Synthesis and research of a controller for microclimate stabilization in an automobile based on finite state machines

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Abstract: The model is designed to control the temperature in a car body by opening and closing a window. The control of the window is done mechanically, by a button for lowering and raising or automatically, by a logic controller realized on the basis of the theory of finite state machines. Automatic control leads to energy savings and helps maintain the driver's concentration.

Keywords: *energy saving, logic controller, climate control*.

1. Introduction

Maintaining a favorable microclimate in the cabin of a car is related to ensuring the performance of passengers and directly affects the mood and emotions of both the driver and passengers. Energy efficiency in this process is particularly important in order to save energy, hence fuel and protect the environment.

The general statement of the research is shown in Fig.1. This is a Matlab-Simulink model [4].

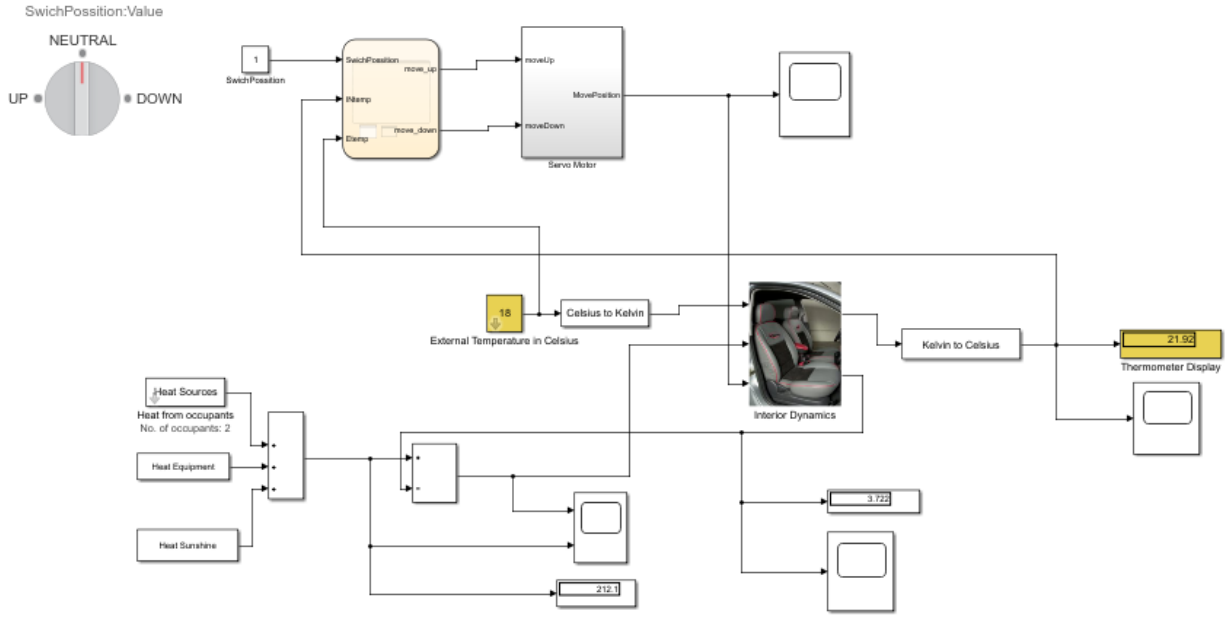

Figure 1. The general statement of the research

2. Processes in the interior dynamics

The temperature in the cabin is accumulated by:

- incoming energy emitted by the number of passengers;
- the energy from the working appliances in the cabin;
- solar energy that enters through glazed surfaces;
- thermal convection, which occurs when opening and closing the window.

The model of thermal and thermodynamic processes in the car body are shown in Fig.2.

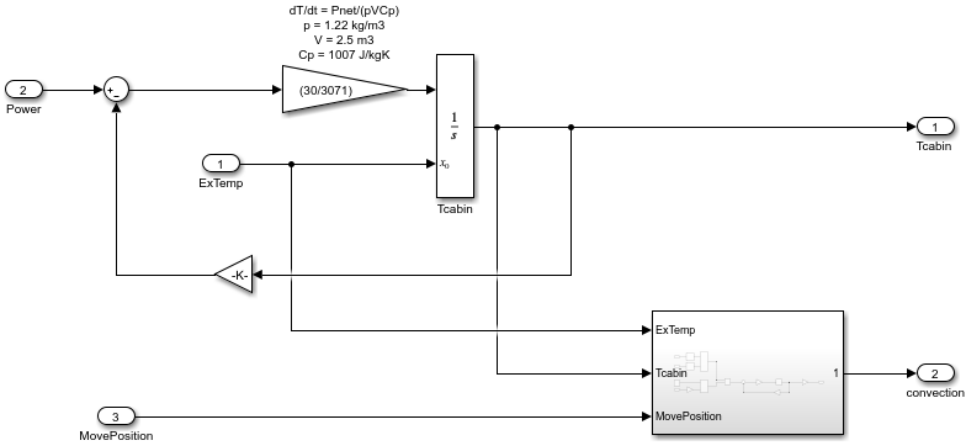

Figure 2. Mathematical model of the thermal processes in the car

The heat given off by the equipment operating in the passenger compartment is determined by [1]:

- electrical heat equivalent Y / kWh;
- power used kW;
- the coefficient of useful activity.

The value of the conditional solar constant is 1.32-1.34 Kw / (m² x min) [2].

The rate of heat transfer by convection Q˙_conv is determined by Newton's law of cooling [3], expressed as:

$$\dot{Q}_{conv} = hA(T_S - T_f) \quad (1)$$

where: $\dot{Q}_{conv}$ is heat transfer rate, (W); A is heat transfer area, (m^2); *h* is convective heat transfer coefficient, (W / (m^2.K)); T_s is surface temperature, (K); T_f is outdoor temperature, (K).

The model of the convection system is shown in Fig.3.

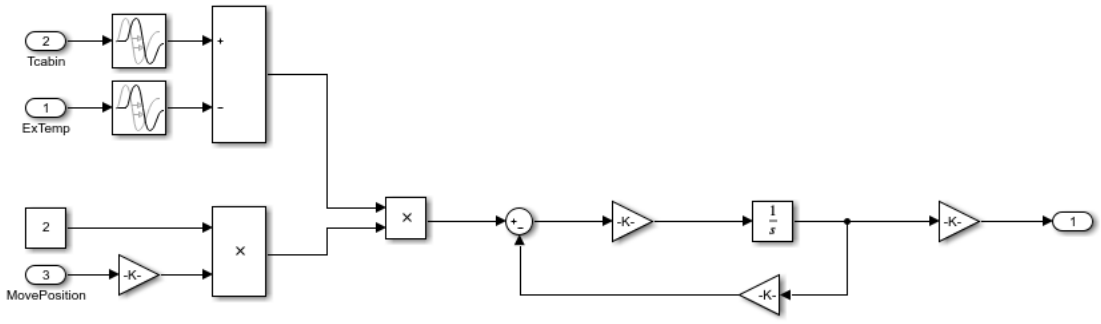

Figure 3. Convection system model

3. Inputs and Outputs

The model is realized so that it is possible at any time to monitor the incoming heat energy in the interior dynamics of a car compartment and the outgoing energy from convection. The working process of temperature regulation can be seen in Fig.4. In this figure, the temperature is shown like function of time.

The working actuator in this system is a window of the car. The temperature is regulated by changing of the window position. Temperature changes in the cabin and the movement of the window

are observed until the thermal processes are stabilized. The process of moving the window is shown on Fig.5. In this figure the moving of the windows is shown like function of the time.

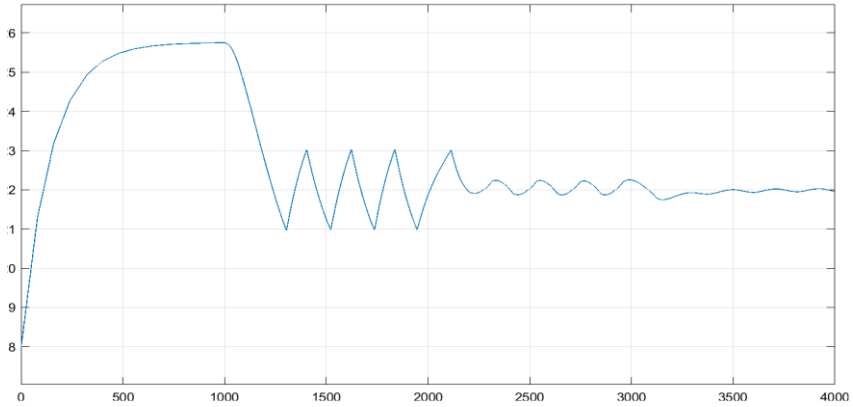

Figure 4. Graph of temperature changes of interior dynamics like function of the time

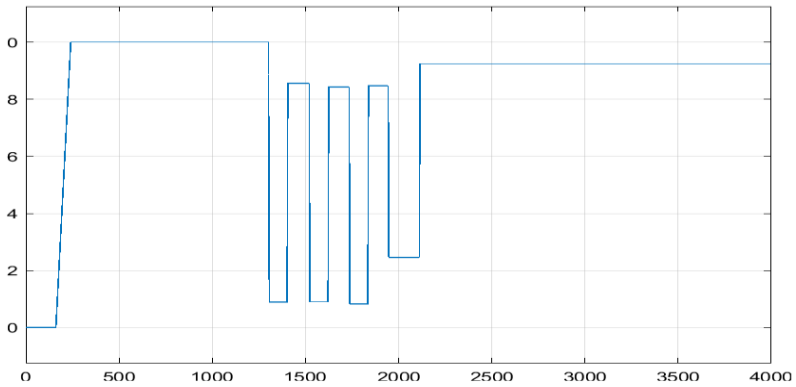

Figure 5. Window movement schedule like function of the time

4. Implement a controller for Automatic window control based on finite state machines

The logic of the controller driving the process of thermoregulation of the car body has been developed, using the theory of the finite state machines. This logic is shown in Fig.6.

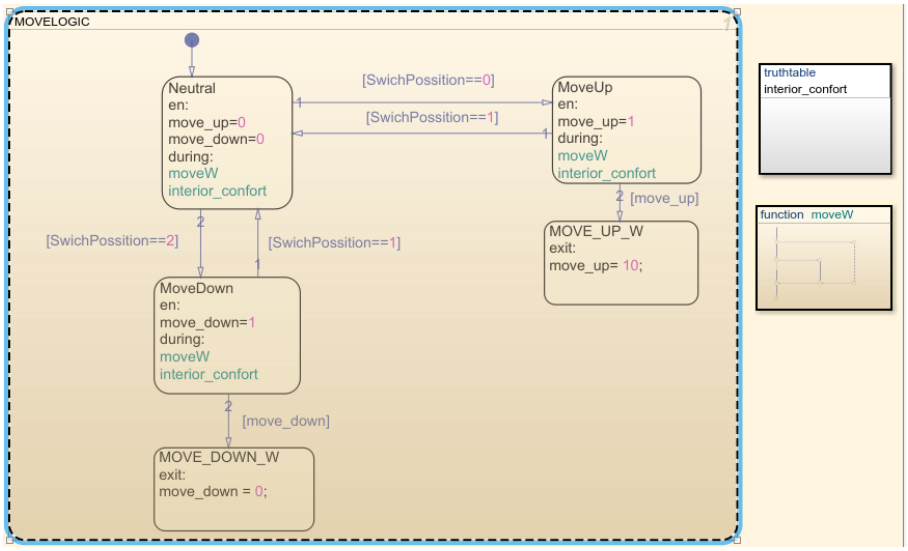

Figure 6. The control logic of termoregulation

Fig.6 shows that the control logic is based on three main states: Neutral; Move up; Move down. 4.2. The transition from one state to another is done by a condition for the position of the key. While the logic is in a given state, it sends a signal to the servo motor that drives the window. The mechanical drive is set by a function If-Else-If-Else on Fig.7:

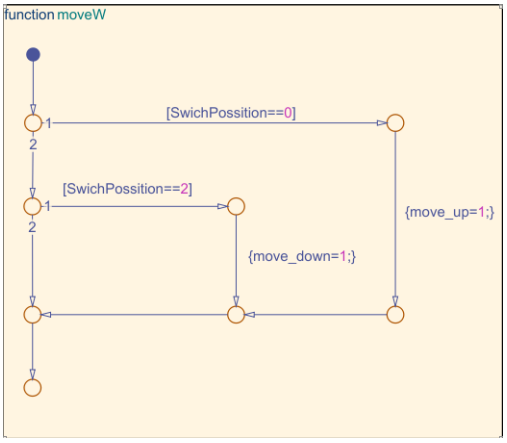

Figure 7. If-Else-If-Else function to perform a conditional action

In the automatic mode the window drive is controlled by a truth table shown in Fig.8.

Condition Table

	DESCRIPTION	CONDITION	D1	D2	D3	D4
1		INtemp>=23 && Etemp<=23	T	-	-	-
2		INtemp<=23 && INtemp>=21 && Etemp<=21	-	T	-	-
3		INtemp<=21 && Etemp<=21	-	-	T	-
		ACTIONS: SPECIFY A ROW FROM THE ACTION TABLE	A1	A3	A2	A3

Action Table

	DESCRIPTION	ACTION
1	Move Down Window	A1: move_down=1; move_up=0;
2	Move Up Window	A2: move_down=0; move_up=1;
3	Neutral Window Position;	A3: move_down=0; move_up=0

Figure 8. Truth table to command a window according to temperature

The truth table fulfills the conditions:

- if the internal temperature is greater than or equal to 23 degrees and the external temperature is less than or equal to 23 degrees, send a move signal down to window;
- if the inside temperature is between 23 degrees and 21 degrees and the outside temperature is less than 21 degrees, the window stay in the neutral position;
- if the internal temperature is less than or equal to 21 degrees and the external temperature is less than or equal to 21 degrees, send a signal to window to move up.

The controller takes a signal for the position of the key, a signal from the outside temperature and a signal from the temperature in the compartment. One signals is output from the controller to the servo motor, for upward and downward movement.

5.Conclusions

1. The Finite State Machine are widely used in the control of automated devices. The program for the development of stateflow automata is convenient for programming, as it works in conjunction with other programming languages.
2. Working with Simulink allows the installation of the Finite State Machine in many ready-made models. The Finite State Machines allow the development of different complexity control models through different built-in logics.
3. The advantage of vending machines is that they have a memory that allows you to start from the last active state when revisiting

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