A Model of Distributed Control for the Hybrid Transmission System using Multi-Agents

EUGEN DIACONESCU
Electronic and Computer Science Faculty
University of Pitesti
Str. Tirgu din Vale, Nr. 1
eugen.diaconescu@upit.ro
ROMANIA

Abstract: - By contrast with the classical vehicle, designed for a source of a single type of fuel, (either gasoline or Diesel), the vehicles of the (near) future will have on board a hybrid source of energy, composed of more than one type of passive (stored) or active electrical power. The management of electric power sources mostly depends of the vehicle’s dynamical functioning regime. Hence, the vehicles’ overall control system follows strict requirements which impose complex classical solutions that are difficult or almost impossible to implement by using classical control technologies, while still incurring reasonable costs. This work brings forward a solution of distributed control which falls within the category of multi-agent systems. The environment for developing and programming multi-agents is the common software for standard and dedicated equipments, which is currently used to design the control structures on the mobile vehicles.

Key-Words: - hybrid vehicle, hybrid source, multi-agent system, multi-agent control system

1 Introduction

Work [1] comes with a proposal of control architecture for hybrid technologies by directly referring to the hybrid electric vehicles [HEV]. The proposal uses a model based on agent algorithms for structuring the control system, multi-objective optimization functions, methods based on fuzzy classification logic and genetic algorithms, results of Matlab simulations and multi-agent development in Mobile Agent Platform Grasshoppers, in Java language. The proposed solution has the inherent limitations of a model for a slow process. A hybrid electrical vehicle system, irrespective of its type, is, however, on the whole, a fast process.

The work makes an attempt to identify a model for a more realistic case. The speed and reliability requirements for building a practical HEV system are extremely high and the solution of MAS on PC [1] under a classical operating system is unsure. In the best case, the solution is applicable onto an experimental – demonstrative stand/bed.

During the last years, extremely compact and robust control standardized equipments which can be fitted on mobile terrestrial or maritime vehicles, functioning in exceptionally difficult conditions (e.g. shocks, vibrations, chemical agents, etc.) have been developed. A particular category is represented by the special made PLCs for mobile vehicles [2], supporting IEC 61131 language standard. In addition, the development environment LabVIEW of National Instruments has reached a maturity stage and may be a solution for complex problems such as the control of hybrid electrical vehicles.

Currently, the question is whether the languages LabVIEW or IEC 61131 (IL, Ladder, FBD, SFC and ST) have the ability to be servers for the multi-agent system, namely to support the development of an agency. In order to provide an answer, this work includes a brief analysis of the minimum qualities that the software entities must fulfill in order to correspond to exigencies, at least theoretically.

The first and the most important condition which has to be fulfilled by a software environment in order to allow the design of a multi-agent system is to be a concurring environment for the software processes corresponding to agents. In addition, there is a subtle difference between a multi-agent system and a concurrent system: processes’ synchronization. In a pure concurring system the synchronization is made in the design phase, while in the multi-agent system, the synchronization of agents takes place during run-time [4]. The parallel execution of LabVIEW sequences is a result of the data flux model in LabVIEW. In addition, the event oriented programming is possible. The “event” structure waits until an event occurs, then executes the action programmed for this event. This behavior is important for the agents-environment interaction.
The execution sequences in LabVIEW are placed in block diagrams (BD) in the form of structures or graphical symbols and can remain disconnected one from the other. We take for example the placement of two while loops, one near the other (figure 1) with the index showing the value of their current iteration when the program runs. It is not possible to determine how this value will be modified during run time, because the program running order in the BD structure cannot be determined. For example, the first while loop in figure 1 can run thousands of times before the second loop runs at least one time. Their parallel execution is undetermined. The order in which the two while loops are executed cannot be determined from the block diagram. It is not possible to predict if the loops will equally alternate one after the other, whether they would unequally alternate, or if a loop will be executed at all times, while the other would wait an indefinite time. This property of parallel execution in LabVIEW may benefit the design of a multi-agent system.

Fig. 1 The parallel execution of the while loops in LabVIEW

The agent concurrence, if run in a PLC, is a rather surprising result, given the PLCs’ way of functioning. While in ordinary computers, a program (process, task) is activated by the operating system and executed in mono-tasking or multi-tasking regime, from the first instruction up to the last one, the PLC executes, usually very fast, a continuous cycle with three phases, (figure 2) [5]. In the phase of inputs’ reading (Process Image Input Table, PIIT), the PLC inputs are scanned and tabled. The treatment phase, named Processing Program (PP), executes the instruction sequences S1, S2, ..., Sn. In the output updating phase, Process Image Output (PIO), the results of processing are transferred from memory to output. This sequencing of a PLC functioning totally disconnects the processing phase of the program, (a string of sequences which may be software agents), from the input and output phases of the environment. Thus, the very fast succeeding of phases makes the sequence (agent) running seem concurrent and independent, without any synchronization in the design phase. In Figure 3, agent S1 can run many times while the agent S2 can be activated only once or even at all. There is not any constraint between the executions of the two sequences imposed by the PLC software. It only depends on the context whether there is synchronization or cooperation between the program sequences at execution.

In addition, the software concurrence may be enhanced by multitasking, when the software allows it [3]. A PLC task is a program unit with independent execution in time. It is defined by a name, a priority and a type determining which condition will trigger the task. The conditions, events and priorities will set the chronological order of task execution.

Fig. 2 The continuous execution cycle with three phases of the PLC

Fig. 3 If the contacts of the rung S1 are different from the contacts of the rung S2, the program sequence S1 is independent of S2

2 THE PARALLEL HEV
At the University of Pitesti, a simulation stand of a parallel HEV was realized, figure 4.

Fig. 4 The parallel transmission model

The hybrid parallel model allows that both engine (E) and electrical motor (ME) generate torque in parallel to move the wheels. Because both E and EM
are coupled with the propulsion shaft individually, the propulsion energy can be taken either from the engine or from the electrical motor, or from the two. The electrical motor, conceptually, contributes to the emission and consume lowering. ME can be used in general for the battery charging by regenerative braking or load for Engine, when the total generated power is bigger than the needful power for vehicle moving.

There are four main modes of operating of a parallel HEV: startup/acceleration, normal driving, deceleration/braking and battery charging during driving.

Typically, the relative distribution of functioning time between engine E and electrical motor EM is 80 – 20%. In normal functioning time, only engine E alone can produce the needful power for the vehicle propulsion, while ME is stopped.

In the braking or decelerating time, the electric motor actions as a generator for battery charging by means of the converter of energy power. In addition, because E and ME can be coupled on the same shaft, E may charge the battery through the ME as generator when run with small load. We tested also the (redundant) solution of addition of an electrical machine having the specialized and efficient function of generator to the shaft of engine to charge on demand the battery.

The control strategies must satisfy a number of objectives of parallel HEV. There are four key objectives: maximum fuel economy, minimal noxious emissions, minimal system costs, very good performances. The designing of energetic control strategies for HEV supports several considerations, among the more important followings.

- HEV must to function only in optimal operating range of engine. An operating point in the speed – couple plane of engine assures fuel economy maximization, minimization of emissions or a compromise between this. The set of optimal functioning point means optimal operating line of engine, figure 5.
- The engine run practically into preferential optimal range in the plane couple-speed for witch the fuel consumption is optimal.
- The speed of engine functioning must be controlled so that any fast fluctuation will be canceled to cut the vibrations. In addition, at small number of revolutions the fuel consumption is big.
- The engine have to start and stopp not too frequently. The battery must have adequate capacity. The tension on battery must be kept between some limits; otherwise, it can deteriorate.
- The ultra-capacitor will be of great utility in acceleration time for supplementary energy or in deceleration time for fast storage of recovered energy.

The hybridization degree (the distribution of power demand between engine and battery) must have a uniform distribution in the time of driving cycle.

- HEV will run in urban zone only in electric mode (geographical politics).

Because of incomplete combustion, a big part of noxious emissions, as for example CO, HC, NOx and material particles PM are eliminated in atmosphere. A performance function FP(t) can be defined, and with regard to input test data, can be used for the optimal instant calculus.

\[
FP(t) = \sum w_i \left[ \frac{CO(t) - CO_{opt}}{CO_{opt}} + \frac{HC(t) - HC_{opt}}{HC_{opt}} + \frac{NO_x(t) - NO_{x, opt}}{NO_{x, opt}} + \frac{FC(t) - FC_{opt}}{FC_{opt}} + \frac{SO(t) - SO_{opt}}{SO_{opt}} \right]
\]

The value of defined integral of performance function FP(t), computed between two time limits, can be considered an objective function for the propulsion hybrid system. The objective function and performance function can be computed for...
different control strategies, and the results can be compared through tables or diagrams.

4 MODELING THE CONTROL SYSTEM BY AGENTS AND AGENCIES

In respect of instantaneously demand of energy, the targets of optimizations become now: the economy of energy, the minimisation of noxious instant emissions (HC, CO, NOx) and the state of charge of the battery.

A classical centralized control system for this case has a large cost and it is difficult to design. A solution of distributed control, realized through multi-agents, simplifies the structure and reduces the costs of the design and testing by imposing a modular treating of problem. In the figure 6, the proposed structure of distributed control system (DCS) based on multi-agents is showed. Not only agents, but also agencies appear in the proposed MAS structure; an example is Hybrid Source composed of individual agents with the internal structure in figure 7.

Obviously, the structure of system control showed in figures 6 has as first result the reduction of computing time and the distribution of computing needs to different processors. The possibility to express the modular structure of control system in a form of multi-agent system is used to built the DCS having the coordination and concurrence of agents as essential feature.

Fig. 6 The structure of the multi-agent system which models the control system of the hybrid

Fig. 7 The agent internal structure

Hierarchy of agents. The design and implementation of DCS divide the divers distributed agents in three distributed levels: vehicle, optimization and decision.

Vehicle level is composed of the environment agency, electrical consumers’ agency and hybrid source agency. The vehicle level agents have sensors for measuring of engine temperature, oil pressure, fuel consumption, noxious emissions, and
battery state of charge.

The optimization level comprises the optimal strategies, knowledge base, and human driver profile agents. The knowledge base holds the records of state variables of vehicles as vehicle speed, battery state of charge, engine temperature, and the computed optimal hybridization for one or many standard cycles. The element number in the database could be reduced by an optimization process. The human driver may select the optimization algorithms. Artificial intelligent algorithms would be used in this stage.

Decision level contains the agents: decision, hybridisation degree, course planning, power/torque demand, geographical politics and human driver assisting.

CONCLUSIONS

The classical control solution of these both slow and fast processes, not optimized on the whole, subject of human driver interventions, does no longer provide satisfactory results in relation to energy economy and environment protection requests.

This work brings forward a model of a distributed agent-based control of the transmission system of hybrid electric vehicle. Continuously Variable Transmission (CVT) favors the building of analytical models of systems, which allow the application of optimized algorithms.

First it was estimated whether the software environments, which could help implement various control structures of a vehicle, could be an adequate environment for the design and functioning of a multi-agent system. Then, a complex agent and agency based structure of the entire hybrid propulsion system was proposed, showing both common and individual objectives. A common general architecture for the building of multi-agent systems was outlined.

The validity of the model proposed in this work will be demonstrated by simulation and experiments at the stand built at the University of Pitesti with the financial support of the National Authority for Research and Development and the National Center for Program Management within the frame of PNCDI II/contract 72209.

References: