GENERIC MOTOR FOR SIMULATION ANALYSIS

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ABSTRACT

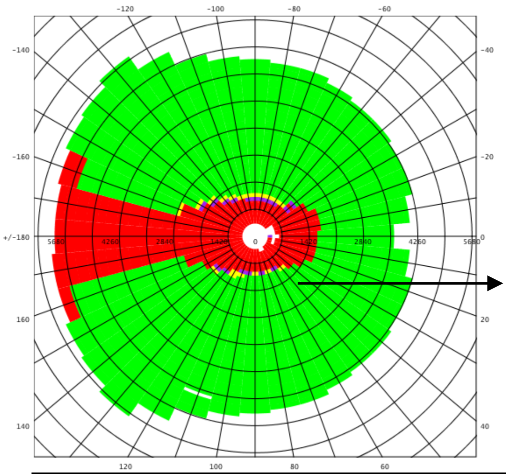
In the area of aircraft/missile simulation, the result “target/missile final distance” or “decoy/not decoy”, needs to be explained. One solution to get those informations is to ask an expert to analyze the simulation signals. At about ten minutes by simulation for a thousand simulations, it takes roughly a month of work. Another way of getting those informations is to use a “generic motor for simulation analysis” which allows defining automatically a diagnostic for each simulation. This kind of diagnostic takes only a little more simulation time for the computer, fifteen minutes for a six hours simulation as example and no time of an expert. The purpose of the document is to present how to build this kind of “generic motor for simulation analysis”. This motor is not limited to this kind of simulation and can also be used for other simulations where complex diagnostic is requested.

Keywords: aircraft/missile simulation, automatic diagnostic, infrared seeker, flares

1. INTRODUCTION

DGA Information Superiority, part of FRANCE Department of National Defence builds tomorrow’s defence. DGA Information Superiority uses aircraft/missile simulations. The simulation tools used for this work employ many models: threats, targets, infra-red scene generator… each one at the appropriate level of modeling. The result of simulation is the “target/missile final distance”, “decoy/not decoy” information. This information is very useful but not sufficient enough to understand what happens during the simulation and to deliver validated advices to the forces.

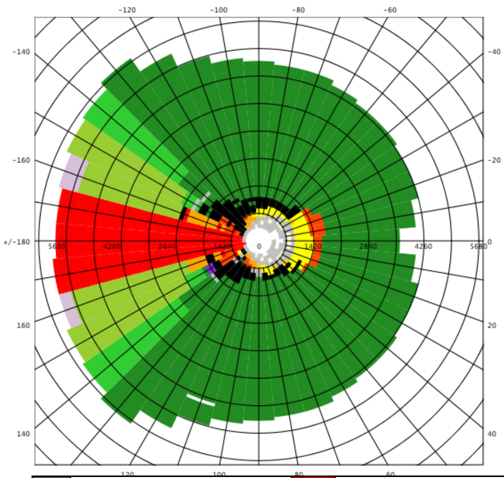
In Figure 1, for an aircraft flying from the left to the right, threats are placed around the aircraft (Polar coordinates: Rho, Theta). The “target/missile final distance” is indicated with a color code: green for a target not hit and red for a hit target for example. To understand the result, improve the materials tied to the simulation and also to increase the confidence in the result, more detailed information is needed. As a study to protect an aircraft can involve easily to more than one hundred thousand simulations, the method to ask at one expert should be extremely limited.



	Target hit		Target not hit

Figure 1: Missile/target Final Distance

Figure 2 is a diagnostic of simulation create with a “generic motor for simulation analysis» displaying in several color codes the reasons of each result.



	Decoy, good KC		Not decoy, KC to low
	Decoy, KC middle		Not decoy, CCM
	Decoy, KC low		Decoy, no separation

Figure 2: Diagnostic of simulation

This diagnostic is more accurate that the diagnostic of an expert because the motor performs the analyses for each simulation and at each step of the simulation.

To build this kind of motor, a prerequisite is needed: an expert should be able to analyze the simulation with the signals of simulation. In fact, as this motor looks differently at the simulation, it can be interesting to look at the first steps of motor construction, which can give ideas to analyze the simulation. Building this kind of motor is like a project of “valued engineering” or a project of “experimental planning” because there is a big amount of analysis required at first. This work of analysis is followed by a process of motor construction and a process of configuration and testing. Each simulation should have a specific motor even if the big steps of building are the same.

2. PRINCIPLE OF CONSTRUCTION

Figure 3 shows the principle of construction. A final result is associated to an instantaneous result. The reasons of a final result are linked to reasons of instantaneous result. The time evolution analysis of the reasons of instantaneous reasons allows to define reasons of the final result.

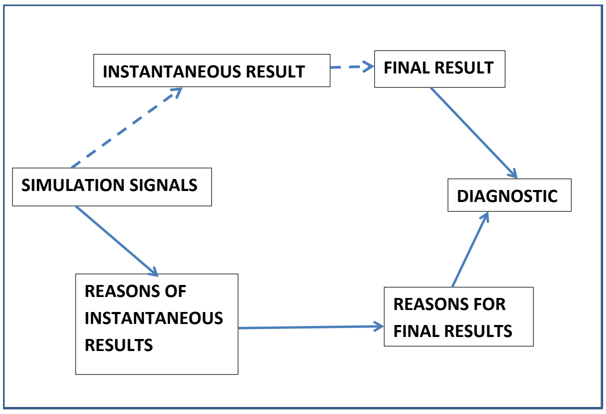


Figure 3: Motor action (high level)

In the area of aircraft/missile simulation, the instantaneous result is the direction followed by the missile and reasons of instantaneous result depend on each threat, defined differently depending on the threat and the kind of modeling.

A behavioral model of the seeker gives at each moment the point followed by the seeker (instantaneous result) and the reasons of the choice of this point can be understood through the behavioral equations (instantaneous reasons).

A detailed model of the seeker gives at each moment, an order to the flight control surfaces of the missile. This order can be of two kinds: on-off order or a proportionnal order. For an on-off order, the on-off equation will be used by the motor to determine the instantaneous reasons and the result. For a proportionnal order, it is necessary to think differently about electronics. Electronics should no more be seen only as “Automatic Gain Control”, “Limiters”, Filters”… The question to answer is “How this function will act on the order to the flight control surfaces of the missile for this object. For example, a limiter prevents to take too much in account a new object with high energy level, like a flare.

Two create a motor, there are five steps:

- Static analysis
- Dynamic analysis
- Specification definition
- Motor construction
- Motor configuration and tests

The two firsts steps of analyses are mandatory to validate the feasibility of the motor construction.

2.1. Static analysis

The goals of the static analysis are:

- To define the four items (instantaneous result, final result, reasons of instantaneous result and reasons for final results)
- To check the coherence between these four items
- To check the coherence with the simulation signals

The coherence checking will be made following rules of §3. The most difficult job in static analysis is to define the reasons of instantaneous results which are the base of the motor construction. The other items are only present to check the coherence of the analyses and don’t need to be so accurate. The reasons of instantaneous result should be defined carefully by:

- Definition of the objects of the simulation
- Definition of the aspects angle of the simulation objects
- Definition of simulation signals useful to analyze the aspects angle of each object
- Creation of new signals if necessary to analyze the aspects angle of each object
- Creation of logical signals from previous signals
- In case of periodic scan, creation of logical signals by scan period to synthetize periodic information
- Creation of logical states by logic combination of logical signals for each aspect angle of each object
- Simulation to test relevance of logical states if necessary
- The reasons of instantaneous result might not be defined at each step of the simulation, non-determined cases may occur for some steps, if signals are too difficult to analyses.

The decomposition of instantaneous result in aspects angle by object is a key point of motor construction. An aspect angle view is the list of exhaustive cases where one object can be seen following an aspect angle at one moment.

The simulation models have limited inputs signals to be representative of reality, but the motor has no limitation of input signals to respect. The motor knows who is each object, target or flare, the positions of the objects, when an object is on the detector of the seeker and which energy it has … The motor knows the total time of the simulation

The fact than a motor, can get extra signals to allow the automatic diagnostic is also a key point of the building. For behavioral models, reasons of instantaneous result could be defined easily by an expert without simulation. For complex models, this process can be re-made several times before getting logical states sufficient for motor construction. The explanation of the simulation is a complex problem which is divided in several simple problems to perform the automatic analysis.

2.2. Static analysis for aircraft/missile simulation

The result of the simulation exists and is already given by the simulation and the instantaneous result is the point followed by the seeker. A preliminary list of reasons for final results has to be built by the expert, but the reasons for final results will be defined by concatenation of the time analysis result of instantaneous reasons in the dynamic analysis. The reasons for instantaneous result are explained in figure 4 which shows three aspect angle views for each flare (seeker view, scene generator view and ignition rising edge view) and one for the target (seeker view).

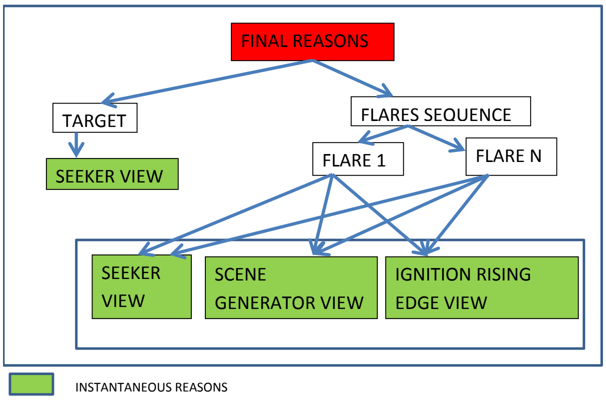


Figure 4: Instantaneous reasons decomposition

For example, a seeker can follow an object for reasons A, B, C or not follow an object for reasons D, E, F tied to the counter-counter-measure of the seeker. The SEEKER's VIEW will be made by the cases: A, B, C, D, E, F. As the seeker's view is defined, it is easy to apply it at the different objects of the simulation, target and flares

An expert knows well that it is necessary to have another look of the object to understand what happens sometimes. This other look is the "**scene generator view**", which can give information about the objects.

It's up to the expert to define other information useful for the diagnostic as for example the "**ignition rising edge view**" of the flares.

The details of signals construction depending on each model cannot be explained here and needs a very high level of expertise.

2.3. Dynamic analysis

The dynamic analysis will define how to move from instantaneous reasons to reasons of final result with a finite state machine, how to define the diagnostic as shown in figure 5.

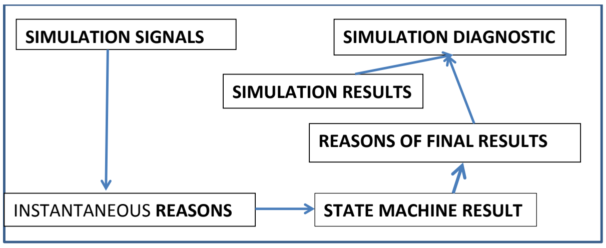


Figure 5: Dynamic analysis

The most difficult job is to build the finite state machine because diagnostic concatenation is only logical combination.

To build the finite state machine, it is necessary:

- To define the states of the machine
- To fulfill the finite state machine transition

The states of the machines consist of:

- Stabilizes instantaneous reasons (alone or grouped) tied with the reasons of final result
- Interesting succession of instantaneous reasons tied with the reasons of final reasons
- Other cases valuables for the expert

In the case of many instantaneous reasons, it can be interesting to build a two level finite state machine. Instantaneous reasons are grouped to main instantaneous reasons which are used to build the first level of the finite state machine. The second level of the finite state machine identifies the difference in a main reason. All the main states have the same second state even if some are never used. A finite state machine can be represented as shown in figure 6.

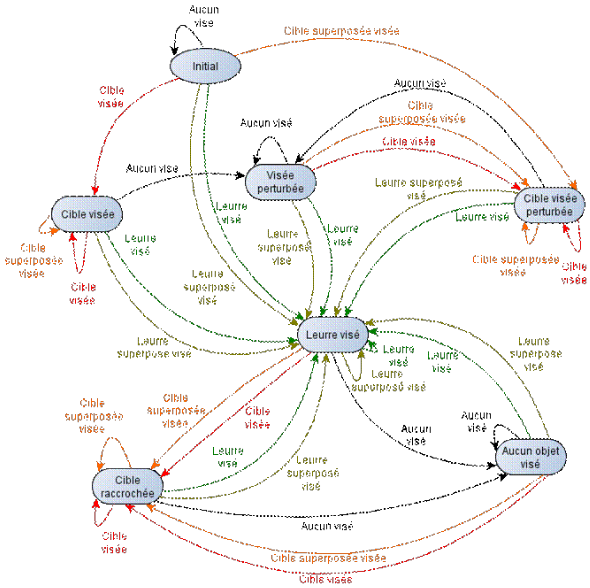


Figure 6: Finite state machine

Proceedings of the International Defense and Homeland Security Simulation Workshop 2014, ISBN 978-88-97999-41-6; Bruzzone, Frydman, Longo, Sokolowski and Sottilare Eds.

The reasons of final result are made by logic combination of the finite state machine results. To simplify this work, the use of several steps as shown in figure 7 is recommended.

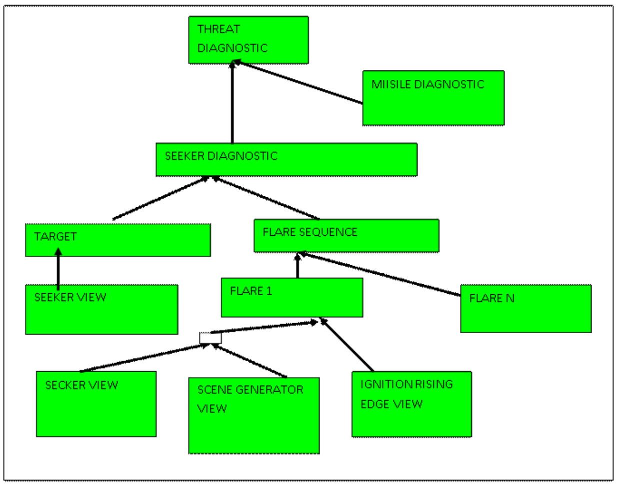


Figure 7: Diagnostic combination steps

A practical way to perform diagnostic combination at one step is to use a matrix.

Table 1: Diagnostic combination

	VIEW B				
VIEW A	FRB1	FRB2	FRB3	FRB4	FRB5
FRA1	FR1	FR2	FR1	FR1	FR1
FRA2	FR1	FR2	FR7	FR4	FR2
FRA3	FR3	FR6	FR3	FR3	FR8
FRA4	FR4	FR4	FR3	FR4	FR4

FR FINAL REASON

The diagnostic can sometimes be completed by extra information like missile diagnostic due to the fact that kinematics limits can sometimes modify the result. The dynamic analysis should be checked following rules of §3.

2.3.1. Specification definition

The static analysis and the dynamic analysis, if successful, have allowed to determine the feasibility of the motor and defining how the motor will work. In this case, the specification of the motor can be done.

The specification definition consists to define the informatics specification of the motor from the static and dynamic analysis. These specifications include the synoptic of the motor as shown in the example of figure 8 which resumes the static and dynamic analysis. The specification definition becomes standard informatics specification as soon as static and dynamic analyses are well made and will not be described here.

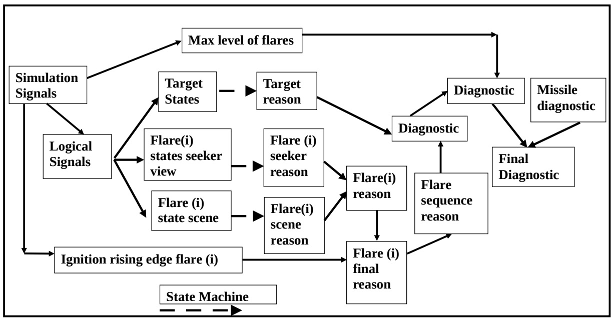


Figure 8: Synoptic motor example

2.4. Motor construction

Motor construction is informatics work, which will not be developed here. It is possible to make a prototype or directly upgrade the simulation. A thousand lines code are sufficient on MATLAB to define this kind of motor.

2.5. Motor configuration and tests

The configuration and tests of the motor are important tasks to be performed.

2.5.1. Motor Configuration

The motor configuration consists of :

- Adjust thresholds
- Optimize signals for analyses
- Adjust inputs of finite state machine
- Adjust outputs of finite states machine
- Finalize combination matrix
- Adjust last moment of motor analyses

The thresholds used to get logical signals could be simple threshold (one value), variable threshold (table) or adaptive thresholds. They should be adjusted by looking at logical signals, logical states, and outputs of states machines.

The analyses view by object is sometimes not compatible with global signals including effect of all objects. It can be necessary to optimize signals for analyses by:

- Use additional signals to limit the list of object impacting the global signals to influent objects
- Use parallel treatment to allow view by objects…

The inputs of the finite state machine should be sometimes adjusted to manage:

- Transition incoherent information not adapted to motor operation
- Switching errors in transition, limit cases
- Need of stabilized inputs for motor operation

The outputs of the finite state machine should be sometimes secured or weighted by statistics on instantaneous reasons.

The combination matrix should be finalized to manage undetermined cases.

The last moment of motor operation should be adjusted because too late or too early, diagnostic could be not optimal.

Motor configuration is not a simple task because of it's adaptation of the theories analysis to the reality of simulation which depends of each simulation.

2.5.2. Motor Configuration Validation

The validation of the motor configuration has to be made at two levels, global and detailed.

For global validation, look at the coherence of the results for a set of simulations (like in figure 1)for:

- The final diagnostic
- The different steps of combination
- The statistics on instantaneous reasons

For detailed validation, check motor operation on some specific simulations

2.5.3. Motor tests

As this work is VV&A (Verification, Validation and Accreditation), it will not be detailed here.

3. RULES OF CONSTRUCTION

To build a generic motor for simulation analysis, the different steps of construction should fulfil rules detailed here after.

3.1.1. Static analysis rules

The static analysis rules between elements of the motor shown on the next figure are described below.

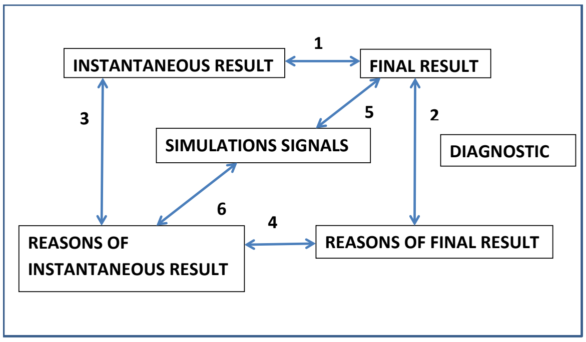


Figure 9: Static analysis rules

1. Each final result of the simulation must be associated with one instantaneous result, the opposite is not true. Each instantaneous result could be associated with no or one final result (an instantaneous result can be transitional…)
2. Each final result of the simulation could be associated with one or more reasons for the final result, the opposite is not true. At each reason of the final result could be associated only one final result. (a reason used to differentiate the final result can not apply to several possible results)
3. To each instantaneous result could be associated one or more reasons of instantaneous result for each aspect of view of each object, the opposite is not true. Each reason of the instantaneous result for each aspect of view of each object could be associated with only one instantaneous result. (a reason used to differentiate the instantaneous result can not apply to several possible results)
4. To each reason of the final result could be associated one or more reason of the instantaneous result for each aspect of each object, the opposite is true.
5. Each final result should be defined by simulations signals clearly to prevent indeterminate cases.
6. Each reason of instantaneous result for each aspect of each object should be defined by simulations signals clearly to prevent indeterminate cases.

In addition to these rules between elements of the motor, the following rule applies too.

7. All the relations between elements of the motor should be justified in the description of the static analysis of the motor to prevent possible misunderstandings in case of evolution of the motor.

3.1.2. Dynamic analysis rules

The dynamic analysis rules between elements of the motor shown on the next figure are described below.

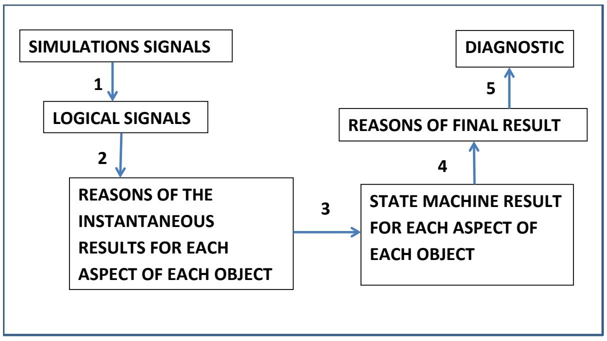


Figure 10: Dynamic analysis rules

8. Each logical signal should be defined by one or more simulation signals clearly to prevent indeterminate cases.
9. The reasons of the instantaneous results for each aspect of each object should be defined by total logic combination of one or more logical signals to prevent indeterminate cases.
10. The finite state machine should be checked carefully to prevent indeterminate cases.
11. The reasons of a final result should be determinate by total logic combination of the finite state machine results to prevent indeterminate cases.
12. The diagnostic should be determinated by total logic combination of the reasons of the final results with the final result and extra information if needed.

In addition to these rules between elements of the motor, the following rules apply too.

13. With all the choices of logic combinations, the finite finite state machine should be justified in the description of the dynamic analysis of the motor to prevent possible misunderstandings in case of the evolution of the motor.
14. The number of reasons of the instantaneous results for each aspect of each object should be limited to prevent an excessive size of finite state machine. The major reasons are not all interesting. A maximum of 10 reasons is preconized.
15. Use if necessary an indeterminate case. Signals simulations are not clear at each moment especially for detailed models, also it is preconized to not take in account these cases. Clear states are sufficient to define a diagnostic.
16. The number of outputs of logical combination should be limited to prevent excessive size of the following matrix. The main logic combinations are not all interesting. An increase of 1.5 of the biggest vector is preconized. This rule applies too to the finite state machine.
17. The reasons of final result should be obtained by several steps of logic combination to prevent an excessive number of combination.
18. In the definition of the finite state machine, each stable reason of the instantaneous result should be associated a state of the finite state machine.
19. In the definition of the finite state machine, each interesting succession of reason of the instantaneous result should be associated with a state of the finite state machine.
20. To prevent to have a final diagnostic with too much case not really interesting, rationalize the possible cases by groups of similar cases.

3.1.3. Motor configuration rules

21. Introduce systematically in the code management devices for unforeseen cases
22. Use a good test coverage basis (tests for each possible diagnostic, tests for typical use of the simulation…)
23. Redo the basis of test in case of modification of configuration
24. Perform tests on parameter sensibility to adjust them at best
25. In case of undetermined diagnostic, perform a detailed analysis of motor operation to correct the right item.

4. RESULTS

As motors have been built for classified simulations, an example of diagnostic (out of context) has only been shown in the introduction and it's not possible to show all the information given by the motor.

This diagnostic modify methodology of aircraft self-protection studies because it's now possible to quantify reasons of result, the action of each flare instead of general consideration of the expert.

On the results, the following message can be given: As the motor used logic combination, the only cases of dysfunctions are logic combination not taken in account. If the analyzis and the configuration are well done, diagnostic can be made at nearly 100%.

5. APPLICATION CASES

The generic motor for simulation analysis have been built and defined for aircraft/missile simulations.

This motor can be used for other simulations for which a diagnostic is requested. The diagnostic can be a final diagnostic or a temporary diagnostic for a monitoring system for example. The only conditions to build a motor is that Static and Dynamic Analyses are successful.

If an expert knows how to analyze the simulation, it is helpful, but not necessary to build a motor. The different way of thinking to build this motor has shown that making static and dynamic analysis can help in simulation analysis.

6. CONCLUSION

The present work on a generic motor for simulation analysis allows to notably increase the coverage ratio of analysis of simulations well as the reliability of the results and show a new image of the results with the statistics on the behavior of the simulation.

The construction of a motor is not a quick and easy task, but the added value and the time spare by an expert for manual analysis can make it interesting. The time to build a motor depends on how well the procedure is defined, so the present document has tried to described it with details.

The present method to build a generic motor for simulation analysis has been described based on the feedback of motor realized in a specific aera. This method will evolve with the construction of new motors and every one can adapt it for his purpose.

The “Simulation diagnostic expert” will be perhaps a new job as “value engineering expert”, “experiment plan expert”.

ACKNOWLEDGMENTS

Didier RAU wishes to thank The “Mission pour le développement de l'innovation participative” of the DGA for the funding of the industrialization of the generic motor for simulations analysis.

Didier RAU wishes to thank Olivier PUECH and Benoit MELLIER for their thorough re-rereading of this paper.

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