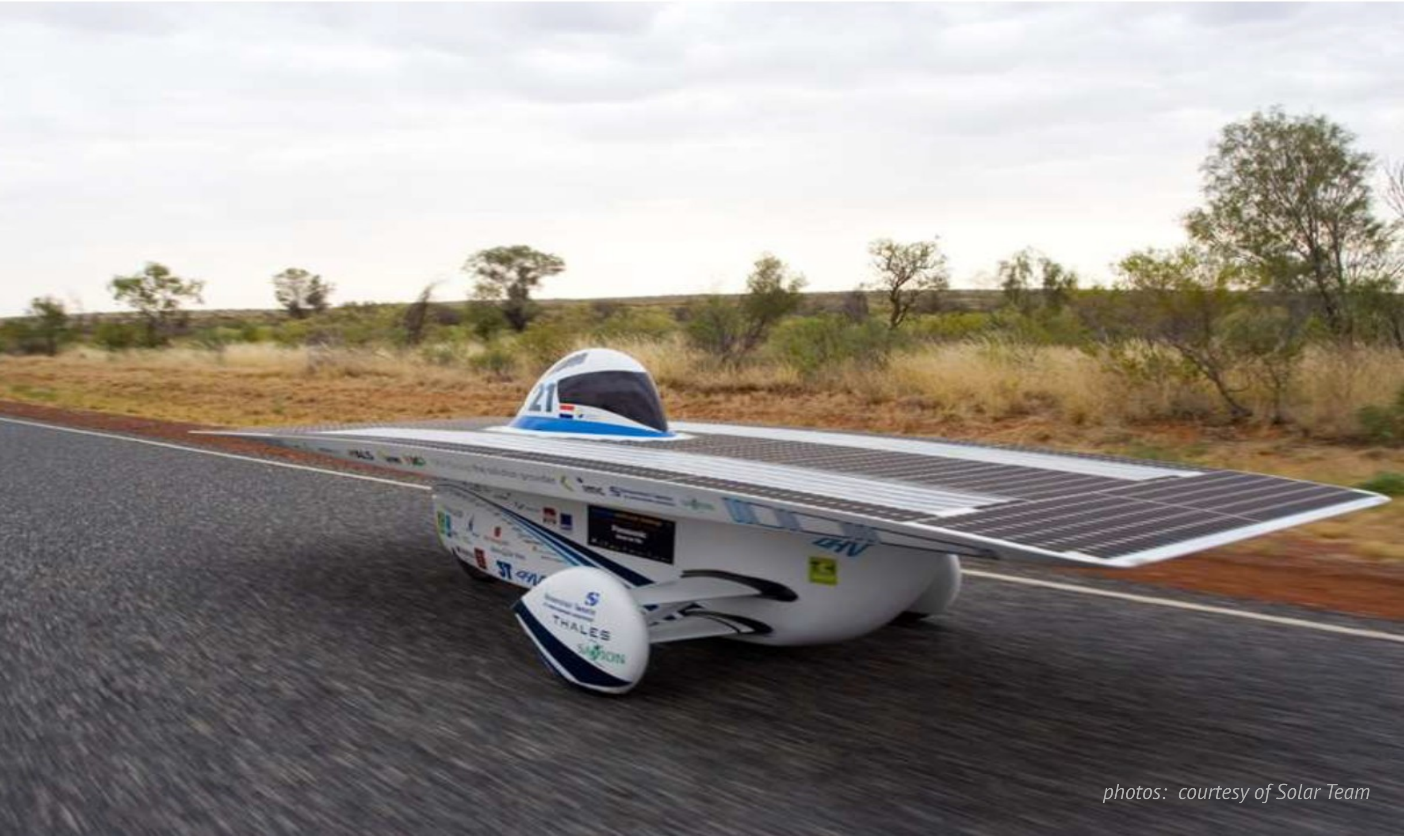

photos: courtesy of Solar Team

Automotive

Solar Team Twente race strategy

By Martin Vermeer and Anne Leenstra - Solar Team Twente

In November 2007 the Solar Team Twente competed for the second time in the World Solar Challenge. This event is held every two years in Australia. The goal is to cover a distance of 3012 kilometers in the shortest time possible with the sun as the only allowable energy source. Determining the optimal speed of the solar vehicle is one of the key factors in winning the race. As a lot of factors, like weather and aerodynamics, play an important role, it is a though task to determine the optimal speed. Therefore the solar car and its environment had to be modeled aiming to find the optimal speed profile for the complete 3012 km. For this task Controllab Products assisted the Solar Team Twente with modeling, programming and dedicated add-ons to the 20-sim program in order to fulfill this task.

Solar vehicle

A solar vehicle consists of three main components. The first is the solar panel, which converts the solar energy to electricity. The batteries of the vehicle can store the electric energy. Finally the energy can be consumed by the motor for propulsion. The battery enables the use of a racing strategy: use the energy directly for propulsion or store for later use. The '21', the solar vehicle of the Solar Team Twente was quite special. The car had a tilting wing and a solar concentration system using Fresnel lenses (see figure 1). In 2008 a patent was granted for this Fresnel system. Although these two distinctive features give the car an enormous energy boost, it makes the modeling of the vehicle even more complex and challenging.

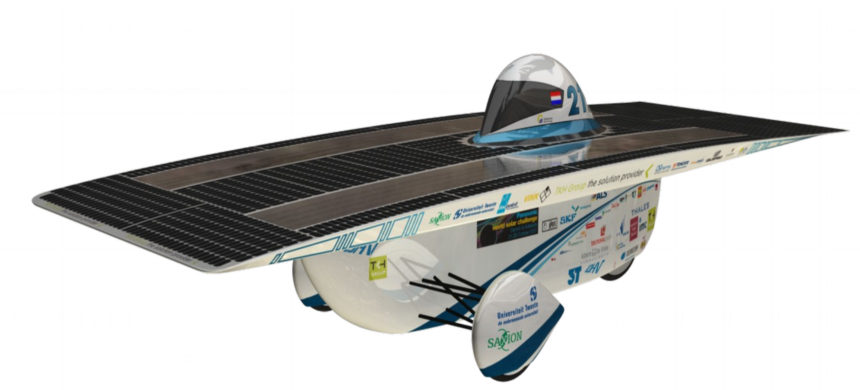

Figure 1: The solar car of the Solar Team Twente as it was used during the 2007-edition of the World Solar Challenge.

Problem

The problem of finding the best strategy for the solar vehicle can be divided in two parts: (1) determining the optimal speed and (2) monitoring the strategic velocity with the actual velocities. To find the optimal velocity of the vehicle, a model of the system should be made. This model must be representative for the real behavior of the solar vehicle, therefore the car must be modeled at a detailed level. This not only includes modeling the route and its direction, but also including the most accurate weather forecasts. As the weather conditions will affect the energy revenues as well as the energy consumption of the car. This is due to clouds, wind, temperature and other circumstances. After making a model of the solar car there still is an optimization challenge: how can we find the optimal speed for a certain position and time on the track. During the race the determined optimal race strategy has to be monitored and continuously compared to actual data given by one of the cars sensors. For this task Controllab Products extended their 20-sim program with several dedicated add-ons, which enabled the strategic monitoring.

Simulation

The simulation of the race was done in a few steps:

- The solar car dynamics were modeled.
- Weather conditions were implemented in the model.
- Route information and race rules were added.
- An optimization done to find the optimal velocity.

The dynamic car model is drawn in figure 2. This model is part of a more extensive model which also includes the weather forecasts and race regulations. The car model contains an electrical and a mechanical part. The advance of programming in 20-sim is that an electrical model can be made from standard 20-sim components as well as a mechanical model for the mechanical part. Besides standard blocks 20-sim allows the inclusion of mathematical expressions, as it was used for calculating the optimal tilting angle of the solar panel, as well as the energy revenues of the solar panel.

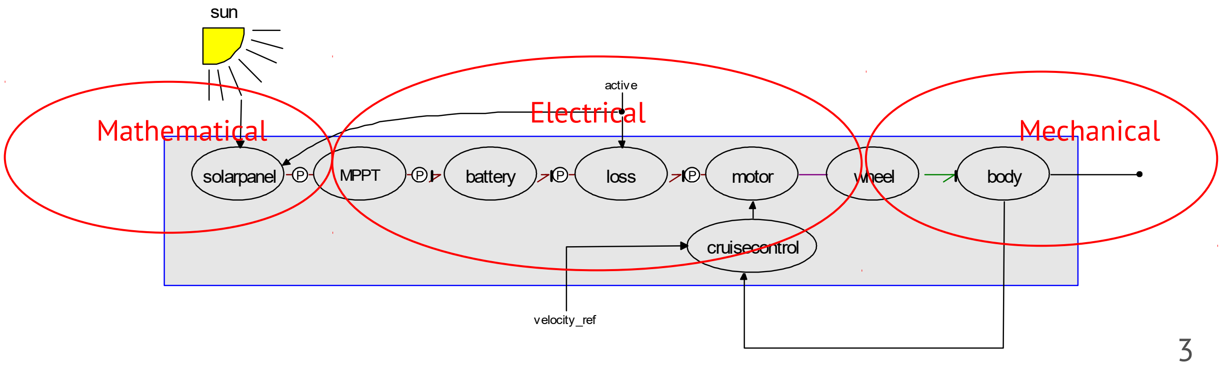

Figure 2: Model of the electrical, mechanical and mathematical part of the solar vehicle

On the one hand the electrical part of the car covers the conversion of solar power to the electric energy flowing to the battery pack and the motor. On the other hand the mechanical model of the car includes the wheel and body, which is responsible for the rolling resistance and aerodynamic drag. The standard optimization methods of 20-sim enable to optimize the vehicle speed for the complete race by dividing the race in stages of 100 km and optimize according to scores given to battery voltage and finishing time.

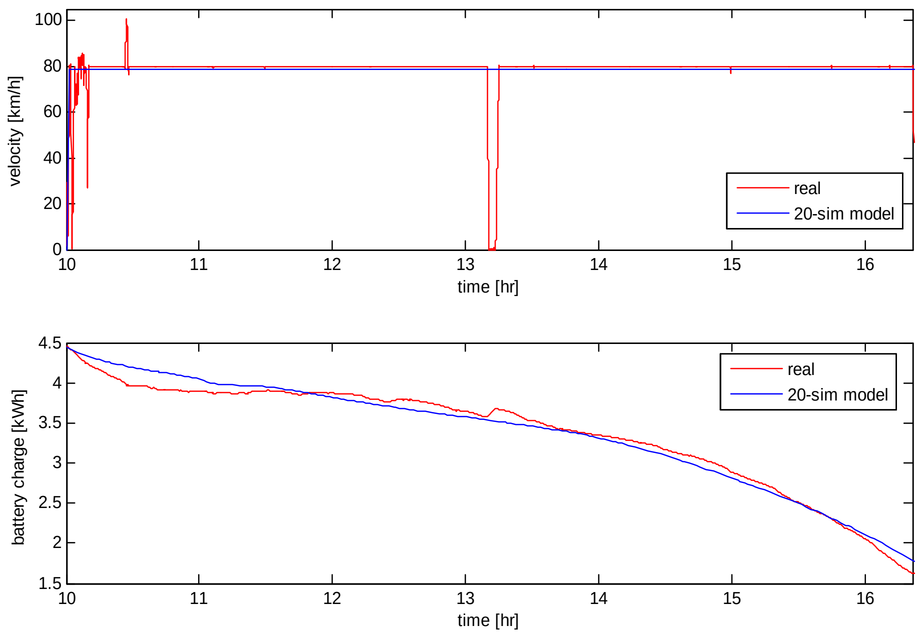

Figure 3: Results of the 4th day during the race

In figure 3, a comparison between the predicted model and the real values is shown. The model showed to be really accurate in predicting the battery charge, which is a combination of energy expenses and energy regeneration. A simulation of the complete route, which covers about 5 days in reality, takes about one second to calculate with the 20-sim program. For optimization about 200 simulations were necessary in order to find the optimal velocity curve for the complete race.

Monitoring

During the race the optimization model was coupled with the actual sensor readings for monitoring and forecasting purposes. With the help of the Controllab and Ordina programmers the 20-sim program was coupled with a database, where all major race data could be stored and accessed by several programs. The cooperation of Ordina and Controllab enabled us to continuously monitor the current race strategy and several alternative race strategies. All of these calculated strategies could be compare to actual sensor readings from the solar vehicle. In addition, it was possible to change all major model parameters of the 20-sim model without having to access the 20-sim program.

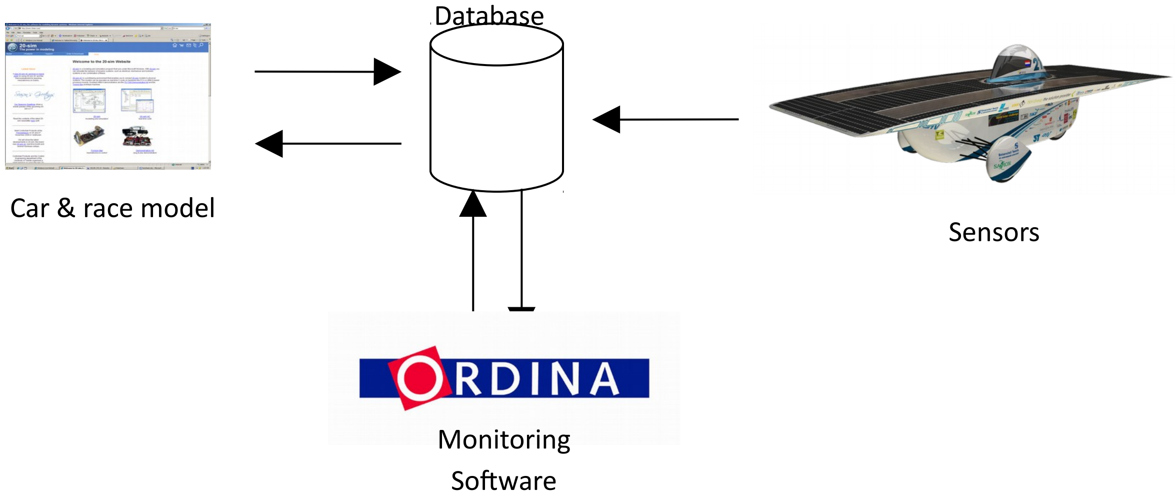

Figure 4: Interfacing between the solar vehicle, the main database, monitoring software and the 20-sim model

The main tab of the interfacing software during the race is shown in figure 5. Here, on the left side the total energy flow could be monitored, from solar panel to motor. In the graph a certain 20-sim model parameter could be selected and compared to actual sensor readings. Besides, the actual sensor readings could be extrapolated for several hours.

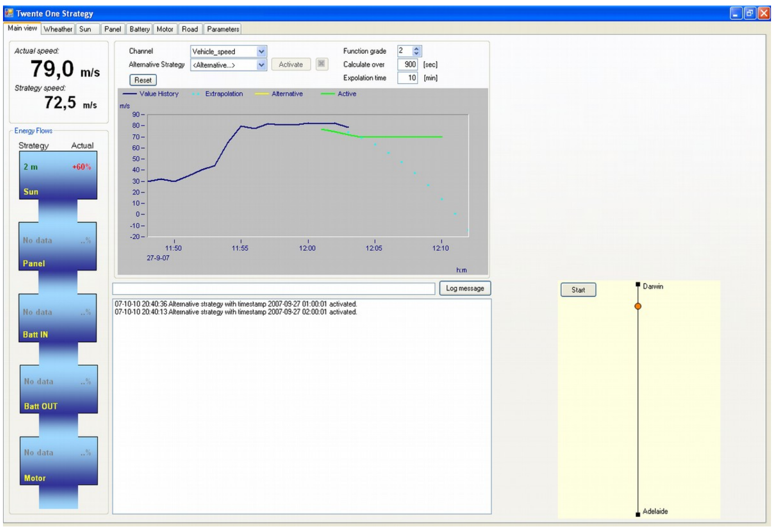

Figure 5: Example of the main tab of the monitoring software.

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