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Minimizing test-point allocation to improve diagnosability in business process models

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ABSTRACT

Diagnosability analysis aims to determine whether observations available during the execution of a system are sufficient to precisely locate the source of a problem. Previous work deals with the diagnosability problem in contexts such as circuits and systems, but no with the adaptation of the diagnosability problem to business processes. In order to improve the diagnosability, a set of test points needs to be allocated. Therefore, the aim of this contribution is to determine a test-point allocation to obtain sufficient observable data in the dataflow to allow the discrimination of faults for a later diagnosis process. The allocation of test points depends on the strategies of the companies, for this reason we defined two possibilities: to improve the diagnosability of a business process for a fixed number of test points and the minimization of the number of test points for a given level of diagnosability. Both strategies have been implemented in the Test-Point Allocator tool in order to facilitate the integration of the test points in the business process model life cycle. Experimental results indicate that diagnosability of business processes can be improved by allocating test points in an acceptable time.

1. Introduction

Nowadays, organizations automate their tasks with business processes (i.e. a set of activities that are performed in coordination in an organizational and technical environment, to jointly realize a business goal (Weske, 2007)) that can be enacted using Business Process Management Systems (BPMS). The fault detection of abnormal behaviours in business processes and the later diagnosis of the responsible for the malfunction are crucial from the strategic point of view of the organizations, since their proper working is an essential requirement. Unexpected faults can provide undesirable halts in the processes, thereby causing cost increase and production decrease. Therefore, to maintain business processes at desirable reliability and production levels, it is necessary to develop automatic techniques to detect and diagnose their faults in order to identify their causes.

Fault diagnosis (hereinafter referred to as diagnosis), is based on observations, which provide information about the behaviour of the process, making possible to discriminate between faults, and hence rendering the business process diagnosable. Without the information obtained from monitoring a process, the faults that occur in runtime cannot be diagnosed since it is not possible to know if the activities composing the business process work correctly.

Therefore, if the information available to perform the diagnosis proceed from few observations, or if observations are not allocated at the most convenient places, it is very difficult to distinguish which parts of the business process are failing. Both the number of observations and the location where they are performed, enable the source of the problem to be precisely located.

Regarding fault handling in business processes, not every kind of fault that can occur is unpredictable. Some faults can be managed at the level of modelling language by catching and handling exceptions, using fault sensors to be fired if a fault occurs during the execution of a monitored activity, thereby detecting the error when it occurs. Nevertheless, according to Han et al. (2009), the existing fault handling mechanism can only detect (identify) the faults which have been pre-defined in standards or by users, but unexpected faults are also the cause of failures in service flows, being necessary an effective diagnosis approach.

The diagnosis process is executed when the actual behaviour of the business process does not correspond to the expected one, being that abnormal behaviour not necessarily perceptible by the use of fault sensors but it may be reported after completion of the execution of the business process (for example, after some customer complaint). In that moment, the diagnosis process is in charge of the isolation of the source of the abnormal behaviour. Therefore, since there is not a single entity that has a global view of information flowing through a business process in runtime, the aim of this approach is to determine the monitoring places in order to guarantee the observability of the data flow at those locations during the execution of a business process instance. This is

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performed by the allocation of test points at intermediate places of business processes, and not only at the input and output as it is done by default. A test point can be allocated in the *flow* (sequence flow, conditional flow or default flow according to BPMN 2.0 (OMG, 2011)). This contribution takes into account that not all flows of a business process are available to house a test point, either due to confidentiality, privacy, security, or due to some flows which are not needed to be monitored.

As an example, Fig. 1 shows a business process composed of nine activities. Without any monitoring, the business process presents the minimum diagnosability level, because the lack of information about the data flowing through the process causes that the faulty behaviour of any of the nine activities cannot be discriminated from the rest. That is, given a customer complaint about an abnormal behaviour of the overall process (caused by an unexpected fault), it is not possible to distinguish which activity or activities may be responsible for the problem. Nevertheless, providing the diagnosis system with some information about the inner behaviour of the process by means of the allocation of (at least) one test point in the process in Fig. 1, the diagnosis system will use that information to exonerate some activities from the abnormal behaviour of the process, this way improving the diagnosability level. For instance, the allocation of a test point after the activity A_6 would allow to distinguish whether the abnormal behaviour of the process is caused by some activity in the subset $\{A_1, A_2, A_3, A_4, A_5, A_6\}$ or in the subset $\{A_7, A_8, A_9\}$.

The errors that affect business processes can be derived from different types of faults: (i) business faults, which occur at specific points in a business process because of application issues, for example, because of data content problems. The fault can be the result of a business rule violation, or a constraint violation. For example, invoking a bank service to transfer funds can result in an insufficient-funds fault; (ii) system faults, which occur because of system-related issues, such as the unavailability of a service, or a network failure; and (iii) behavioural faults, which concerns the faults in the model, such as deadlocks and livelocks. The fault diagnosis process is used for the isolation of those activities or subprocesses which are responsible for any incorrect behaviour within the whole process. Since system faults and behavioural faults have already been taken into account in the literature (Varela-Vaca et al. (2011), Baresi et al. (2006), and Eshuis and Kumar (2010); Lin et al. (2002), Van Der Aalst et al. (2011), and Zha et al. (2011), respectively), the present contribution aims to allocate test points for a future diagnosis of business faults. Nevertheless, our proposal can be extended in order to monitor business processes for identifying system faults, in the same way that it is done in the approach by Varela-Vaca and Gasca (2010).

To carry out the idea of isolating business faults, two objectives for the allocation of test points are proposed in this paper: (i) the improvement of the diagnosability level of a business process for a fixed number of test points; (ii) the minimization of the number of test points to allocate for a desired level of diagnosability.

Previous works in the literature deal with the problem of fault detection in business processes (Conforti et al., 2011; Alodib and Bordbar, 2009), and the monitoring of web services or business processes (Yan et al., 2009; Han et al., 2009; Zhang et al., 2009a; Narendra et al., 2008). However, none of these contributions is focused on the analysis of the diagnosability and its improvement. Some other works in the literature address the diagnosability analysis problem (Bocconi et al., 2007; Dressler and Struss, 2003; Travé-Massuyès et al., 2006; Console et al., 2000) for other scenarios.

The paper is organized as follows. Section 2 defines concepts related to diagnosability and introduces the two objectives in greater depth, presenting an example to illustrate the concept of diagnosability in business processes. Section 3 details the methodology used in the allocation of test points in business processes. Section 4 gives the implementation details and shows experimental results. Section 5 presents an overview of related work found in the literature. And finally, conclusions are drawn and future work is proposed in Section 6.

2. Diagnosability of business processes

In order to present the proposal to determine the allocation of test points, it is necessary to introduce the concepts and definitions related to diagnosis and diagnosability. For the sake of clarity, an example is also included.

2.1. Main concepts and definitions

The specification of a business process can be viewed from different perspectives (Lanz et al., 2012): (1) the control-flow perspective, which describes the activities of a process as well as their ordering and execution constraints, (2) the data perspective, which connects activities with business and process data, (3) the resource perspective, which provides a link between the process specification and the organizational structure, (4) the operational perspective, which refers to the application services executed in the context of activities, and (5) the temporal perspective, which deals with the temporal properties of the processes.

Although a business process is configured and enacted from a correct model, it may present abnormal behaviour during its execution. This abnormal behaviour is detected because how each activity actually works does not correspond to the expected behaviour, producing wrong data in the data perspective of the process. Those data in the data perspective are dataflow variables, which are read and written by the activities composing the process, and which should be at least partially monitored in order to perform a diagnosis process (cf. Definition 1) to discover the source of the faults.

Definition 1 *(Diagnosis).* A diagnosis of a business process is a particular hypothesis which explains why the current behaviour of the process differs from its expected behaviour.

One of the most used methodology to diagnose classic systems has been model-based diagnosis, which has become the most extensive research area in the diagnosis field. The reasoning is carried out from a model which represents the system to diagnose in an explicit way. A fault exists when the observed behaviour does not correspond with the behaviour expected from the model. This model comes from the knowledge of the system. The component responsible for the fault is identified with a later analysis of the discrepancies.

Model-based diagnosis is based on the comparison between the available observations about the operation of a system (by means of the observation of the dataflow), and the predictions made from the model of the system. The observations indicate how the system is behaving, whereas the model expresses how it should behave during a correct execution.

When a symptom (i.e. a discrepancy between the observed and expected behaviour) is detected, it is deduced that at least one of the components involved in it is not working correctly. The description of the systems, done by the models, uses the relations between inputs and outputs. Most of the approximations for components characterize the diagnosis of a system as a collection of minimal sets of components that fail to explain the observed behaviour (symptoms). That is why it is important to count on a detailed model to determine the diagnosis of a system.

As stated in Bocconi et al. (2007), in order to explain the diagnosability concept, it is necessary to distinguish the notion of fault (i.e. individual state of each activity in a business process), and the