083;        all stations
QUEUE,              M;
SEIZE,              HAST(M-Halte_off);
BRANCH,             1:  ! who was predecessor

RELEASE,    STRECKE(St-number);
```

Connections between STATION submodels are modeled with the ROUTE-Block.

4. MODELING WITH SIMAN GUIDED TRANSPORTERS

This section describes an alternative modeling approach. This approach is based on using guided transporters for modeling streetcars and busses.

Stations and switches are modeled as INTERSECTIONS-Elements. In the model tracks are representd by LINKS-Elements which connect INTERSECTIONS-Elements. Busses and streetcars have their own networks, which are modeled in NETWORKS-Elements. Trains are modeled as guided transporters. Every route has its own transporter set. The ´driver´ for a train is modeled as an entity. The driver gets information for his next step from SEQUENCES-Elements. Using this approach provides a clear model structure, as shown in the following example :

```
; Transport on course 1
CREATE      0.0,8;              8 drivers
ASSIGN:     is=1:ns=1;          Index
READ,       ...;        Start from Terminal A
DELAY,      ...;        Wait until time to start
QUEUE,      Q_Call_L1;
REQUEST:    L1(SDS),1,STATION(Sudenburg);
;      take a train
DELAY:      ...;        passengers get in and out
STATION     L1_IN  ;          jump address
ASSIGN:     home = m;
TRANSPORT:          L1,,10/speed;
```

Transport operations are described in the same way for the other routes. Trains will wait at stations and switches, as shown in this example :

```
STATION,    Agnete - Zollstr;  all stations
DELAY:      ... ;  passengers get in and get out
ROUTE:      home    ;

STATION,W_Agnete - W_Zollstr; all switches
DELAY:      ...;        train goes over a switch
ROUTE:      home    ;
```

5. ANIMATION WITH CINEMA

The animation objective is to be able to visuallize the movement of cars and busses in the traffic network. CINEMA is an on-line animation system. Simulation and animation work parallely. Different approaches can be taken for our different modeling approaches. In the first part of this section we discuss animation with Cinema and modeling with elementary SIMAN-Elements.

5.1. Elementary SIMAN-Elements with CINEMA

CINEMA entity symbols graphically represent the entities that move through the system. All trains of one course get their own symbol. An entity symbol is only displayed when it is residing in a dynamic object included in the layout.

CINEMA station symbols were added to the layout. These symbols correspond to the STATION-Blocks in the SIMAN-model. The stations are connected via route paths. Route path animate the inter-station movement corresponding to the transfer of entities between stations via the ROUTE-Block. An entity is displayed while moving along the route paths. At the destination point the entity disappears from the route path and the entity must reappear.

The first block in our STATION submodel is a QUEUE-Block. If the following resource has unused capacity to pick up the entity, the resource can show this new condition and the entity can leave the route path. In another case the entity has to wait on the path. But the animation system doesn't know this fact and the entity disappears. A path-element with an accumulating possibility would be here desirable.

We simulated the case that trains couldn't pass a station but had to wait in front of the station. But the entities disappeared from the screen, leaving no visible evidence of a waiting line.

These difficulties caused us to reject this SIMAN-CINEMA combination.

5.2 Transporter Elements with CINEMA

We defined a special CINEMA-Transporter symbol for every TRANSPORTER-Element. Busy transporters are shown moving along a path. Such a path is constructed with intersection and link symbols.The animation system in connection with the control of the guided vehicle movement allows a good view of the streetcars and busses while they travel in the system.

This combination can only be used for small traffic systems. What are the reasons for this restriction ?

One reason is the pixel-oriented display technique of CINEMA. It wasn't possible to draw all paths and links on the screen. Zoom functions are necessary for traffic networks. Another reason is the higher CPU-time for controlling the vehicle movement. And so this combination of SIMAN and CINEMA was rejected too.

6 ANIMATION WITH PROOF

Proof Animation allows a post-processed animation of streetcar and bus movement in the traffic network. The system allows animation of large networks. With its vector-based geometry it allows zooming for detailed presentations. Figure 4 shows complete network for the streetcar und bus system in Magdeburg.

Three events were defined to write what is known in Proof as an Animation Trace File (ATF):
- creation of a new train
- placement of a train on a path and defination of the travel time
- destruction of a train.

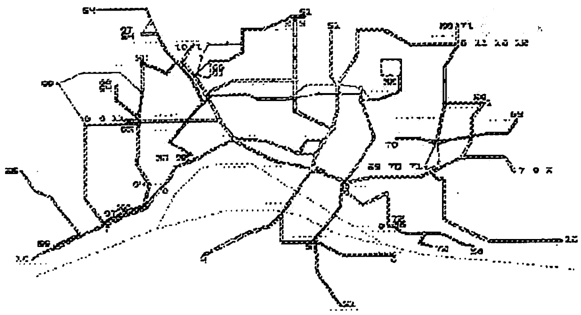

Figure 4: Complete network in Magdeburg

We didn't use the SIMAN WRITE-Block to write out the ATF-File. Special C-routines were used for this. It was necessary to use C-routines because the WRITE-Block can't write string variables to define path names. An ATF-File corresponding to a 10-hour simulation is about 1.5 megabytes in size.

Our work with SIMAN and PROOF shows that this combination is a very powerful tool for simulation and animation of traffic systems.

7 OBSERVATIONS

The following section shows some results using elementary SIMAN-Elements. Figure 5 displays the change times in minutes of passengers between different streetcar lines in one irection at one station

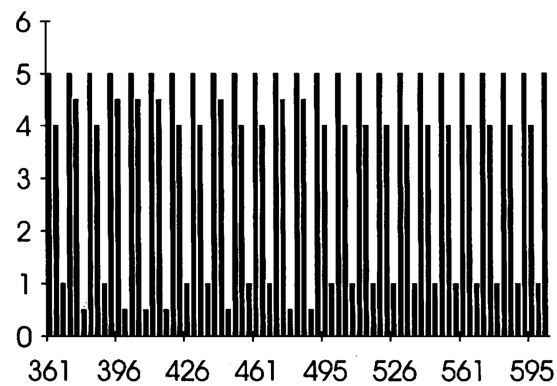

Figure 5: Change times for passengers between different streetcar lines

Total travel times per day differ according to the routes and trains. Figure 6 presents thees times for all trains from course 1.

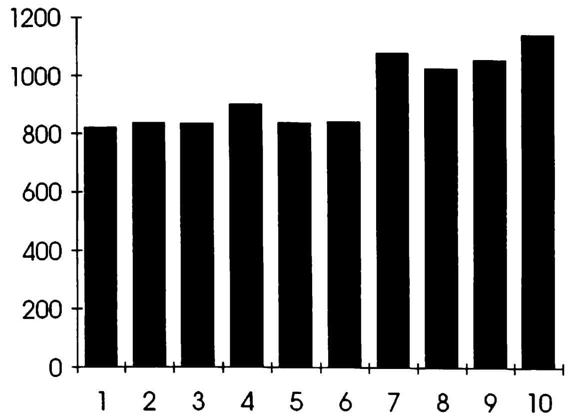

Figure 6: Total travel times per day for some trains

Total number of all trains in use at a particular time is an important value for the management. Figure 7 shows this total number from 6.00 a.m. to 12.00 a.m. on a normal day.

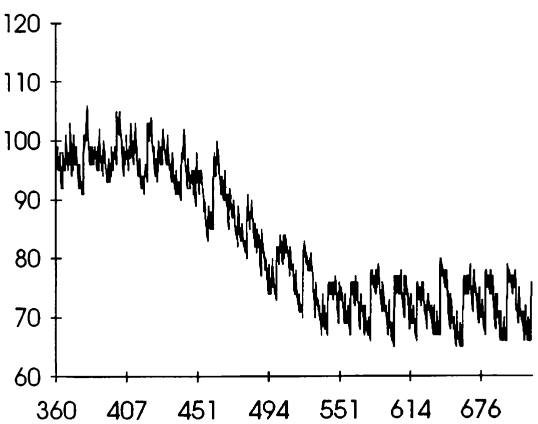

Figure 7: Total number of trains in use

The changing times between streetcars and buses are important for passengers and so for the acceptance of new routes and new time tables. Figure 8 shows thees changing times at a crossing point between streetcars und buses depending on the time of day.

The simulator provides the MVB management and engineers with a very powerful tool for the detailed analysis of track layouts, schedules and special technical parameters.

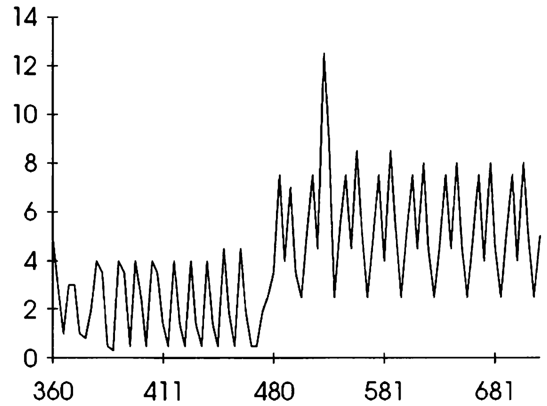

Figure 8: Changing times for passengers between streetcars and busses

REFERENCES

Henrikson, J.O. and N.J. Earle, Proof Animation : The General Purpose Animator In *Proceedings of the 1992 Winter Simulation Conference,* ed. J.J. Swain, D. Goldsman, R.C.Crain, J.R.Wilson, 366 pp.

Conrad, S.A. , Sturrock, D.T. and J.P.Poorte, Introduction to SIMAN/Cinema In *Proceedings of the 1992 Winter Simulation Conference*, ed. J.J. Swain, D. Goldsman, R.C.Crain, J.R.Wilson, 366 pp.

Atala, O.M. , Brill, J.C: and J.S. Carson, A General Rapid Transit Simulation Model with Both Automatic and Manual Train Control In *Proceedings of the 1992 Winter Simulation Conference,* ed. J.J. Swain, D. Goldsman, R.C.Crain, J.R.Wilson, 366 pp.

AUTHOR BIOGRAPHY

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