Fault Detection and Isolation in Hybrid Systems with Dynamic Bayesian Networks and Consistency Based Diagnosis

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ABSTRACT

It is well known the importance of fault diagnosis, systems have to be working in a safe and reliable mode. The way to keep systems working properly is not only to detect when a fault occurs, but also where the fault has occurred as well as its magnitude. Model-based diagnosis techniques have been successfully used for fault diagnosis tasks. However, model-based diagnosis techniques faced some problems when dealing with continuous systems governed by discrete events. Continuous systems governed by digital controllers appear frequently in embedded systems. The work developed with those systems, using a hybrid automata modeling formalism, shows the complexity of tracking all different modes and possible faults. The dissertation presented in this paper proposes a more efficient way to perform fault diagnosis in hybrid systems using Dynamic Bayesian Networks and Possible Conflicts.

1. OUTLINE OF THE THESIS

This proposal works upon the idea of developing an efficient method to carry out Fault Detection and Isolation (FDI) within continuous systems governed by discrete events. The proposed tool to model those systems is Dynamic Bayesian Networks (DBNs).

The main advantage we want to obtain with the use of DBNs is avoiding the problems discovered with previous methods using a hybrid automata modeling approach (Henzinger, 1996). On the other hand, DBNs have also several disadvantages. The first disadvantage is the high computational effort needed to do exact inference but this has been solved using Particle Filter (PF) approach. Another issue about DBNs is the difficulty getting an accurate convergence when there are several unknown states.

Possible Conflicts (PCs) (Pulido & Alonso-Gonzalez, 2004) allow the decomposition of a system within minimal subsystems with analytical redundancy. PCs has been used successfully to reduce the complexity in identification tasks without reducing the accuracy. PCs will be used to divide the DBN of the complete system model into smaller DBNs which will reduce the number of unknown states.

The main motivation for this thesis is to advance recent methods for hybrid diagnosis by developing a model-based solution that performs FDI in uncertain (i.e., noisy) environments with DBNs. DBNs with PF inference will be used on every aforementioned diagnosis steps. To reduce the computational burden of fault isolation and identification, methods will be developed to generate ”minimal” DBNs from PCs.

2. EXPECTED CONTRIBUTIONS

The thesis is expected to provide the contributions listed below:

- Methods to efficiently track hybrid systems under controlled mode changes using DBNs and PF.
- Methods to derive DBNs using PCs to reduce DBN size (nodes and arcs).
- A diagnosis arquitecture integrating DBNs and PCs for hybrid systems

3. PROPOSED PLAN

The proposed work plan of this thesis is divided in two main tasks: i) the work which has already been done and ii) the work which will be done from now until the defense of the dissertation.

3.1 Work Performed

During the last two years I have been working on the second and third contributions. A method to derive the DBNs directly from PCs structure has been developed. Two different approaches available to represent PCs have been considered: i) Temporal Causal Graphs (TCG) (Bregon, Pulido, Biswas, & Koutsoukos, 2009) form and ii) hypergraph (Pulido & Alonso-Gonzalez, 2004).

DBNs derived from PCs are used to track the nominal system, so they can be used to detect faults in the system. DBNs are also used to track faults and estimate the value of the parameter which has the fault. The method to implement DBNs to track faults is the approach described in (Roychoudhury, Biswas, & Koutsoukos, 2008). The nominal DBN is augmented with a node representing the faulty parameter which is linked with the other nodes it influences.

Once the first step was completed, it was integrated in a diagnosis architecture. Figure 1 shows an example of that architecture including the DBNs derived from PCs. This work have been presented in the DX 2010 Workshop (Alonso-Gonzalez, Moya, & Biswas, 2010). This architecture will be generalized to work with the hybrid systems considered in this work.

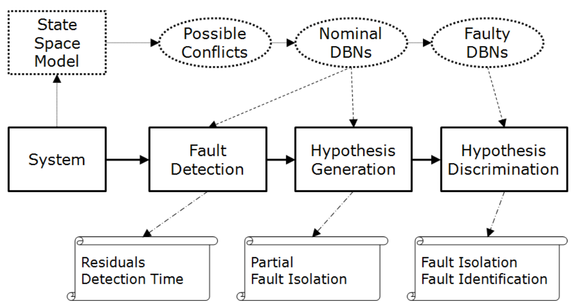

Figure 1: Diagnosis arquitecture integrating DBNs and PCs.

During the work explained above other research topics came up, for example the need to check the observability of a system before building its DBN. The problem is that a DBN of a non-observable system will not behave properly while tracking the system. A study of the structural observability property in Bond Graphs (BG) has been done while the observability of PCs has been tested too. PCs provide a decomposition of the system into smaller subsystems which we have proved that are always structurally observable. This contribution has been presented in the DX 2010 Workshop (Moya, Biswas, Alonso-Gonzalez, & Koutsoukos, 2010).

Regarding the first contribution, I have started working with Hybrid BGs (HBGs) as a tool to model the hybrid systems (Roychoudhury, Daigle, Biswas, & Koutsoukos, 2010).

3.2 Future Work

During the performed work it has come up the idea to consider structural uncertainty in BGs modeling the system (Kam & Dauphin-Tanguy, 2005). The main reason to introduce this concept is that once we know there is a fault, we are not able to know exactly the model of the system. When a fault occurs something is not behaving properly in the system and we do not know what it is so we cannot model it properly. I have start working on this topic.

Once the contributions presented in the previous section have been developed to use in continuous systems they need to be applied also to hybrid systems.

First, I will extend the approach of (Podgursky, Biswas, & Koutsoukos, 2010), consisting on online incremental generation of continuous equations for new system modes, to tracking the hybrid systems with DBNs. Afterwards, hybrid PCs will be generated on line with a similar approach. We expect this will allow us to track the hybrid systems with DBNs obtained from the PCs of the current mode in an efficiently manner.

As a final step, all the work developed for FDI of hybrid systems will be integrated in a diagnosis architecture similar to the one in Figure 1.

4. CONCLUSION

The use of DBNs allows to perform fault diagnosis in continuous systems governed by discrete events without the problems of the hybrid automata modeling formalism. Moreover, using PCs to derive DBNs helps to get less complex DBNs and it also avoids the need to check its structural observability. We expect that the proposed approach will be able to perform fault detection, isolation and identification of hybrid systems in noisy environments efficiently.

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