Evolution of
Petrinet Modeled Knowledge Intensive Processes

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Abstract: The domain of Knowledge Intensive Process Improvement (Knowiπ) will be considered in this paper. For the improvement of knowledge intensive processes (KnowiP) we suggest Genetic Algorithms (GAs). The representation needed by the GA depends on the modelling language of KnowiPs. We will use Petrinets for the process modelling and then use the incidence matrix of the corresponding Petrinet as problem representation. The processes are evaluated according to performance metrics adapted to knowledge intensive processes. Two particular GAs are applied to improve a special class of KnowiPs, one single objective GA and one multi objective GA, namely the Multi-Sexual GA (MSGA) multiple criteria simultaneously.

1 Knowledge Intensive Process Improvement (Knowiπ)

Business processes can be found in any organisation. Today, they are more and more based on required knowledge and supposed to be flexible and adaptable to the changing surrounding conditions as the economic market conditions change rapidly.

A BUSINESS PROCESS is a sequence of activities aiming at the creation of one or more products or services with a value for a customer. It is started and finished by one or more events. As it proceeds in an organisation there is an underlying organisational structure [RvHS04]. Furthermore, the activities usually need one or more resources (like people, processors, data, software, etc.) that belong to predefined resource classes.

In this paper we want to consider special processes, namely knowledge intensive business processes or simply knowledge intensive processes, as already defined in [GW04]:

A process is a KNOWLEDGE INTENSIVE (BUSINESS) PROCESS (KNOWIP) if its value can only be created through the fulfillment of the knowledge requirements of the process participants. Typically knowledge flows and knowledge transfers between media and persons are necessary to achieve a successful process completion.

Business processes can be structured, semistructured and unstructured. Structured processes are completely predefined. There are fixed and non changeable rules for the execution of every activity. Semistructured processes contain structured parts and non structured parts. Unstructured processes are completely unpredictable.

To improve processes continuously Business Process Improvement (BPI) or Continuous Process Improvement (CPI) is known as an evolutionary method. This method can be transfered to knowledge intensive business processes. We will call it Knowledge intensive process improvement (Knowiπ).

KNOWLEDGE INTENSIVE PROCESS IMPROVEMENT (KNOWIπ) is an evolutionary method to improve knowledge intensive business processes aiming at a continuous and incremental improvement of these processes.

The use of performance metrics (see [Gad01] for details) enables the evaluation of the process improvement. They can be classified into process oriented and resource oriented and also into time oriented, value oriented and quantity oriented metrics. We extend this classification list with respect to knowledge intensive processes by a knowledge oriented and a quality oriented view. The considered knowledge oriented performance metrics are e. g. time for acquisition, adaptation and handling, costs of acquisition, adaptation and handling, used and not used knowledge sources, and the quality of knowledge.

The surroundings of a KnowiP can either depend on its business area or they can be domain independent. Examples for either type of surroundings are preconditions for the process like dependencies between activities, dependencies between resources, dependencies between activities and resources, resource restrictions or even market conditions like a changing quality standard. Moreover, KnowiPs can depend on the used knowledge infrastructure and resources; e. g. the unavailability of a knowledge base or a knowledge resource can significantly change the corresponding process.

The change of surrounding conditions can influence one or more performance metrics and therefore lead to critical and undesirable values. Critical conditions can be all important oversteppings of fixed values for certain performance metrics. For example a throughput time for a contract (or an important letter which needs to be send exactly on time) higher than the available time could lead to a cancellation of the contract. Moreover, a sudden malfunction of a knowledge resource (e. g. an important expert becoming ill etc.) could temporarily or permanently stop a running process. Consequently it will be necessary to define all important performance metrics with their critical values in advance.

2 Genetic Algorithm Methodology

Genetic Algorithms solve problems in a heuristic way under consideration of the problem's environment. The solutions of the problem are encoded in a certain representation. These solutions can then be evaluated with respect to the environment, i. e. an evaluation function is needed that represents the environment's evaluation of a proposed solution. Therefore GAs require three main components, a *representation*, an *evaluation*, and some *operators* to be applied, basically the selection, crossover, and mutation operator. The universal GA proceeds as follows: A population of potential solutions (individuals) is generated in its representation. Then each individual is evaluated and obtains a fitness value. Afterwards, the mating members are selected dependent on their fitness value and crossover and mutation occurs to the selected mating members. At the end the entire population is replaced. This process is repeated until a chosen stop condition is satisfied.

Knowiπ generally requires the consideration of more than one performance metric to be evaluated. Therefore it requires the handling of multiple criteria. Several GAs for multi-objective optimisation (MOGAs) have already been presented in the literature. One, the Multi-Sexual GA (MSGA) presented by Lis and Eiben [LE96], was already successfully applied in [BS03] to a flexible manufacturing problem.

3 GA Approach to Knowiπ

The surrounding conditions of knowledge based business processes, can be seen as the problem's environment with respect to the application of GAs. We consider the special class of structured KnowiPs with constrained resources (KnowiP$_{\mathrm{CR}}$). Constrained means that there exists at least one resource class containing less resources than required by the activities of the process at the same time. A simple example is the availability of a limited number of experts that are assigned to a complex subprocess (see Figure 1). To model this process it is possible to apply the modelling language of Petrinets.

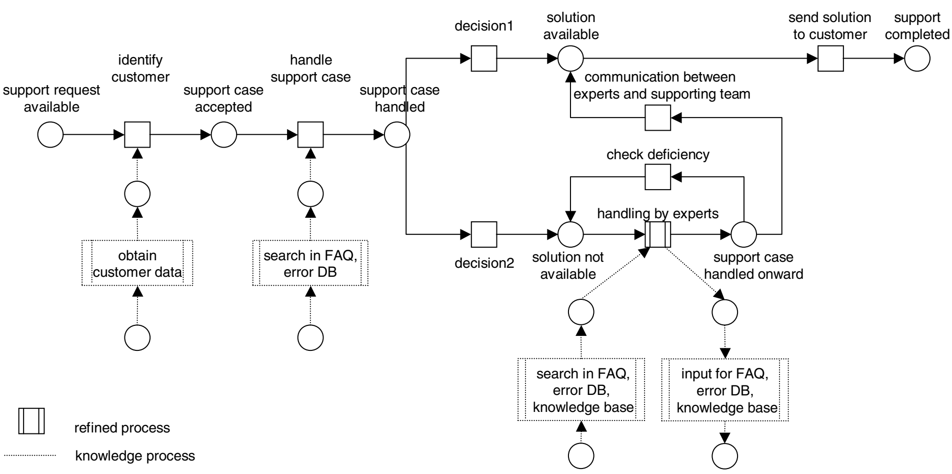

Figure 1: Example for a structured KnowiP

A particular GA is applied to the special class of KnowiP$_{\mathrm{CR}}$ considering the duration of execution as single criterion. The *representation* of the solutions is a ternary string using the ternary alphabet $\{-1, 0, 1\}$. This encoding results from the presentation of a Petrinet by an incidence matrix and describes the reachability of all pairs of activities. This representation is redundant, but promises some saving of time because of the maintenance of more information. The single criterion 'duration of execution' delivers the *evaluation* and thus the fitness value. As *operators*, the usual roulette-wheel-operator and a best-half-operator were applied for selection. The best-half-operator combines all members of the best half with one randomly choosen member. The crossover occurs as general one-point-crossover including the transitive closure and the mutation as simple random bit flip.

For the multi-objective $\text{KnowiP}_{\text{CR}}$ problem the Multi-Sexual GA is applied, because its applications delivered good experiences (see e. g. [LE96] and [BS03]). An improved GA performance was already observed for some problems simply using a multi-parent crossover operator, suggested e. g. in [ERR94]. One important advantage of multi-parent crossover operators is that they are more explorative and less sensitive to premature convergence. MSGAs require as many sexes as optimisation criteria are used and each individual is evaluated according to the optimisation criterion related to its sex. Furthermore, a multi-parent crossover (requiring one parent from each sex) is applied to generate offspring.

For the applied MSGA the *representation* of the solutions again is a ternary string but this time with a sex marker (integer) at the last string position. The criteria 'aquisition time', 'aquisition costs' and 'resource usage' deliver the three partial *evaluation* functions. The *operators* are selected as combinations from the operators as used in the single-objective Knowiπ problem and used according to [LE96]. Another operator is used after completing these three operators to check the validity of the obtained solution. Changed surrounding conditions of the KnowiP can result in critical conditions. This demands another operator that checks the fixed critical values of the performance metrics.

4 Conclusion and Future Work

The customised MSGA was successfully applied to one of the manyfold Knowiπ problems, the $\text{KnowiP}_{\text{CR}}$. It remains to discover the potential of the described MSGA as well as other MOGAs featuring specially customised operators to other Knowiπ problems. Open questions are the fitting of MSGAs to semi- or even unstructured KnowiPs. Because of the occurrence of many constraints (maybe for the critical conditions) it should be worthwhile to investigate the implementation of a rule base. Furthermore, it is interesting to extend our version of the MSGA or some different MOGAs to the control and the automated improvement of KnowiPs. This process should be self-adaptive and promises an automated adaptation without user interaction.

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