Fuzzy Based Approach for Decision Support System

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Abstract – **The paper discusses a methodology for decision making over alternative execution of plans represented as control nets, based on a class of Petri nets. The idea is that fuzzy attributes are associated to operations, each with their weight. Fuzzy attributes of operations extend to fuzzy attributes of executions. Optimal executions can be computed as intersections of execution attributes. The methodology is supported of computer tools to graphical plan representation and computations, which are necessary of controlling plan executions in real time.**

Keywords – **decision making, DSS, fuzzy logic, Petri nets, fuzzy attributes**

I. Introduction

Conceiving projects and devising plans are characteristic expressions of any goal-directed human activity. In practice, many different plans will be necessary for making a project realizable: scheduling plans, cost plans, plans of resource flow, etc. How to integrate heterogeneous, possibly conflicting, plan attributes for choosing an optimal course of action during the realization of project? In general, plans allow for alternative executions, and always they have different times, costs, failure rates, setup times, etc. Choosing an optimal course of action is a critical question when running plans which allow for alternative moves. In this paper we discuss a multi-attribute methodology for making decision over alternative execution of plans represented as control nets. This methodology is suitable for making decisions at operational level of running a plan.

II. Control nets

Considered methodology requires plans, where, by constructions, alternative courses of action do not interact, and choice between alternatives is controlled by one decision. Control nets are a class of place/transition Petri nets defined with this issue in mind. In plans expressed by control nets the independence of execution alternatives is guaranteed. Decisions are only made at control places, special places associated with the sets of alternative executions – one control place for each such set.

Control nets are based on four composition modules: T-sequence, S-sequence, synchronization and choice. T-sequence represents sets of operations to be executed one after the other. Synchronization modules represent simultaneous production and subsequent simultaneous consumption of a set of resources. S-sequence represents sets of resources which are available one after the other. Choice modules represent resource sharing by alternative operations, both forward and backward.

Control nets are constrained in structure. The gain of this limitation is the clear-cut definition of execution alternatives. Decision over execution alternatives arise at some places of choice modules, and only there. And every branch out of such a place is guaranteed to represent an executable alternative.

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III. Methodology to support decision making

Plans allow for alternative executions, and different executions will mostly have a different degree of desirability, depending on times, costs, failure rates, setup times, etc. The execution supervisor is responsible of making better decision in choice situations. He has to attach fuzzy attributes to operations – such as short time, low costs, acceptable failure rates, low labour rates, etc. From operation attributes he can deduce attributes of the alternative executions – fuzzy too. This done, the supervisor can use different multiatribute decision making techniques: to find optimal alternatives by intersecting attributes or to apply outranking techniques in order to partition the set of alternatives into several preference classes.

A. Fuzzy attributes over Operations

Let N = (S, T, F, W, M_0) is a control net, and *c* = (S', T', F', W', M') is a primary choice schema of it.

The execution supervisor has to associate a finite set of fuzzy attributes with T_c - the transition set of *c*. A fuzzy attributes over operations is a fuzzy set A = {t, μ(t)} with support T_c. The degree of membership μ (t) of transition *t* is to be interpreted as the degree, to which operation *t* exhibits attribute A [1], [3].

Short durations, low costs, small failure rates, etc. are examples of properties which may well be expressed as fuzzy attributes. Consider the choice schema in Fig. 1, which has four branches. The property "low cost" could be specified by the fuzzy set C= {t, μ_C (t)} with

μ_C (t) = {(1, 0.9), (2, 0.4), (3, 1.0), (4, 0.2)}

and property "short duration" could be specified by the fuzzy set D= {t, μ_D (t)} with

μ_D (t) = {(1, 0.2), (2, 0.8), (3, 0.0), (4, 0.6)}.

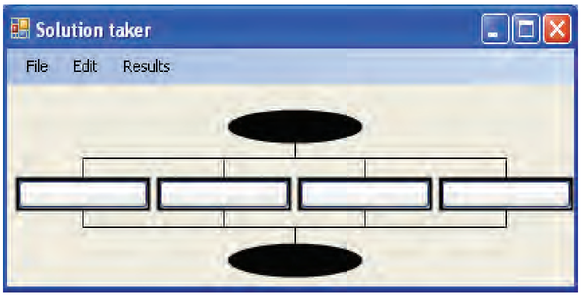


Fig.1. Choice schema

These two attributes mean: the degree to which operation 1 has the attribute “low cost” is 0.9 and “short duration” - 0.2, etc.

B. Attributes over Alternatives

Alternatives of primary choice schema are made up of sequences and of synchronization modules. Hence, the extension of an attribute over operations to an attribute over executions require two operators, one for aggregating the membership degree of transitions belonging to sequences, and one for aggregating the membership degree of transitions belonging to synchronization modules. These two operators must be specified by the supervisor for every operation attribute. The specification of these two operators expresses the supervisor’s beliefs about how the considered attribute spreads from operations to execution alternatives. This requires taking the meaning of the individual attributes into account. For instance, the aggregation of time related attributes must be different from the aggregation of cost related ones. Indeed, it is natural to view the joint cost of two parallel activities as the sum of their costs, but their joint duration will naturally be interpreted as the union of the corresponding time intervals.

Consider a primary choice schema *c*, and a fuzzy attribute A= {t, μ (t)}, defined over its set of transitions. Let C = $\{c_1, c_2, \dots, c_n\}$ be the set of alternatives of *c*. Let a fuzzy attribute over the alternatives of *c* to be a fuzzy set A’= $\{c_i, \mu'(c_i)\}$ with support *C* which membership function is computed on basis of a fuzzy operation attribute *A* by means of two operators assigned by the supervisor: operator *X* for aggregating the membership degree of operations belonging to sequences, and operator *Y* for aggregating the membership degree of operations belonging to synchronization schemata [3]. Operators *X* and *Y* must be specified so that:

for every S or T- sequences *s* with transitions set $\{t_1, t_2, \dots, t_n\}$

$X(s) := X(\mu(t_1), \mu(t_2), \dots, \mu(t_n)) \in [0, 1]$;

for every synchronization schema *z* with transitions set $\{t_1, t_2, \dots, t_n\}$

$Y(z) := Y(\mu(t_1), \mu(t_2), \dots, \mu(t_n)) \in [0, 1]$.

The membership degree $\mu'(c_i)$ of alternative c_i for the fuzzy attribute over alternatives A’ is obtained in the following way:

1. If c_i is an S-sequence, we set $\mu'(c_i) := X(c_i)$ and terminate.
2. If not, we run bottom-up through the hierarchy of plans, which we assume indexed by h = 1,2, …, n, and carry out the following computations:

Set $\mu_n(t) := \mu(t)$ for all transitions t_n, and h := n;

REPEAT

- decrement h by 1;
- for each macro place p of the level h plan which is substituted by an S-sequence *a* in the level h+1 plan, set $\mu_h(p) := X(a)$;
- for each macro transition t of the level h plan which is substituted by an T-sequence *b* in the level h+1 plan, set $\mu_h(t) := X(b)$;
- for each macro transition t of the level h plan which is substituted by synchronization module *w* in the level h+1 plan, set $\mu_h(t) := Y(w)$;
- for all places p and transitions t for which $\mu_{h+1}(p)$ or respectively $\mu_{h+1}(t)$ were defined, set

$\mu_h(p) := \mu_{h+1}(p)$ and $\mu_h(t) := \mu_{h+1}(t)$

UNTIL in the level h plan c_i contains exactly one transition t’;

3. Set $\mu'(c_i) := \mu_h(t')$ and terminate.

C. Attributes over Executions

Fuzzy attribute over alternatives lead naturally to fuzzy attributes over executions.

Executions of choice schemata are executions of multisets of concurrently enabled alternatives. If $c_1, c_2, \dots, c_n$ are the actually enabled alternatives of choice schema c, multiset

$e := m_1c_1 \oplus m_2c_2 \oplus \dots \oplus m_nc_n$

represents the execution of c consisting in executing – in any order and for all i – m_i times alternative c_i.

Let E denote the actual execution set of *c*. The fuzzy attribute over the executions of *c* is the fuzzy set A’’= {e, μ’’(e)} with support C which membership function

$\mu''(e) = [m_1\mu'(c_1) + m_2\mu'(c_2) \dots + m_n\mu'(c_n)] / \sum_i m_i$,

with $\sum_i m_i = M(c')$.

The membership degree of execution e in the fuzzy attribute over executions is the weighted average of the membership degrees of the alternatives constituting *e* in corresponding fuzzy attribute over alternatives. The membership degree of *e* in fuzzy set A’’ is a linear function of the membership degree of c_i in fuzzy set A’.

D. Preference degree of executions. Optimal Executions

Fuzzy attributes over executions can be used to determine the set of optimal execution by the follow way. Consider any choice schema *c*, together with its actual marking M.

Let E = $\{e_1, e_2, \dots, e_n\}$ be actual set of executions of *c*, and A = $\{A_i\}$ a finite set of fuzzy attributes over E, with $A_i = \{e, \mu_i(e)\}$. Let all the above attributes express desirable features

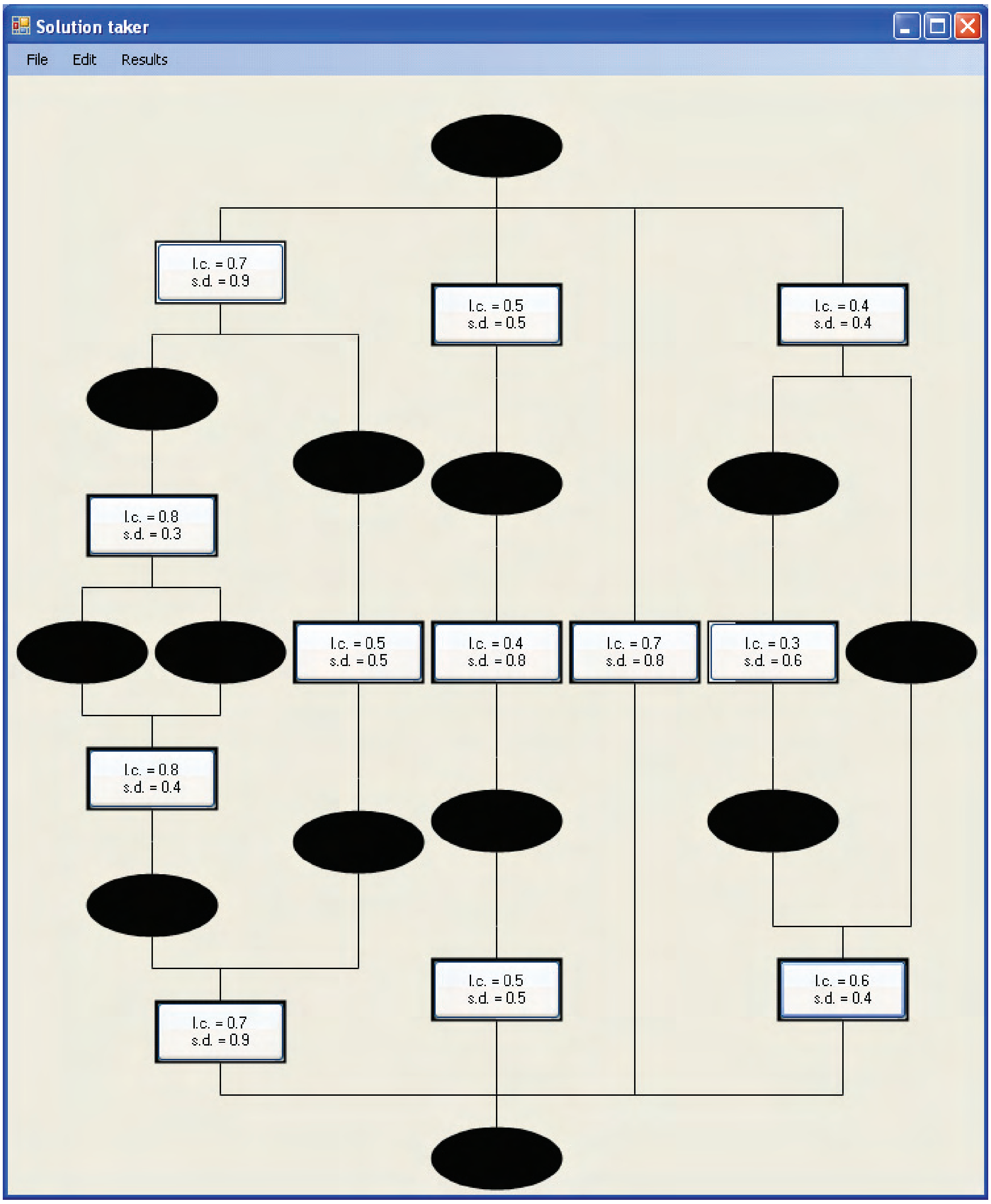


Fig.2. Control net, represented simple project plan with assigned 2 fuzzy attributes for every operation

of executions. The real number μ_i (e) represents the degree to which execution *e* exhibits attribute A*i*.

The intersection Δ of the fuzzy sets A*i* is fuzzy set over E too:

$\Delta := \cap_i A_i = \{e, :\Delta (e)\}$.

The membership degree of execution *e* in fuzzy set Δ is the smallest membership degree of *e* in any fuzzy set A_i:

$\mu_\Delta (e) := \min_i \mu_i (e)$.

μ_Δ (e) represents the degree to which execution e possesses the set of attributes A. Since the attributes A_i express desirable feature of executions, Δ may be interpreted as the fuzzy attribute “preferable”. $\mu_\Delta(e)$ represents then the preference degree of execution *e*.

Optimal executions are executions with maximum preference degree. That is: optimal decisions are execution e’ $\in$ E such that

$\mu_\Delta (e') := \max_E \mu_\Delta (e)$.

IV. Decision support sysytem “Solution Taker”

The above methodology is embedded in the developed decision support system "Solution Taker". The system allows easy construction of a control net for a project plan, assigning fuzzy attributes to the operations and automated calculation of relevant attributes for the execution alternatives. In Fig.2 is given an example of sample project plan, constructed by this graphical tools. The figure is the result of top-down expanding of the simple choice module, given in Fig.1. In Fig.3 is shown the way of attaching different attributes to the operations. To each operation are assigned the fuzzy attributes “low costs” and “short time” with their degree of membership.

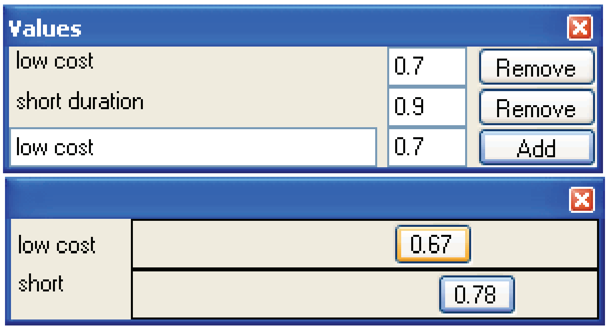
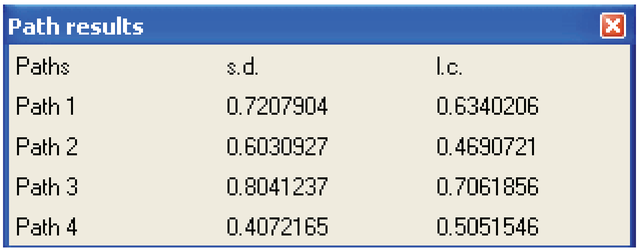


Fig.3. Tools for adding fuzzy attributes to the operations and giving them values

In Fig.4 we can see the values of attributes for every alternative for the choice schema in Fig.2 and that the most effective on the examined criteria is the third alternative.


Path results

Paths	s.d.	l.c.
Path 1	0.7207904	0.6340206
Path 2	0.6030927	0.4690721
Path 3	0.8041237	0.7061856
Path 4	0.4072165	0.5051546

Fig.4. Path results for the fuzzy attributes

V. Conclusion

In this paper is proposed a methodology for making operational decisions on the basis of multiple fuzzy attributes and software product is developed to support this methodology. The ability to graphically display and automation of the calculations make the system useful for making and maintaining solutions to manage systems in real time.

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