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Full Length Research Paper

Using structured analysis for the control of real-time systems

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After a presentation of the real time system analysis and design, we present the Structured Analysis for Real Time Systems, or SA-RT. This graphical design notation is focusing on analyzing the functional behaviour and information flow through a system. In fact, the modeling of the real time systems helps us to understand its working, without eliminating its complexity. Then, we present the graphic and textual formalism of the SA-RT method on the one hand and we apply this method on a practical case of an ABS braking system, on the other hand.

Key words: Real time systems, SA-RT method, ABS braking system.

INTRODUCTION

Domains of development of real time systems are various. Classically, one recovers the levels network and transport of the heterogeneous communication systems in the domain of telecommunications; the embarked software; the aerial control for what concerns the aerospace domain; the follow-up of production processes or the control of the manufacture in factories; electronics or the convivial software interfacings for the user in the domain of the micro computing (Dorseuil and Pillot, 1993).

The first essential characteristic of a real time system must be its reliability and its safety. Two parameters are to consider: the frequency of failings and consequences of these last in presence of no controlled entrance data (Gomaa, 1994; Ryan and Heavey, 2006).

An operator's behavior facing a critical situation is not still foreseeable. If techniques of redundancies of information and resources have the tendency to encourage a reliable and sure working, they degrade in counterpart the temporal performances of the whole of the system. Otherwise, difficulties of test in true size remain an essential question for teams of development working on projects of big span (Jane and Liu, 2000; Tschirhart, 1990).

In real time systems, the formal methods enable us to clear essential functionalities of the system to achieve (Cottet, 2005). For this type of real time system, we can identify five essential phases in the development of the system: the development of the load notebook; the functional analysis phase; the design phase; the coding phase; the test and clarification phase.

The object of this article is to present the interest of the structured analysis approach based on the method SA-RT (Structured Analysis Real Time). So, we present the different tools of representation exploited by this method. A practical case study of an ABS (Anti-lock Braking) braking system was presented and discussed.

METHODOLOGY

Real time systems analysis and design

The specification of systems supposes the two essential characteristics: the temporal evolution of components of the system and the interaction system - environment. Indeed, the complexity of relations between a system and its environment is especially verified in the domain of process conduct (Attiogbe and Vailly, 1996).

Among techniques of system specification, we mention: the methods of analysis that enable to systematise and to canalise the various perceptions of the needs; the languages of specification possessing syntax and a very definite semantics and the languages of simulation enabling to develop tools for the help of the decision (Drix and Robin, 1992).

Methods of analysis and design provide standard notations and convenient advices that enables to lead to the reasonable conceptions, but one will always make call to the inventor's creativeness (Melese, 1990; Vautier, 1999).

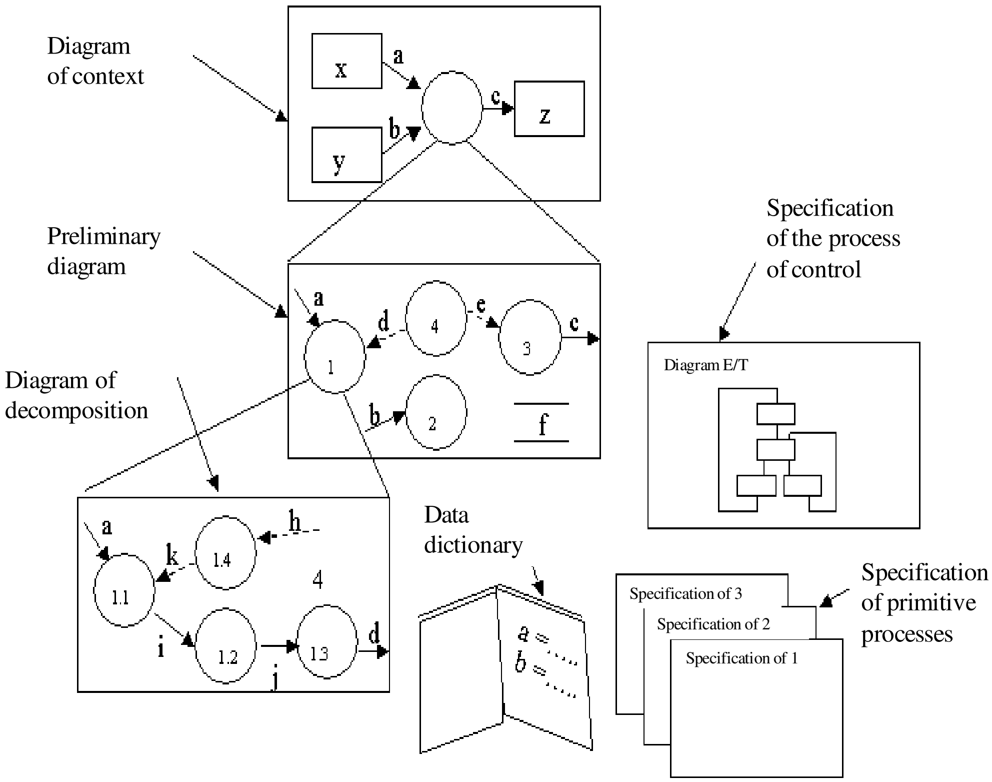

Figure 1. Organization of the SA-RT model.

In the functional strategy, a system is seen like a whole of units in interaction, having each a clearly definite function. Functions arrange a local state, but the system has a shared state, that is centralized and accessible by the whole of the functions (Sticklen and William, 1991).

Oriented-object strategies consider that the system is a whole of interacted objects. Every object arranges a whole of attributes describing its state and the state of the system is described by the state of the whole (Larvet, 1994).

Contrary to most of the functional methods, the oriented-object methods are considered the methods of analysis and design (Budgen, 1995; Lecardinal et al., 1999).

We are interested in this work to the different methods of structured analysis. We cam mention, for instance, the methods: SA (Structured Analysis), SADT (Structured Analysis and Design Technique) and SA-RT. These methods can be used in order to lead to a global functional analysis of a system (Jaulent, 1992; Sommerville, 1988).

In the methods of structured analysis, the highest level is called Context Diagram (CD). Indeed, the box of Data Flows Diagram (DFD) represents a process and must be decomposed. Every process (or treatment) not decomposed is described by the "mini-specification". The dictionary specifies the definition of data, processes and storage zones.

For example the SADT method (Jaulent, 1989; Lissandre, 1990) enables to produce a model of the software under a coherent following and hierarchies of diagrams gotten by successive decompositions.

The structured analysis was insufficient to express constraints of time and synchronization; extensions have been brought to this effect: addition of the graph of Control Flows and specifications of control: information of process activation-deactivation; utilization of diagrams states-transitions.

Presentation of the SA-RT method

Structured Analysis for Real-Time Systems, or SA-RT, is a graphical design notation focusing on analyzing the functional behaviour and information flow through a system. SA-RT, which in turn is a refinement of the structural analysis methods originally introduced by Douglass Ross and popularized by Tom DeMarco in the seventies, was first introduced by Ward and Mellor in 1985 and has thereafter been refined and modified by other researchers, one well-known example being the Hatley and Pirbhai proposal (Hatley and Pirbhai, 1991).

Among the graphical methods most commonly used in industry, two of the leading methods are SA-RT and Statecharts. SA-RT is a short name for Structured Analysis Methods with extensions for Real Time. The model is represented as a hierarchical set of diagrams that includes data and control transformations (processes). Control transformations are specified using State Transition diagrams, and events are represented using control flows. The other graphical and state based paradigm for specification of real time systems is Statecharts. The system is represented as a set of hierarchical states instead of processes. Each state can be decomposed into sub states and so on. The statecharts notation is more compact than the SA-RT notation and has been formally defined.

Thus, SA-RT is a complex method for system analysis and design. This is one of the most frequently used design method in technical and real-time oriented applications adopted by various Case-Tools. It is a graphical, hierarchical and implementation independent method for top-down development (Figure 1).

SA-RT method enables us to identify an entrance and an exit of data in an algorithm or a computer program. It is divided in three modules: Context Diagram (CD), Data Flows Diagram (DFD) and Control Flows Diagram (CFD). Every module includes in its graphic

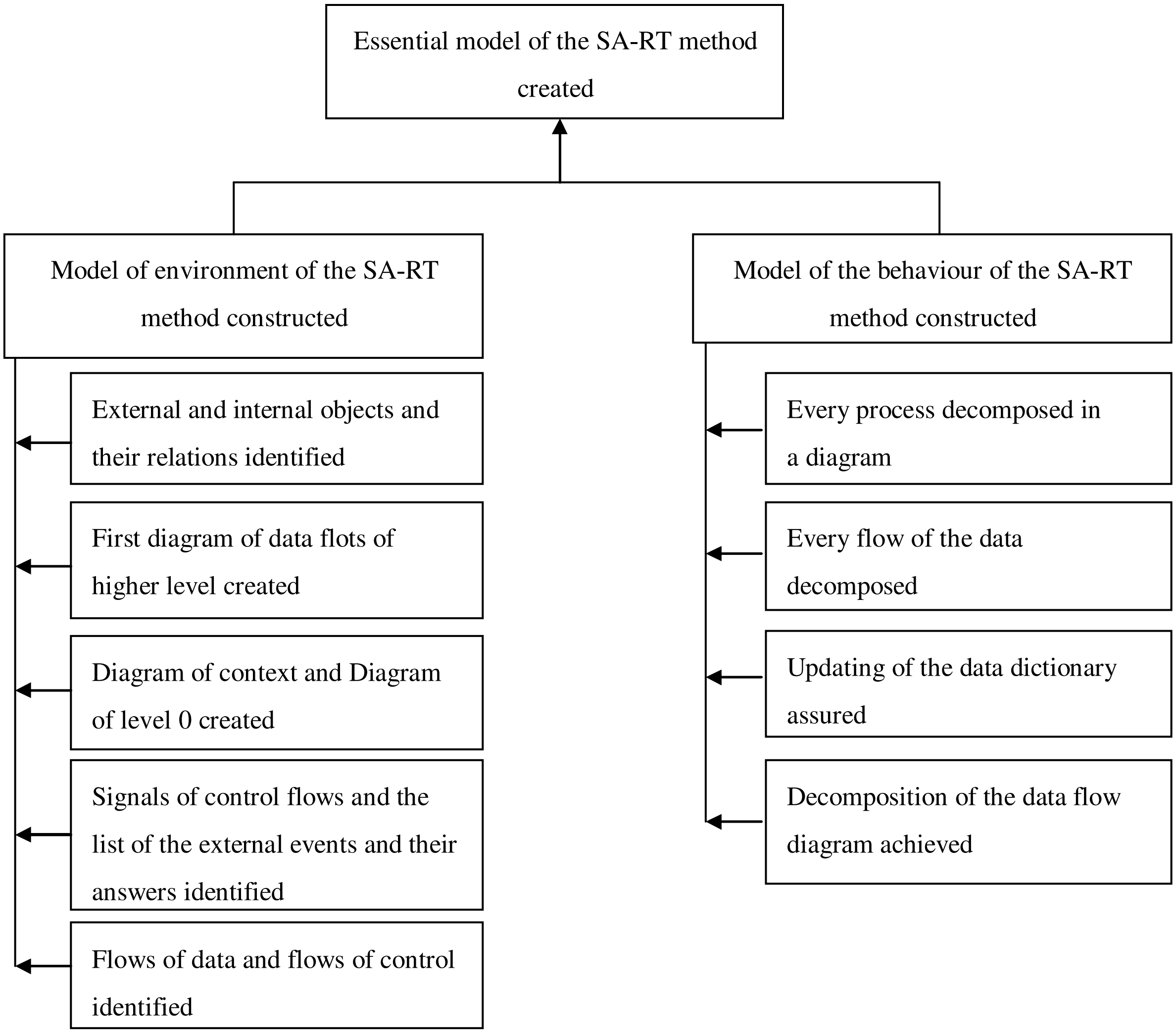

Figure 2. Essential model of the SA-RT.

interpretation different symbols (Hatley and Pirbhai, 1991).

Indeed, the CD in the SA-RT method is going to enable us to identify a process in a program in relation to the entered and exits of data. This process can have different units. This process will be able to be identified per seconds, in term of constant or variable but as this process will be able to be material type (Process interfacing).

The different symbols used in a CD of the SA-RT method are:

1. The terminator is the element in end, final element that encloses the action.
2. The flow of data is the final element that opens up on a last action.
3. The flow of control is generally a tie back of the process toward the terminator. It can be a main element of the process.

The termination is generally a direct tie between a terminator and the process. The DFD is an under-process of the CD. One can analyze every element of the CD and more especially terminators and flows of data. It is going to concern entrances and exits of process exclusively.

The CFD is the last stage of the SA-RT analysis. The CFD represents in fact a summarized of the Diagram of Context and the DFD while integrating the new exits and entrances.

The Process of control is going to either define a function, a procedure or a place with its internal or external parameters. It can happen that a process of control corresponds to a structure. It can be carrier of parameters in the setting of function or procedure but it is especially a tie between the process of control and the under-process.

Figure 2 presents Essential model of the SA-RT composed two models: a model of environment of the SA-RT method constructed; a model of the behaviour of the SA-RT method constructed.

Practical case of an ABS braking system

The braking knew undoubtedly the most spectacular important evolutions concerning the unblocking of wheels: the ABS (Anti-lock Braking); a system that made its apparition in 1952 on planes, then since 1978, on cars; thanks to the Bosch, inventor of the process. Reliable and efficient, one finds it in series today on all ranges of vehicles. Let's recall that the ABS acts as soon as a wheel wants to block itself. It does not brake shorter on the distance. Its role is the

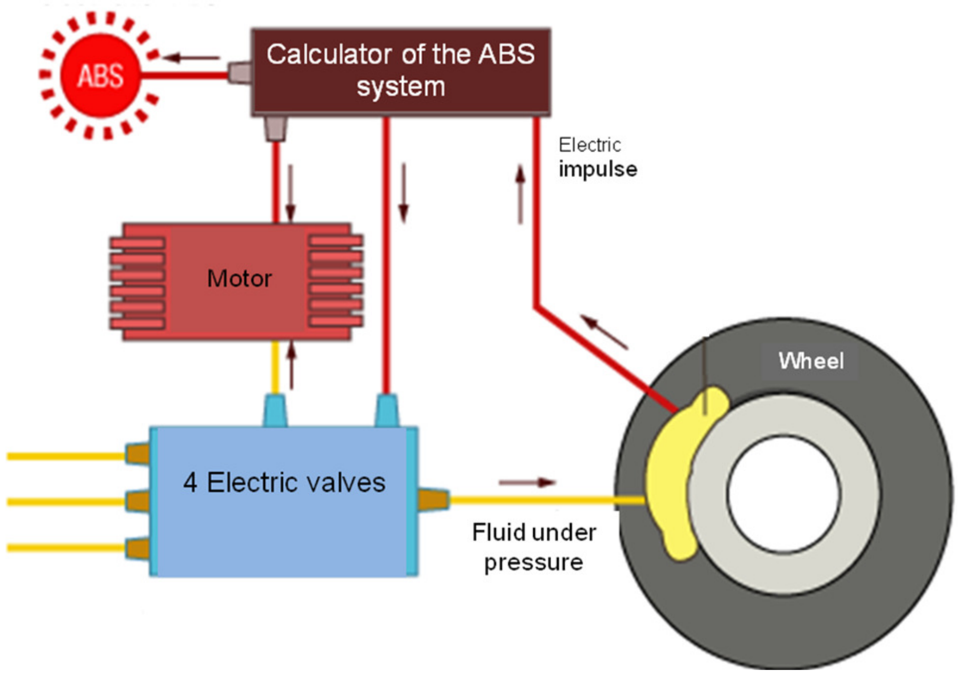

Figure 3. ABS braking system.

unblocking of wheels to help to avoid the obstacle while braking (Figure 3).

When there is blocking of wheels to the braking, it is not more possible to preserve the control of the trajectory of the vehicle, for example, to avoid an obstacle. The ABS system is going to avoid this blockage therefore while using the maximal adhesion of the air. The advantage for the driver is an optimal braking on difficult road, while limiting risks of skid and while keeping the possibility to direct his vehicle.

In a situation of normal braking, the electric valves are opened. When the ABS enters in action, it starts with closing a first electric valve that stops the consignment of the brake liquid. If the blockage persists, a second electric valve is closed, and so on. Stirrups of brake loosened wheels are freed. As soon as the wheel begins to take the speed, the pressure is sent back, still by stages, until the moment where the wheel reaches the speed of others rotation or until a next beginning of blockage.

This operation can take place until 12 times by second, to assure a pretty much homogeneous braking. The ABS requires a regulator therefore extremely sophisticated: it must not only react on the news very precise way that arrive him, but also to take in account the different inertias of the braking system, or same the diameter different of a spare wheel that would not have the same diameter.

RESULTS

In this paragraph, we present an SA-RT analysis of an automotive braking system composed on the one hand of a classic whole of a brake pedal (braking demand) and a brake (braking actuator) and on the other hand of an ABS system (Cottet, 2005). A sensor sliding of wheel is associated to this ABS system. To simplify, the working of the ABS is based on a stop of braking when a sliding is detected on the wheels and it even though the driver's demand is always efficient. The driver has the possibility to either activate this ABS system with the help of a specific button (button to two steady states: switch). A seer permits to indicate it the activation of the ABS system. But then, it is not possible to deactivate the ABS system during braking that is during the support on the brake pedal.

The whole of data or events exchanged with the outside of the functional process that represents the application, constitute specifications of entrances and exits of the application. The description of these Inputs/Outputs will be made in the dictionary of data.

The context diagram (Figure 4) is constituted of the functional process "to control the braking system" and of five terminators:

1. "Brake pedal" providing the data "braking demand ";
2. "Activation Button of the ABS" providing the data "ABS activation ";
3. "Sliding sensor" providing the data "Wheel sliding ";
4. "Braking system" consuming the data "Braking command";
5. "ABS light" consuming the data "Display ABS".

This context diagram perfectly defines the interfacing between the inventor and the customer that is data to either provide or to generate.

The preliminary diagram is constituted of five functional processes (Figure 5). We can immediately underline at the level the obligatory consistency between the context diagram and the preliminary diagram at the level of the data flows in entrance and in exit. The passage of data

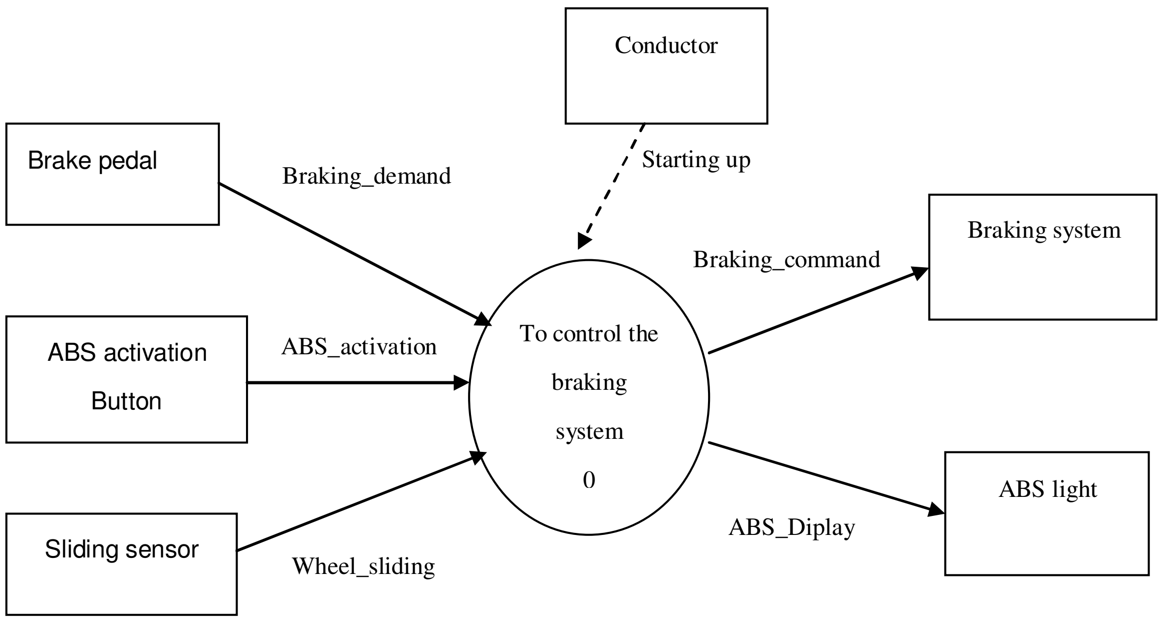

Figure 4. Context diagram.

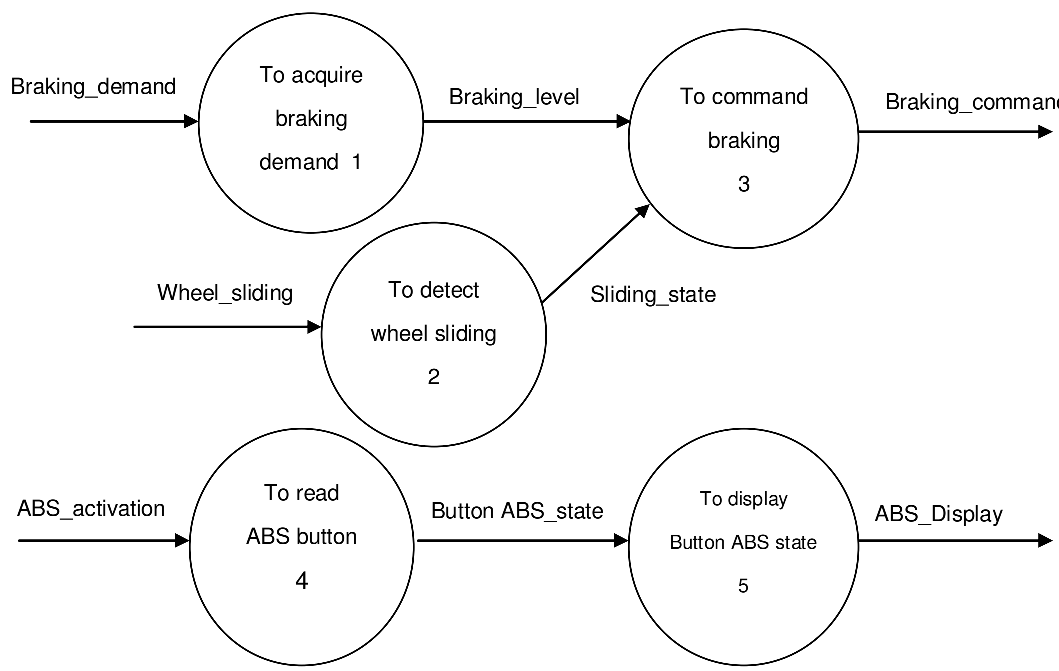

Figure 5. Data flow diagram.

between the functional processes is done in a direct way. It is important to note that the data "Sliding_state" and the data "Button_ABS_state" are Boolean type.

We implanted a control process in the preliminary diagram in order to coordinate the different functional process execution (Figure 6). This control process will therefore interact with a functional process either to launch or to activate its execution and, in return, the functional process will provide if necessary an event indicating the result of its treatment in order to give some useful information to change the control states.

In order to specify the control process of the application, we present the representation of the state-transition diagram (Figure 7).

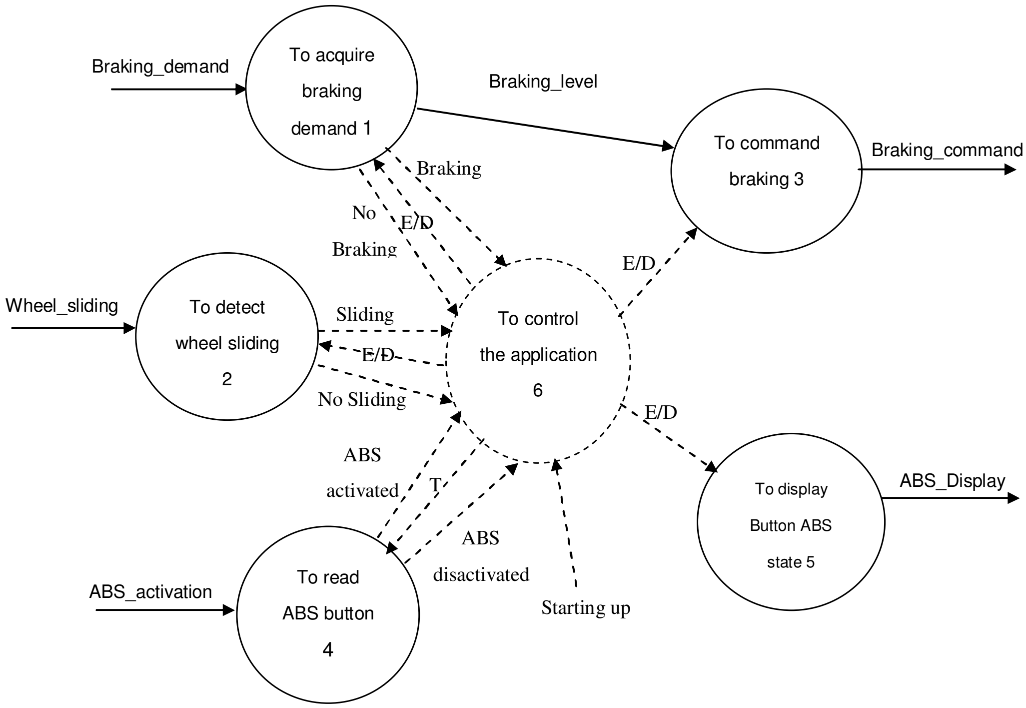

Figure 6. Control flow diagram.

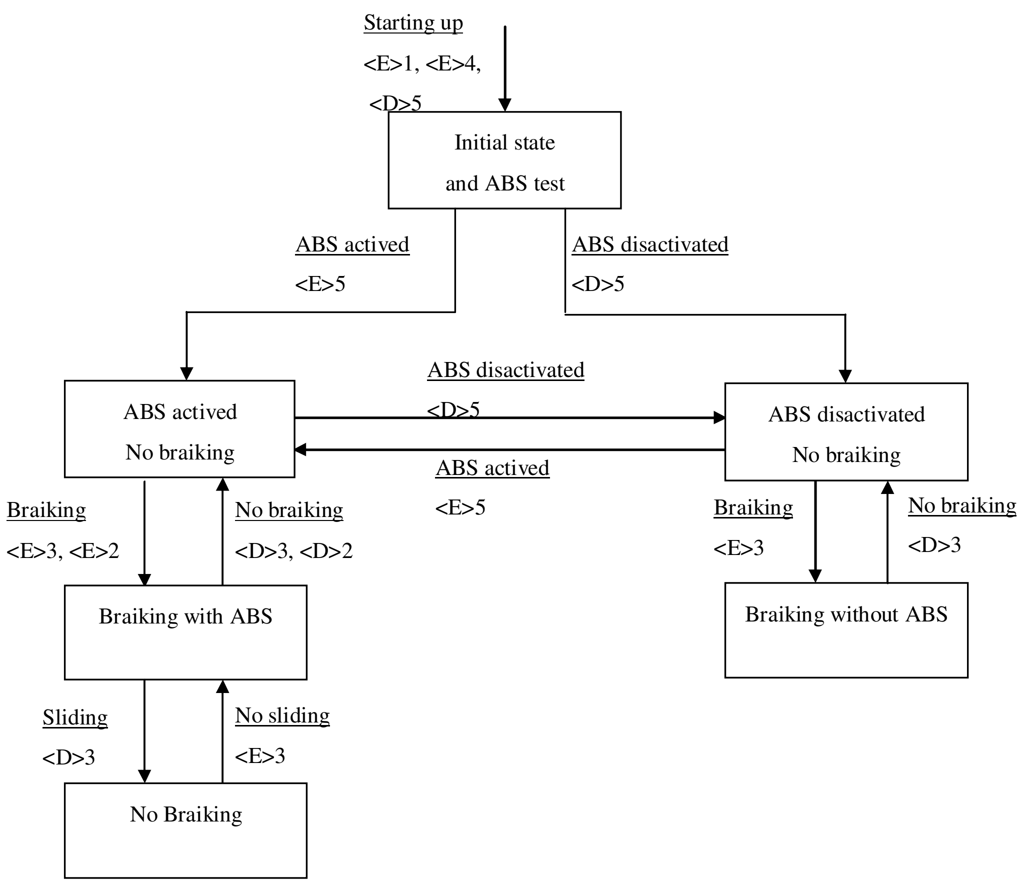

Figure 7. State – Transition diagram.

Conclusion

The modeling of real time systems helps us to understand its working, without eliminating its complexity. In fact, different methods are used for the specification of real time systems. These methods are characterized by their graphic and textual formalism that are necessary to understand and to exploit with a coherent and a correct manner.

In this paper, we present on the one hand the method SA-RT and on the other hand an application of this method on a practical case of an ABS braking system. This application shows the interest of the graphic and textual formalism of SA-RT for the analysis and design of a real time system.

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