Intelligent Systems for Users' Automated Guidance

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***Abstract*. Future developments for case management must evolve from the current systems based on rigid, workflow based processes into context-aware, agile dynamic structures. We propose to combine a declarative approach for process design and the use of formal methods to enable a set of automated techniques for process analysis and validation based on model checking and theorem proving. Thus, they improve the level of automated user support allowing maximum run time flexibility.**

This paper defines a roadmap for a PhD research, aiming at developing the automated guidance provided by intelligent systems. The main idea is to explore formal methods and formal concept analysis to build a new approach for knowledge-intensive process modeling, simulation and analysis. In this paper, we consider the example of an intelligent city operation center.

Keywords—intelligent systems; formal methods; formal concept analysis; knowledge-intensive processes.

I. INTRODUCTION

The world we live in may be considered as a complex network environment that combines a variety of components (e.g. education system, healthcare, transport network, urban infrastructure, etc.). Day by day it is becoming more instrumented, connected and smart. Responding to the challenges of modernity, in all aspects of planning and management, the traditional way of thinking is being replaced by a systemic view. And a systemic view often implies involving intelligent systems.

The notion of an "intelligent system" means a formal or informal system that manages data gathering to obtain, process and interpret data, and to provide reasoned judgments to decision makers as a basis for action. This term is not limited to intelligence organizations or services but includes any system that accomplishes the listed tasks.

Intelligent assistants for decision-making have to deal with unpredictable processes, which means that in order to work properly they need to constantly adapt to various "unknowns" while analyzing current situations. These "unknowns" may include client situation and needs, economical and technological trends, expert skills, available equipment, environmental conditions, etc. Functioning for years following predefined scenarios only is not an option for these intelligent systems.

Dependence on changing data and other unknown circumstances makes it really challenging for intelligent systems to provide users with automated guidance. Due to extremely high unpredictability of processes these systems work with, it is not an easy task to create an automated guidance in decision-making. Existing solutions can offer quite a limited number of options: monitoring the object, informing the user when something happens with the object, reacting in critical situations according to a predefined plan of actions.

This paper defines a roadmap for a PhD research, aiming at developing intelligent systems for users' automated guidance.

The paper is organized as follows. We first briefly describe the context of this work in terms of intelligent system support to knowledge-intensive processes and of process modeling methods. We discuss the limits of existing approaches in these areas and illustrate research challenges on the example of a City Operation Center. We finally propose a roadmap for our future research, divided into 3 main challenges, related respectively to process modeling, process analysis and intelligent system's process support.

II. CONTEXT

A. *Knowledge-intensive processes, their support in intelligent systems*

Intelligent systems are in particular needed to support knowledge-intensive processes due to their dependence on the knowledge of an expert (a user) and, as a consequence, high flexibility of the contextual scenario.

In [1] a process is defined as knowledge-intensive if its value can only be created through the fulfillment of the knowledge requirements of the process participants, while Davenport recognizes the knowledge intensity by the diversity and uncertainty of process input and output [2].

In our view, a knowledge-intensive process is characterized by activities that may change on the fly, are driven by the scenario that the process is embedded in and, most importantly, depend on the completeness of available contextual information. The scenario dictates who should be involved and who is the right person to execute a particular step, and the set of involved users may not be formally defined and rather be discovered as the process scenario unfolds. That is why such processes cannot be automated. However some guidance can be offered to these experts by intelligent systems to help them make their decisions faster, taking more parameters into account.

B. Modeling methods

In order to assist users in managing knowledge-intensive processes we need to make the right choice of a modeling method.

The majority of existing methods for process modeling follow imperative principles, implying that the order of events is predefined [6]. As a result, all meaningful process events and corresponding actions need to be predefined at design time. However, providing a high degree of control, imperative formalism suffers from a lack of agility, because at run time processes follow the configured model with limited possibilities to deviate from the predefined scenario.

We consider shifting that method towards a declarative process model which focuses on “what” needs to be done in order to achieve the process goal and not on “how” it has to be done. This allows us to handle process events whose order of occurrence is undetermined and to define the corresponding handling scenarios at run time.

The shift of the traditional imperative paradigm for process design and exploration of declarative principles will ensure a greater agility.

In this section, we have identified some weaknesses of existing knowledge-intensive processes and modeling methods which do not provide sufficient agility or automated guidance to users. In the following section, we illustrate the potential of automated guidance in the specific context of city operation centers.

III. AUTOMATED GUIDANCE FOR CITY OPERATION CENTERS

A City Operation Center is a complex system that offers centralized, real-time collaborative environment for planning, monitoring, organizing and sharing information across city departments and agencies. It processes data feeds and event information from individual departments, then presents that information in a citywide view.

Our colleagues from the research team in Center of Open Systems and High Technologies (COS&HT) in Moscow have presented in [3] their project for smart cities - COS Operation Center (COSOC).

In this section, we review the main functions of COSOC, define the limits of this system and propose our solution to expand its functionality.

A. Existing functionality of COSOC

The main functions of COSOC can be divided in four categories:

- *Monitor citywide issues (events, tactical situations, emergencies and operations) in real-time mode.*

  COSOC provides an executive dashboard (fig.1) to help city leaders gain insight into different aspects of city management. It captures information from a variety of sources, such as crime statistics, traffic reports and city camera recordings, and converts it into usable data.

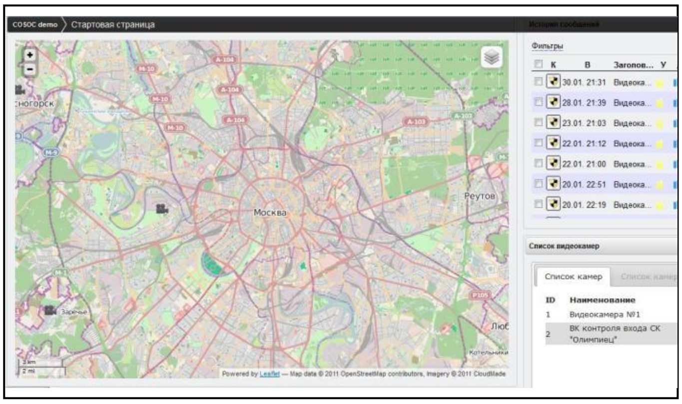

Fig. 1. The executive dashboard of COSOC provides user with a city map, list of events, accidents, emergencies and a list of cameras set throughout the city.

  Whether users want a fast overview of an emergency situation or a deep dive into performance metrics, they can rapidly access the information they need from the executive dashboard. Historical reports enable users to view graphical representations of the number of alerts received according to urgency, severity or certainty.

- *Involve citizens and businesses in incident reporting and resolution.*

  Every citizen can inform the system about new events (e.g. accident on the road, a crime he/she had witnessed, a stray dog bite, etc.).

- *Respond to events based on inputs received across agencies.*

  The executive dashboard spans agencies (e.g. emergency management, public safety, social services, water and electricity supply, transportation, etc.) and enables drill-down capability into underlying agencies.

- *Plan and manage a broad range of city operations.*

  Based on inputs, the near-real-time Key Performance Indicators (KPI) are calculated by predetermined formulas (e.g. number of car accidents, broken traffic lights, etc.). Their values define the current state of all monitored objects within the city. Considering this information, the user can manage and optimize the performance of any of the city services.

Thus, COSOC enables cities to manage large complex environments, communicate more effectively with citizens, understand the state of the city and collaborate between departments.

But this system suffers from several limits.

The first one deals with so-called tactical situations. A tactical situation in COSOC corresponds to a single or multiple events, united by territorial, time characteristics or cause-and-effect relationships, for which the system offers a concrete scenario to execute. In fact, all tactical situations must be predefined in COSOC as well as possible scenarios (which are BPMN-processes) for every one of them. So, if “unknown” tactical situation happen, there is no plan of actions ready for this particular situation.

That example illustrates the boundaries of the imperative process modeling approach: one cannot predefine all possible situations and create an adapted workflow in advance.

However, and this is a second limitation, if any contextual situation can be predefined in COSOC so far, it is a tactical situation or a scheduled (regularly expected and occurred) event only. Other events are considered “unpredictable”, because there is no tool for predictive analysis used in COSOC.

The third important limitation of COSOC lies in its inability to separate new incoming events and the consequences of an executed action. This problem makes it impossible to analyze directly the consequences of any action performed.

By applying our theory and algorithms for managing knowledge-intensive processes, these limits could be overstepped.

B. *Potential benefits from the automated guidance*

Once the imperative paradigm is shifted, new functions and possibilities appear.

Based on the history of past events, the evolution of KPI values and the identified dependencies between the events, more new incoming events, situations and emergencies (that were previously considered as unexpected) could be predicted.

Declarative modeling approach can also help in teaching COSOC to recognize consequences of the performed actions. Furthermore, these consequences could finally be analyzed separately from the new incoming events. This would provide COSOC with a highly improved accuracy in predicting.

Defining a set of "navigation" rules (e.g. with the help of Alloy specification [9]) can teach COSOC which decision is "right" at the moment, so that the system would be able to recommend user some course of actions based on a context at run-time.

Eventually, COSOC will combine case navigation and city management functions. As a result, the architecture of the system is expected to correspond to the scheme, illustrated on fig. 2.

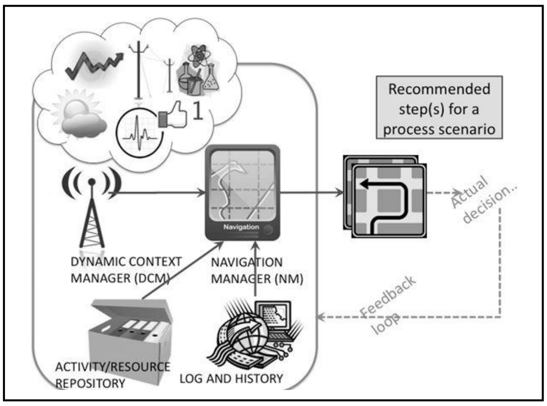

Fig. 2. The architecture of COSOC system with automated guidance.

Therefore, the proposed theoretical foundation can easily find its application in this life intelligent system.

In the following section, we give a detailed roadmap for our future research, distinguish the key questions we need to answer and set the direction of the development of the automated guidance provided by intelligent systems.

IV. ROADMAP FOR THE FUTURE RESEARCH

The idea of users’ automated guidance is grounded on the intersection of several scientific disciplines (business process modeling, formal methods and formal concept analysis (FCA); dynamic context modeling; complex event processing; process mining). We propose to explore formal methods, formal concept analysis [10], [11], [12] and dynamic context modeling in order to build a novel approach for agile process modeling, simulation and analysis [4]. In particular, we propose to apply these techniques knowledge-intensive processes supported by intelligent systems.

The main challenges we have to face can be roughly divided in three categories:

- Theoretical challenges related to overall problem complexity and the number of “unknowns” to manage.
- Technological problems (e.g. scalability and robustness of algorithms, availability and quality of appropriate ICT technologies).
- Challenges related to adoption by the users (e.g. user perception of complexity versus utility, appreciation and willingness to adopt this solution).

In this paper, we discuss the theoretical challenges in detail and elaborate a list of relevant questions for our future research.

A. *Process modeling*

Based on previous research [7], we consider that the knowledge-intensive process cannot be represented only using an imperative model such as workflow due to high unpredictability [4], and should be specified using a declarative [5] or mixed (imperative and declarative) model.

In the earlier works of our research team, state machines have been considered as a promising model of computation and operational semantics for processes that depend on the knowledge of an expert and may change on the fly.

State machines model implies that we need to represent the process as moving in a coordinate system where each coordinate takes the value of some context parameter. A single point or a group of points in this coordinate system corresponds to a state of the object at a given moment of time. In that case events are playing role of triggers that can lead to a state change.

Aside from model selection, the authors of [8] have proposed a method for specification of agile processes based on formal concept analysis.

This constitutes a relevant knowledge base for our research.

The goal of this PhD is to go further, and to continue this research we have identified several research questions:

1) How to select the relevant set of states? Should it be fixed or dynamically extendable? Based on what?

We need to test our state machines model on different types of processes to look for dependencies, to understand the mechanism of a state change in both approaches (fixed or dynamically extendable states), then find their advantages and, most importantly, their limits.

2) How to handle the "unknown" events? What do we do if an "unpredictable" event happens?

Rules for classification of the events must be defined (probably, we need to cluster them according to their features) as well as "navigation" rules for a system to know how to handle any event occurred.

3) How to choose the "right" action? What does the "right" action actually mean? How to measure "rightness"?

We need to determine initial and expected final states, to define rules for state transitions and to select events that could be considered as triggers for state evolution towards the expected final state with minimal consequences.

After the process is designed we have to face issues related to process analysis.

B. Process analysis

Once the process formalism is chosen and the process can be described or documented, the next step is to simulate, analyze and improve it (as traditional workflow-based approaches do).

This leads us to another group of questions:

1) How to simulate a declarative process specification? How to interpret the results?

Formal methods (e.g. Z notation, B-method, Alloy specification) can provide a formal specification of the system to be developed at different levels of details and allow for accurate refinement (transition from one level to another). We consider Automata semantics as a promising approach to knowledge-intensive processes.

2) How to define and formalize "navigation" rules?

In order to teach the system how to recognize the successful scenarios and to avoid dangerous ones, a set of initial rules must be defined. Alloy specification could be one of the possible solutions.

3) What kinds of analysis/validation can be required? Which techniques to apply?

Formal Concept Analysis discipline proposes a set of methods and tools for data processing and predictive analysis. Its joint use with context modeling [7] is very promising in the context of intelligent system support.

In our research, besides providing solid theoretical foundations and algorithms we are going to create working prototypes for the intelligent systems automated support.

C. Intelligent system's process support

The key point of implementation of our methodology is to develop a prospective prototype that can be considered a working system. But this is only possible after simulation, validation and testing our system on multiple real life examples.

In order to achieve this goal we need to handle several issues:

1) Which case-specific parameters should be considered relevant? How to measure them and identify the current case state?

Rules for the inclusion/exclusion of context elements to be considered must be defined as well as strict hierarchy of all the parameters and data storage for their values (to follow changes, find trends, similarities, intersections or dependences).

2) How to identify probable scenarios (sequences of states) taking into account, if possible, previous experience?

We need to define rules for state transitions, to determine final states and case management scenarios, to discover the case abstract states and scenarios from the log and history, to verify if they are applicable for current situation.

3) How to exclude those scenarios that are forbidden/not feasible for current case (i.e. regulations, availability of resources, etc.)?

This is a stage of model checking. Due to defined "navigation" rules and notion of "right action", the simulation and validation the case scenarios against these rules must be carried out.

4) How to select the scenarios that can lead the case towards its target state with maximum probability? What if there are none?

With the help of FCA tools we need to identify the best next state given the current state.

Thus, the intelligent assistant for knowledge-intensive processes has to efficiently predict the successful scenarios and recommend to a user some course of actions based on certain criteria.

V. Conclusion

In this paper, we presented a roadmap for a PhD research, aiming at developing the automated guidance provided by intelligent systems.

We described the context in terms of knowledge-intensive processes and of process modeling methods, presented the limits of existing approaches in these areas and illustrated research challenges on the example of the City Operation

Center COSOC. We have raised many research questions on this subject.

In the future, we will focus on the COSOC use case. First, we are going to determine "navigation" rules for the system so that it will lead us to understanding which set of states to consider relevant and the notion of "right" action.

We consider, however, the theory and algorithms we are going to develop, to be applicable in the domain of intelligent systems in general.

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