PiE - Processes in Events: Interconnections in Ambient Assisted Living

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Abstract. In the era of Internet of Things (IoT), sensors distributed in the environment can provide essential information to be exploited. In this work we propose to exploit the advantage of a sensor-enriched environment for supporting the processes of several cooperating organizations. Our approach, PiE (Processes in Events), aims to identify and exploit interconnections between processes, without demanding the restructuring of their inner structure. Starting from a set of events generated by sensors and business processes (BPs), we propose a methodology for multiple process annotation. From the analysis of the events correlations, we can discover interconnections among processes of several organizations involved in the same goal and derived additional information about the processes being executed. An example within an Ambient Assisted Living (AAL) scenario is studied, where several organizations cooperate to provide social and health care to a subject.

1 Introduction

Nowadays, organizations cooperate in order to provide a better service to their customers, by combining their expertise. Most of the time, they act separately, without any high level coordination, following an independent process to provide their contribution. This approach is problematic from several points of view. First of all, the information items over which the processes of the different organizations work are not independent, and the data used and produced by each of them should be shared to provide a better service. Another relevant aspect is that these processes, even if independently executed by different organizations, are not actually independent. In fact, they are implicitly related to each other and this relation should be exploited in order to provide a better global service.

In addition, several sensors could be available in the environment, not necessarily related to the process execution: also events generated by these sensors can be exploited to provide additional useful information on the processes and their possible implicit dependencies.

In this work, we aim to discover implicit relations among processes and events, and to exploit this knowledge to provide additional information about the global process. To achieve this goal, we propose the PiE (Process in Events) methodology: starting from a set of business processes (BPs) and from a set of events recorded during the execution of the processes, we aim to provide a deeper

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knowledge about the global process, analyzing relations between processes and events, between events, and between processes. This knowledge, acquired in an automatic way, can also be exploited for conducting advanced analysis about the behaviour of the involved processes. As an example, we show how PiE can be applied to a case of health and social care of elderly people in an Ambient Assisted Living (AAL) scenario.

The paper is organized as follows. In Sect. 2 we discuss related work. In Sect. 3 we describe a running example. Sect. 4 illustrates the events being considered in the analysis. Sect. 5 describes the first phase of the methodology, in which relationships between different types of events events are discovered. In the second phase, illustrated in Sect. 6, possible ways of analyzing global processes through mining information from events are discussed.

2 State of the Art

The need of living in a sensitive and interacting environment has brought to the study of technologies needed to realize such an environment, e.g. Ambient Intelligence (AmI) and Internet of Things (IoT). One of the first definitions of AmI can be found in [3] where it is described as a developing technology to enhance the sensitivity and the reactivity of the environment to the human presence. In [6] authors envision the future as a non perceivable integration of technology in the environment to ease and improve human life. The six features of this enriched environment are defined in [5]: sensitive, adaptive, reactive, transparent, ubiquitous, and intelligent. This environment produces a big amount of information that has to be managed for getting advantage of its richness.

Information gathered by AmI and IoT can be also used to support business processes of several kinds. An event-based approach has been proposed as a basis of business process modelling by several authors. A summary of the main approaches is described in Weske's book [11]. In particular, many approaches are based on events related to the start and end of processes and activities, and on other significant events for the process, such as incoming and outgoing message exchanges, time outs, exceptions, cancellation and termination. In the area of business process analysis, first workflow mining [1] and, later, process mining [2] have been proposed to derive process models from logs of events, with different purposes: reconstructing actual process models from events of activities, to avoid the complex and error-prone manual design activities; comparing actual flows with the designed ones in order to check for compliance; discovering new flows in addition to the ones which have been originally designed. The recent challenges mentioned in [10] are being considered also for analysing the relation between processes and events. The challenge presented in BPI 2015[1] asks to identify how changes in the organization or in the procedures or regulations have affected the processes in general, to identify possible improvements, or the impact of some changes. In [8], the authors started to propose a systematic approach to analyze sets of events originating from a process not only for process mining, but also to

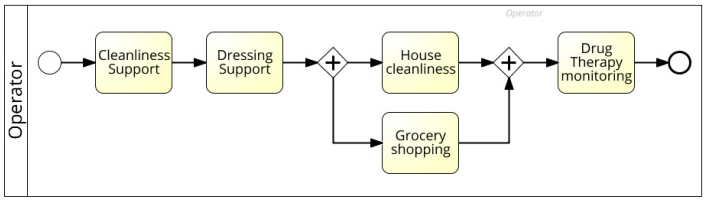
[1] http://www.win.tue.nl/bpi/2015/challenge

derive some additional information to relate the events occurring in a process. It is possible, for instance, to uncover bottlenecks or other problems, by adding to the original events log trace other information related to event derived from the process log, such as associating the duration of an activity to its starting event, or the next activity in the trace. In this way it is possible to build decision trees to answer questions about possible process characteristics. In [9], the proposal to extend process logs with events from supplementary sources is focused on recognizing missing events with the support of other traces. In our paper, we want to extend the possibility of analyzing related events examining not only internal events or information within a process, but also external events derived from other processes and from sensors.

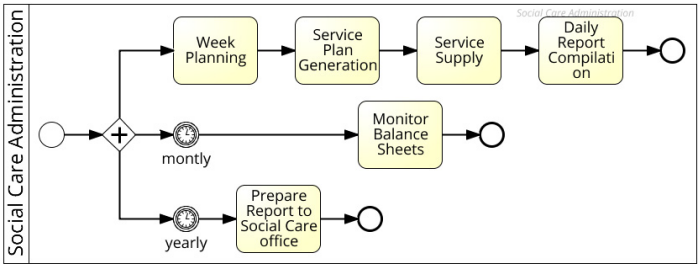
3 Running Example

Nowadays, the assistance at home of elderly and non sufficient people is an important topic from a social and care perspective. Moreover, it can significantly benefit from the support of technologies. We consider a typical context in which AAL can be employed. The subject lives in an environment enriched with sensors and devices to collect useful information about his social and health care status. Several organizations can interact to provide assistance to the subject, each of them with its own processes to follow. These organizations, even if not directly coordinated, need to share common information and to be aware of important events related to the subject. This information may be composed of different kinds of data, such as data coming from sensors inside the house of the subject, or data produced by the BPs. From the collection and the analysis of these data, useful information can emerge to help in providing assistance.

The technological infrastructure to provide such an environment is being developed within the Attiv@bili project, centred on a middleware realised to exchange events between all operators in home care [7]. In the running example, we consider two BPs, part of the Attiv@bili scenario: (i) the *Operator Process* models the activities performed by an operator involved in the assistance process and the interactions with the subject (Fig. 1(a)); (ii) the *Administration Process* models a process performed by the administration in order to decide the activities needed for the subject and to manage reports and payments to the operators (Fig. 1(b)). The environment is enriched with sensors which monitor the environment and create events: devices installed in the house of the subject allow the registration of the exit and entrance of operators; wearable devices, in the specific case a wrist watch, monitor physiological parameters and activities of the subject (fall and stillness detection, exit and entrance in the house). Finally, other events may be manually created and inserted in the system through a web interface by operators, such as the registration of a health service or the approval of a plan for health and social care for a new subject.



(a) The operator process



(b) The administration process

Fig. 1. Attiv@bili: two examples of social/health care processes

4 Events Classification

In the proposed approach, events are information captured and recorded in the system, coming from several sources. Through events it is possible to detect important phases of the processes and to collect information generated by sensors and/or devices belonging to the observed environment. According to this definition, an event is a generic container of information with a well-specified structure. The description of the structure of events goes beyond the scope of this paper, since whichever format is adopted, it is not a limitation for the approach. The only constraint is to have a shared structure for all the events and that the system is designed in order to capture relevant information. In the methodology we distinguish between two categories of events:

- *Process Events* (P): they are generated during the execution of one of the processes of the organizations. In this category we find start/end events generated by the activities, together with information generated during the activity execution. This kind of events is directly connected to the process and can be easily mapped to the execution of a specific activity. In this category we distinguish between *internal* and *external events*. Internal events are directly connected to a specific process, while external events may have a relation with events being generated by other processes.
- *Environmental Events* (E): these events are generated by sensors distributed in the environment or placed in devices provided to the subject in order to monitor physiological activities. This information is not directly linked to the processes, but can have an indirect relation with some of them.

Table 1. Events classification in the Attiv@bili platform

ID	Name	Cat.	Description
T_1	Operator Entrance	E	Records when an operator enters into the subject house
T_2	Operator Exit	E	Records when an operator exits from the subject house
T_3	Service Registration	P	Records a service performed by an operator
T_4	Expense Report	P	Records a cost paid for offering a service to the subject
T_5	Drugs Report	P	Generation of a report about the drug therapy of the subject
T_6	Payment Emission	P	Records a payment addressed for a service by the social care
T_7	Week Plan Creation	P	Records when a week plan is created for a subject
T_8	Subject Fall	E	Detects the fall of the subject
T_9	Subject Immobility	E	Detects a lasting absence of movement for the subject

For each category, several types of events can be defined by providing a description of their structure and the kind of information carried by them. Every time a specific event is recorded, we call it an event instance.

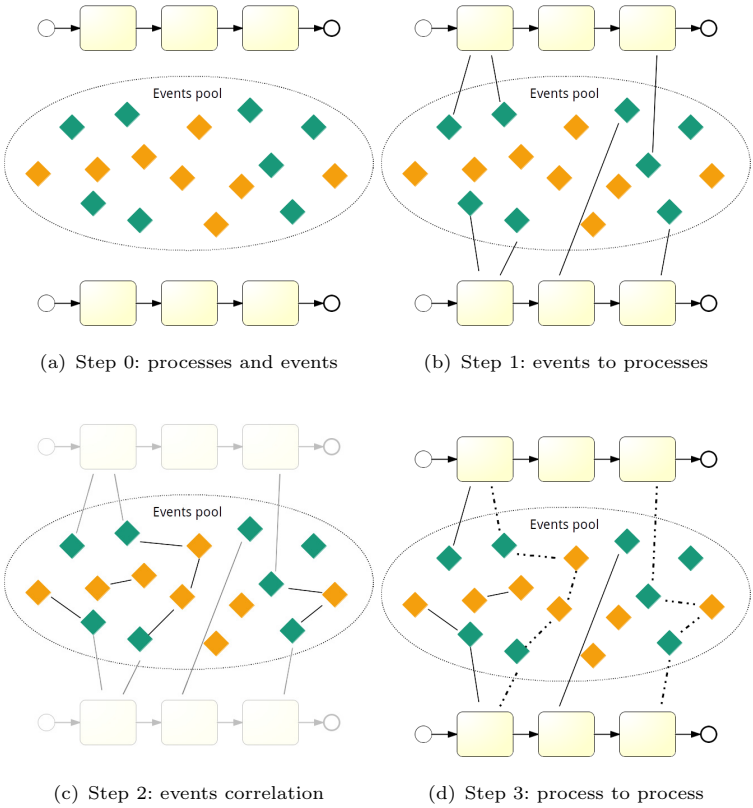
Definition 1. *An event instance e_i is the recording of an event detected in the observed environment. It is defined by a tuple $e_i =< c, T_j, ts >$, where c is the information recorded in the event (content), T_j is the type to which it belongs, and ts is the timestamp at which it has been recorded.*

Tab. 1 contains a classification of events recorded in the Attiv@bili platform that are useful for our case study.

5 Multiple Process Annotation

In PiE we exploit the availability of information contained in the events to acquire a deeper knowledge about the processes involved in the global scenario and about their hidden interrelations. We claim that this knowledge can be important to better understand each of the systems involved and to improve the way each organization operates in the described scenario. The proposed PiE methodology consists of two main phases: (i) multiple process annotation; (ii) process mining (see Sect. 6). In this section we describe the first phase. The idea is to start with a set of processes described in a notation representing the set of activities composing the process and the order in which they are executed. Given this information, we imagine to immerse the process in the pool of events, obtaining a set of annotated and interconnected processes. The annotation procedure consists of three steps:

1. *Events to Processes Mapping*: events are analysed to find a relation between them and the activities of each of the involved processes (Sect. 5.1);



(a) Step 0: processes and events (b) Step 1: events to processes

(c) Step 2: events correlation (d) Step 3: process to process

Fig. 2. The PiE annotation phase

2. *Events Correlation Discovery*: the pool of event instances is analysed to find implicit relations among event types, building a network of events describing the discovered interconnections (Sect. 5.2);
3. *Process to Process Interconnection*: events interconnections and the mapping of events to processes are used to find indirect relations among processes, discovering hidden dependencies. (Sect. 5.3).

Fig. 2 shows a graphical representation of the approach. In Fig. 2(a) two processes are represented together with their pool of events: process events are shown using a darker colour and environmental events in lighter colour. In the rest of this section we analyse each of these steps in more detail.

5.1 Events to Processes Mapping

The first step of the annotation process consists in associating process events to the BPs activities. Given a process, the events recorded during the execution

of its instances are analysed in order to detect relations with the execution of the activities. In this step, the approach links the internal process events to the process, obtaining an annotated process. As described in Sect. 4, internal events are process events that are intrinsically connected to one or more processes, and this connection is expressed in the event definition. In order to create the links, the body c of the event is analysed. The discovered relation is a link $L(A_p, e_i)$ connecting an activity of a process to an event instance. This first step is represented in Fig. 2(b), where some of the activities of the two processes depicted in the figure are linked with one or more process events.

5.2 Events Correlation Discovery

The second step investigates relations between events, both of process and environmental kind. Given the pool of event instances $E = \{e_i\}$, relations are analysed in order to detect hidden dependencies. The analysis is performed considering the temporal distribution of the event types T_j looking for patterns according to the timestamp at which the event has been recorded ts. The analysis that can be performed over the events are of different kinds and depend from the kind of relations that are to be investigated. Examples are:

- *Pattern Matching*: this technique analyses the temporal succession of events in order to detect regular patterns. These patterns are connected to the temporal distribution of the event instances registration. Pattern matching techniques enable the detection of regular sequences of event types in a specific or in an arbitrary order. The set of patterns detected by the pattern matching analysis is scored according to the number of times the pattern has been identified in the data set;
- *Association Rules*: this technique is used to detect causal relations among events which occur in the same time frame. An association rule is expressed as a premise and a consequence, meaning that when a premise (the detection of a specific set of event types in a time range) is true, then the consequence (another set of event types) is going to be verified too [4]. Association rules are scored using two metrics: support and confidence. Support measures the proportion of events recording which contain the association rules. Confidence measures the proportion of the events that contain the premise which also contain the consequence.

This step is shown in Fig. 2(c), where the pool of events is enriched with links connecting both process and environmental events. The output is a set of links $L(T_j, T_k)$ between event types, each one associated with a score expressing the reliability of the detected relation.

5.3 Process to Process Interconnection

After the focus on the events relations, the third step consists in expanding the vision to the global view in order to find interconnections among processes

of different organizations. These interconnections derive directly from the two steps already defined. The detection of the interconnections is performed by analysing possible paths existing between two activities passing through a set of interconnected events:

Definition 2. *An interconnection between two processes P_a and P_b is detected when it exists a path $\mathcal{P}$ between two activities $A_a \in P_a$ and $A_b \in P_b$:*

$$\mathcal{P}(A_a, A_b) = T' \subseteq T \mid \forall\, T_j \in T' \; \exists\, T_k \mid \exists\, L(T_j, T_k) \tag{1}$$

A threshold can be applied for considering only strong relations among events. Also, given a set of possible paths between two activities, the most reliable one is selected. In Fig. 2(d) two paths are detected (highlighted with dashed lines) linking activities of the first and the second process.

5.4 The AAL Example: Interconnections Between Processes

The methodology described in this section is illustrated considering the running case study introduced in Sect. 3 considering the events described in Tab. 1. Events have been connected to the activities of the two processes and relations among them have been exploited to discover interconnections among processes. The discovered paths link the activities of the operator related to the providing of a service or the registration of expenses to the management of the balance sheets in the administration process. Events relations and paths are shown in Fig. 3.

6 Process Analysis: Mining Information from Events

In the second phase of the PiE methodology, we propose to exploit the results of the first phase for mining useful information about the processes execution. We start from the methodology proposed in [8], that allows mining information from relating different types of events generated by processes. The approach can be extended considering all the relationships derived in the first phase of the methodology, therefore relating events in processes or environmental events which are not necessarily related to each other by design. Information that can be mined can be general and use-case specific:

– *General Information* is about conformance and coverage of the processes. *Conformance* evaluates if the processes observed through the generated events reflect the structure provided by the several organizations or if there are inconsistencies between the modelled and the real processes. *Coverage* measures the total number of activities which are observable through events. In fact, some activities are not sensed by any of the collected events and their execution is not verifiable.

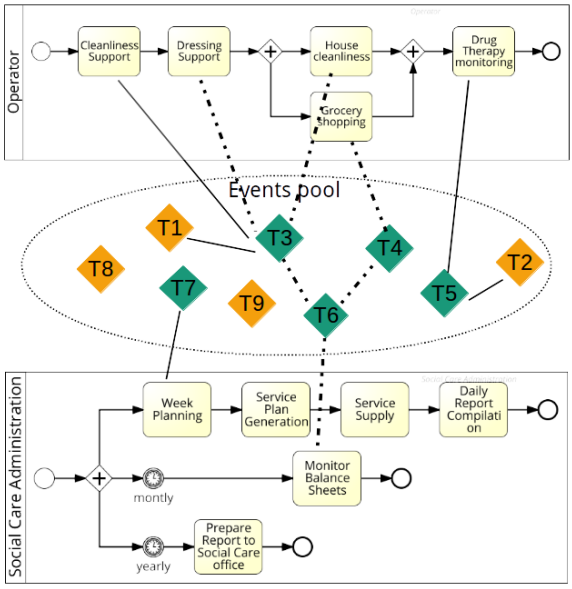


Fig. 3. PiE annotation applied to the Attiv@bili use case

– *Use-case Specific Information* enables to perform complex reasoning about the specific use case. Through mining the information obtained by the PiE framework about interconnections among processes, it can be possible to answer questions about the execution of the processes. In the AAL example considered in this work, possible questions are: (i) Which are the assistance activities followed by the production of a report? (ii) How many activities require a payment and how often they are executed? (iii) Which is the average duration of the cleaning and dressing activities for a specific subject? Is it regular? Does it change with operator? Is it in line with the duration of the same activities on other subjects? (iv) Which is the average cost of the grocery shopping for a specific subject and from what this cost is dependent? Answering these questions can provide an additional knowledge useful for analysing the efficiency and effectiveness of the social and health care service provided to the subject and can help in improving its quality.

7 Final Remarks

In this work we presented a first proposal of the PiE methodology that allows understanding interconnections existing between several BPs of cooperating organizations, starting by available process and environmental events. Processes are first annotated correlating them with events. This additional knowledge enables complex reasoning about the behaviour of the considered processes (process mining). We have illustrated a possible application of the methodology in

the AAL field. The proposed approach is based on the underlying Attiv@bili platform that allows event sharing between processes. Experimentation on running case studies is planned in the next months, to evaluate the methodology and to identify the questions that can be useful for the analysis of the processes under consideration. A tool is being developed to automatically support these analyses on available events.

In future work, we plan to apply the PiE methodology to other fields without substantial modifications. An important issue to be studied in future work is the visibility of events in collaborative processes. In fact, while the BPs models may include messages exchanged between cooperating processes, and therefore the related events are visible to the participating parties, the events related to sensors, and in particular events containing personal information, require to be managed according to access rules for the actors in the processes.

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