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Dealing with imprecision in temporal interdependencies between collaborative tasks: A fuzzy perspective

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Abstract. *In this paper, we advocate that the use of concepts from Soft Computing theory, in particular from fuzzy systems, can be quite useful in the modeling and coordination of collaborative activities. The tolerance of imprecision, uncertainty, and approximation, which is the core of such technology, may provide a more subjective model for such activities, closer to human reasoning. We introduce a fuzzy-based approach to deal with temporal interdependencies between collaborative tasks, aiming to provide a step further toward the flexibility of coordination mechanisms in CSCW systems.*

1. Introduction

The coordination of computer-supported collaborative tasks is one of the most challenging activities in CSCW. The necessity of coordination mechanisms to regulate interaction in collaborative systems has been the focus of a heated discussion.

At one side, there are normative models that try to regulate the collaboration by restricting the interaction between participants and their tasks. The criticisms on such normative approaches may be roughly summarized by the fact that their rigid protocols apply only to very specific scenarios, limiting the flexibility of the collaborative systems. Eventually, there would be situations not predicted by the specified protocols, restraining the application of this kind of coordination approach. At the opposite side, are those advocating that collaborative systems should take flexibility to the extreme, leaving the coordination burden to the users. The criticism on this kind of approach is that they augment the coordination workload, since users must deal with the complexity of articulating their tasks. Besides, giving the coordination responsibilities for the users does not ensure that the activities will be performed according to any prescription.

More recently, advancements in the studies generated a trend toward the conciliation of both approaches, since they appear “seamlessly meshed and blended in the course of real world” [Schmidt and Simone 2000]. In spite of this integration trend, the problem is still far from an effective solution. One of the main difficulties for a conciliatory approach is the diverging nature of both “philosophies”: The search for regulation and flexibility at the same time. One of the reasons for such adversity is that it is sometimes quite difficult to completely characterize the interdependencies underlying collaborative tasks. This happens mainly because, in essence, those relationships tend to display a not so well-defined (i.e., fuzzy) semantics. In this sense, it seems very relevant that such task modeling imprecision be also taken into account when devising and implementing novel coordination mechanisms to be deployed in a range of collaborative scenarios.

In general, it is possible to ascertain that coordination in CSCW can take place on two levels—the activities (temporal) level and the object level [Ellis and Wainer 1994]. On the object level, the coordination describes how to handle the sequential or simultaneous access of multiple participants to the same set of cooperation objects. Conversely, on the temporal level, the coordination defines the sequencing of the tasks that make up an activity, resembling very much what constitutes a typical scheduling or synchronization process. This paper focuses on temporal coordination only.

In this work, we have used some concepts from the fuzzy sets theory to give birth to a novel temporal coordination model. Our objective with such a model is to provide a more manageable perspective to the modeling and coordination of imprecise (or even uncertain) temporal interdependencies between collaborative tasks. With this fuzzy-based approach, our goal is that such temporal interdependencies be characterized in a more subjective manner, closer to human reasoning.

In the following section, the discussion about coordination mechanisms in CSCW is detailed, and some basic fuzzy concepts are presented. In Section 3, the fuzzy temporal synchronization model is presented, and in Section 4, it is descriptively applied in a typical CSCW scenario. In Section 5, final remarks are discussed.

2. Coordination Mechanisms and Fuzzy Concepts

In order to give support to collaborative activities, many coordination mechanisms have been proposed in the context of some collaborative systems. The first generation of coordination models, proposed in the mid-1980s, was restricted to specific scenarios, with rigidly-defined protocols (e.g., [Flores et al. 1988]). Eventually, there would be situations not predicted by the specified protocols, restraining the application of the defined mechanisms. Therefore, 1990s' models strive for flexibility, with coordination mechanisms that can be adapted for each application needs. The so-called second generation of coordination models looks for the development of systems with at least one of the following three characteristics, which are accessibility, interoperability, and flexibility (e.g., the Oval tool [Malone et al. 1995]).

The possible "third generation" of coordination models seems to be focused on the uncertainties in the definition of tasks interdependencies and on the creation of soft relations between collaborative tasks. Uncertainties or imprecision are related to situations where, for instance, two tasks must be executed "almost sequentially", meaning that the second should start when the first is "almost finishing", or when the first is finished, the second should be "almost beginning". Soft relations are those that do not impose a rigid restriction, such as "task *A* must precede task *B*", but gives some information such as "task *A* will facilitate task *B* if it precedes the latter". Although not critical, this information may be important to the efficiency of the collaboration. An example is the task of finding a new book in a library. Although it may be found before, this task will certainly be easily realized if the new books are already sorted and correctly shelved [Decker 1998].

It is our feeling that this new generation of coordination models would capitalize very much upon the resources made available by Soft Computing technologies. The designation "Soft Computing" represents the combination of emerging problem-solving technologies, such as fuzzy logic, probabilistic reasoning, neural networks, and genetic algorithms. Soft computing differs from conventional (hard) computing in that, unlike the latter, it is tolerant of imprecision, uncertainty, partial truth, and approximation [Zadeh 1994]. Although practically unexplored, we believe that much can be gained with the hybridization of concepts from Soft Computing and CSCW fields. Motivated by a previous work [Raposo et al. 2001], in this paper, we give another step in such direction by exploiting the concepts of fuzzy tasks, events, delays, deadlines, phases, and temporal constraints to the modeling of imprecise temporal interdependencies between collaborative tasks. In the following, a brief overview of some fuzzy-set related concepts is provided for the reader unversed on the theme.

2.1. Basic Concepts on Fuzzy Sets

The basic concept underlying fuzzy systems theory is that of a *fuzzy set* [Pedrycz and Gomide 1998]. Fuzzy sets involve capturing, representing, and working with linguistic notions and are very pertinent to be employed in those circumstances where impreciseness, unpredictability, vagueness, approximation, soft gradation, and flexibility are in concern [Zadeh 1994]. A fuzzy set is a generalization of the concept of a (crisp) set and is defined as a clump of objects with membership values between "0" (complete exclusion) and "1" (complete agreement), where these values express the degrees to which each object is compatible with the properties distinctive to the collection.

Formally, a fuzzy set *S* is characterized by a *membership function* (μ_S) mapping the elements of a (finite or not) *universe of discourse* **T** (typically, the real line $\mathfrak{R}$) into the unit interval [0,1]. That is, $\mu_S(t): \mathbf{T} \rightarrow [0,1]$. Reasonable membership functions are piecewise linear curves, such as triangular or trapezoidal functions, or continuously differentiable curves with smooth transitions, such as normalized Gaussian functions. As for crisp sets, fuzzy sets can be compared or aggregated by means of specialized operators, amongst which the fuzzy intersection and union operators, known as *triangular norms* (*t-norms*) and *co-norms* (*s-norms*). Other important properties of fuzzy sets can be summarized as follows—refer to Fig. 1.

The *height* of a fuzzy set *S* is the largest membership grade of any element in that set, i.e. $\text{hgt}(S) = \max\{\mu_S(t), t \in \mathbf{T}\}$, whereas a fuzzy set *S* is called *normal* when $\text{hgt}(S) = 1$, and *subnormal* otherwise. (For our purposes, we have considered to work with normal fuzzy sets only.) The *support* of *S*, $\text{supp}(S)$, is the crisp set with all the elements of **T** satisfying $\mu_S(t) > 0$. Likewise, the *core* of *S*, $\text{core}(S)$, is the crisp set with all the elements of **T** satisfying $\mu_S(t) = 1$, whereas its *boundary*, $\text{bnd}(S)$, encompasses all the elements of **T** with membership grades in the range $]0,1[$. The fuzzy set *S* is termed as a *singleton* if it is normal and its support and core sets contain the same unique element t_0, that is, $\text{supp}(S) = \text{core}(S) = \{t_0\}$.

Having two fuzzy sets *R* and *S* based on **T**, they can be *ranked*, using one of the several methods available for ranking fuzzy sets [Bortolan and Degani 1985]. For our purposes, we consider that $S \tilde{>} R$ (i.e., *S* is higher than *R*) if the following condition is satisfied: $S \tilde{>} R \Leftrightarrow \exists x, y \in \mathbf{T}, x = \inf_{s \in S}\{\mathrm{supp}(S)\}, y = \sup_{r \in R}\{\mathrm{supp}(R)\} \mid x > y$, meaning that the infimum of the support of *S* should be higher than the supremum of the support of *R*. A similar procedure would produce $S \tilde{<} R$ (i.e., *S* is lower than *R*). Moreover, also for our purposes, R and S would be considered as *equal* ($\cong$) if the infimum and supremum of their supports were equal. Otherwise, we say that they are *distinct* ($\tilde{\neq}$). Another less stringent possibility we have also considered for comparing fuzzy sets is to employ their cores, instead of their supports, in the formalization above.

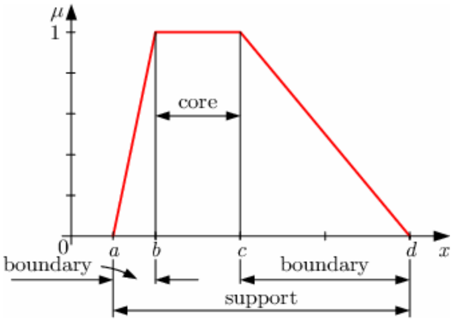

Figure 1. Some concepts related to a fuzzy set.

Closely related to the above definitions are the concepts of *fuzzy numbers* and *linguistic variables*. Fuzzy numbers generalize the notion of a real number, and are used to model imprecise or uncertain quantities in a certain scale of reference. Like crisp numbers, fuzzy numbers can be manipulated arithmetically through the operations of fuzzy addition ($\tilde{+}$) and subtraction ($\tilde{-}$), fuzzy multiplication ($\tilde{\times}$) and division ($\tilde{\div}$), and fuzzy inverse ($\tilde{/}$) [Pedrycz and Gomide 1998].

By other means, in contrast to the idea of a variable assuming crisp numerical values, a linguistic variable is completely described by means of fuzzy, *linguistic terms*, representing words or even sentences in a human-like language. Typically, a linguistic variable is characterized by a name *Δ* (e.g., *phase of a collaborative task*) and a finite set of primary linguistic terms *T(Δ)* (e.g., *T(Δ)* = {*beginning*, *ongoing*, *finishing*}), where each labeled term relates to a particular fuzzy set over the variable's universe of discourse. As well, a linguistic variable may be associated with a set of *modifiers*, such as hedges *H* (e.g., *very*, *more or less*, *quite*, *almost*, *few*), the connectives *and* and *or*, and the negation *not*. The idea of such modifiers is to alter the semantics of the variable's linguistic terms and to provide a means for denoting and computing composite terms, like *very high*, *not low and not very high*, *almost concluded*, etc. In this sense, modifiers are expressed as configurations of elementary membership function operators, such as *dilation*, *concentration*, and *fuzzification* [Pedrycz and Gomide 1998].

Linguistic variables constitute an expressive way of capturing the meaning of a concept or representing knowledge about real-life facts, such as *the temporal phase of R is beginning*. Compound propositions (e.g. *the temporal phase of R is beginning and the temporal phase of S is quite finishing*) may be constructed through conjunctions (t-norms) and/or disjunctions (s-norms) of simpler statements.

By other means, fuzzy sets have been employed in the field of Constraint

Satisfaction Problems (CSP) as an abstraction to the modeling of more flexible, elastic constraints, known as *fuzzy constraints*, defined over some (usually, crisp) variables of interest [Moura-Pires and Prade 2000]. In this context, a fuzzy constraint is basically represented as a fuzzy set on the Cartesian product of the domains of the variables involved. The membership degrees now express preferences among solutions of the constraint by ranking them in accordance with their level of satisfaction. Fuzzy CSP have been deployed in distinct domains of research, such as in structural design and conventional scheduling settings [Badaloni et al. 2004].

In this work, the employment of the notion of fuzzy constraints assumes a different perspective from that of CSP (namely, constraint-based reasoning and problem-solving): We are particularly interested in the use of fuzzy constraints for the *modeling* of temporal relationships between collaborative tasks, aiming further at the *specification* of coordination mechanisms to effectively orchestrate collaborative activities. In this sense, instead of representing soft restrictions to crisp variables identifying solutions to a given problem, the fuzzy constraints of the temporal coordination model depicted in the next section tries to capture imprecise (not stringent) temporal relationships between fuzzy variables (i.e., fuzzy numbers and linguistic terms) associated with time events or temporal phases of collaborative tasks. Moreover, in dealing with temporal issues, the fuzzy constraints of our coordination model were chosen to be solely quantitative (numeric) ones [Badaloni et al. 2004], by involving the fuzzy arithmetic and ranking operations as defined above.

Apart from some few other works, such as [Aranda et al. 2004], on the fuzzy modeling of personal preferences, and [Hadjileontiadou et al. 2004], on the provision of adaptive support, by means of a fuzzy expert system, to the enhancement of the quality of web-based collaborative learning activities between peers, we argue that the exploitation of fuzzy concepts in the CSCW context is still premature. In the following, we present how fuzzy concepts may be applied to the modeling of temporal constraints.

3. A Coordination Model based on Fuzzy Temporal Constraints

As already stated, tasks coordination in the temporal level resembles a typical scheduling or synchronization process. Regarding synchronization, the multimedia domain already provides several modeling categories with respect to how temporal elementary units and temporal dependencies may be expressed [Blakowski and Steinmetz 1996].

Amongst those categories of synchronization models, we particularly believe that three of them can be adapted to the CSCW context: *causality models*, *interval-based models*, and *constraint-based models*. Causality models involve the linkage of begin/end points of temporal objects[1] by means of specific synchronizing *events*, following a “cause-effect” semantics (the relative temporal ordering comes as a byproduct of this process). In interval-based models, each temporal object has an associated interval representing the time required for its execution, and the synchronization requirements are specified by correlating such intervals through a set of

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[1] In the multimedia context, these temporal objects are modeling artifacts representing media components, such as video clips, audio streams, and alike. In our CSCW context, the tasks are the temporal objects.

mutually-exclusive primitive relations. Conversely, in constraint-based models, synchronization aspects are described through sets of constraints of the form $event_1 \{<;=;>\} event_2 + delay$, where $event_i$ refers to atomic events (start/end points in the timeline), and *delay* alludes to a number (zero or beyond) of consecutive time steps.

In this paper, we have considered to work only with the constraint-based class of approaches due to its good expressiveness, relative simplicity, and generality. In this sense, our temporal model for collaborative tasks coordination gears toward the adoption of the generic abstraction of quantitative *fuzzy temporal constraints* (through a non-CSP viewpoint), which, in our case, are defined having in mind five primitive ingredients: *fuzzy tasks*, *fuzzy events*, *fuzzy phases*, *fuzzy delays*, and *fuzzy deadlines*.

From the temporal standpoint, a collaborative task should be labeled as fuzzy if at least one of its temporal properties is not crisp. For our purposes, a fuzzy task may be characterized either by means of the concept of fuzzy number or through the concept of linguistic variable. Fuzzy numbers are used to model fuzzy events which become associated with the occurrences of (some of) the (possibly many) synchronization points (i.e., sync-points) of a task. In the examples given in the following, we have only considered the tasks' endpoints (i.e., beginning and end sync-points), however. Conversely, it is also possible that a task be associated with a linguistic variable representing, qualitatively, its various phases (stages) of execution, being such fuzzy phases (i.e., linguistic terms) the elements that will be effectively synchronized by fuzzy constraints. Finally, fuzzy delays and fuzzy deadlines are fuzzy numbers (either constants or variables) used to represent temporal contingencies, or to impose temporal conditions, upon the tasks execution and interrelation. While a fuzzy deadline represents a fuzzy point (date) in time by which some event (task) should be completed, a fuzzy delay captures the length of time between the moment when some event (task) should start up (or finish) and the moment it actually starts up (or finishes). Rigid (hard) deadlines may also be captured in the constraints by resorting to singletons.

Considering initially the characterization of a fuzzy task by means of fuzzy numbers, the essential elements for specifying a certain fuzzy temporal constraint are the fuzzy events associated with the tasks' sync-points and a ranking operator[2] between these events. For example, to stipulate that the fuzzy event associated with the end of task 1 ($\tilde{e}_1$) should occur before (in the fuzzy perspective) the fuzzy event associated with the beginning of task 2 ($\tilde{b}_2$), it would be enough to express that: $\tilde{e}_1 \lesssim \tilde{b}_2$. Generalizing such line of reasoning, the relations between two fuzzy events associated with two sync-points are formally defined by the expression below:

<fuzzy number: event_1> < fuzzy ranking operator> <fuzzy number: event_2>

It is interesting to note that the two fuzzy events being related in this case may be associated with sync-points pertaining to the same task. (This same observation may also apply to the other cases discussed in the sequence.)

From the discussion above, a fuzzy delay ($\tilde{\delta}$) may be modeled as an additional

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[2] For sake of clarity, in the formalization provided here, we have examined only the binary case, where the constraint-based associations occur between two fuzzy events (or fuzzy phases).

fuzzy temporal parcel representing circumstances where (unexpected) contingencies could take place, like $\tilde{e}_1 \gtrsim \tilde{e}_2 \tilde{+} \tilde{\delta}_{10}$. In this case, we are defining a fuzzy constraint where the completion of task 1 should occur (in a fuzzy perspective) more than 10 time units after the end of task 2. Similarly, the constraint $(\tilde{e}_1 \simeq \tilde{b}_2) \gtrsim \tilde{\delta}_{80}$ specifies that the interval between the end of task 1 and beginning of task 2 should be higher than the fuzzy period of time represented by $\tilde{\delta}_{80}$. Generalizing the use of fuzzy delays, they appear related to fuzzy events associated with some sync-points through fuzzy arithmetical operators:

<fuzzy number: event_1> [<fuzzy arithmetical operator> <fuzzy number: delay>] <fuzzy ranking operator> <fuzzy number: event_2> [<fuzzy arithmetical operator> <fuzzy number: delay>]

A fuzzy deadline, in turn, is modeled as a fuzzy number identifying some position in time that the accomplishment of one or more tasks should meet or not go beyond. For example, the fuzzy constraint $(\tilde{e}_1 \simeq \tilde{b}_1) \tilde{\leq} \tilde{d}_{100}$ defines that the execution of task 1 must occur before the fuzzy deadline $\tilde{d}_{100}$. Similarly, the constraint $(\tilde{e}_1 \simeq \tilde{b}_2) \gtrsim \tilde{d}_{80}$ specifies that the interval between the end of task 1 and beginning of task 2 should occur after the fuzzy deadline $\tilde{d}_{80}$. Generalizing, fuzzy temporal constraints using fuzzy deadlines may be expressed as:

<fuzzy number: event _1> <fuzzy arithmetical operator> <fuzzy number: event _2> <fuzzy ranking operator> <fuzzy number: deadline>

It is possible to extend the use of the above-mentioned constraints to capture the notion of sequential tasks. For example, the constraint $(\tilde{e}_1 \simeq \tilde{b}_1) \tilde{+} (\tilde{e}_2 \simeq \tilde{b}_2) \lesssim \tilde{d}_{150}$ defines that the sequential execution of task 1 and task 2 shall be finished before a fuzzy deadline (for example, the cooperative design followed by the conceptualization of the advertisement of a merchandise by two departments of a firm may not surpass the fuzzy deadline imposed by the launching of the products for sales).

Finally, it is also viable to specify more complex fuzzy constraints through the combination of the cases above; for example, by employing fuzzy deadlines and delays together in the interconnection of the fuzzy events associated with the tasks, like in $((\tilde{e}_2 \simeq \tilde{b}_1) \tilde{+} \tilde{\delta}_{25}) \lesssim \tilde{d}_{150}$.

It is worth to enforce that, although we are presenting situations where all the temporal elements have their semantics somehow fuzzified, it is possible to work with crisp variables in conjunction with fuzzy ones. The notion of singletons is helpful in such regard. For example, fuzzy endpoints may be related to crisp delays or deadlines (i.e., singletons) via fuzzy arithmetical operators.

As mentioned before, an alternative approach to the definition of fuzzy tasks is by making use of the concept of a linguistic variable Δ, which, in our model, represents the (possibly several) temporal phases associated with a given task. In this way, a fuzzy task 1 may be characterized by $T_1(\Delta)$ = {*beginning*, *ongoing*, *finishing*}, while a second task 2 may be portrayed as $T_2(\Delta)$ = {*preparing*, *ready*, *beginning*, *ongoing*, *finishing*, *completed*}. As both linguistic terms and fuzzy numbers are instances of fuzzy sets, the same fuzzy constraints defined above with respect to fuzzy events associated with sync-points may be applied to linguistic terms. By this means, it would be conceivable to formally specify that the "very" beginning ($\tilde{b}_1$) of task 1 should occur around ten time steps before task 2 entering into its ongoing ($\tilde{o}_2$) temporal phase by means of the simple, yet high expressible fuzzy constraint $(\tilde{o}_2 \simeq \mathrm{Con}(\tilde{b}_1)) \cong \tilde{\delta}_{10}$, where $\mathrm{Con}(\tilde{b}_1)$ represents the hedge "very" as a concentration operator over $\tilde{b}_1$'s membership function [Pedrycz and Gomide 1998]. There is no doubt that such kind of specification sounds very natural to a human designer wishing to model collaborative scenarios for coordination purposes.

4. Example

In this section, we illustrate, by means of a simple example, that the proposed model is appropriate to express flexible (i.e., imprecise) temporal tasks interdependencies in typical CSCW scenarios. Moreover, we intend to provide insights into the fact that the well-established mathematical basis behind the fuzzy theory should be viewed as a powerful resource to the construction of coordination mechanisms in several CSCW scenarios, such as in workflows engines, for instance.

Let us consider the scenario of writing a scientific paper: Two authors must conclude a set of tasks whose overall temporal duration must not go beyond a crisp deadline of papers submission. These tasks are: bibliographic revision (*bib*), experiments (*exp*), the writing of the text (*tex*), and final revision of the text (*rev*). The tasks will be referred to in the following by the label showed in parentheses. Consider that the division of tasks between the authors is defined as follows: One author is responsible for the bibliographic revision and the writing of the text, while the other is responsible for conducting the experiments and for the final revision.

The first constraint that could be specified is that the final revision task (which is indeed the last task of the set of tasks) must be concluded no later than the deadline. This could be formally stated as $(\tilde{e}_{rev} \simeq \tilde{b}_{rev}) \lessapprox \tilde{d}_{conf} - \tilde{\delta}_{\varepsilon}$, where $\tilde{d}_{conf}$ is the singleton representing the crisp conference deadline and $\tilde{\delta}_{\varepsilon}$ denotes any fuzzy delay with $\varepsilon \to 0$. In the crisp world, the final revision task would be started only when all the other tasks were finished. The fuzzy modeling perspective, however, allows that such task begins when the writing task is "almost to be finished". This is valid for the author assigned to review the paper should be able to read the initial parts of the text, which are certainly already prepared when the text is deemed as "almost written".

A similar "fuzzy precedence" relation occurs between the bibliographic revision and the writing of the text. The author does not need to have the bibliographic revision completely finished to start writing introductory parts of the text. In this case, it would be possible to assert that the bibliographic revision task should "cease" almost when the writing of the text enters its "ongoing" phase. This could be modeled by synchronizing the linguistic terms "ceasing" ($\tilde{c}_{rev}$) and "ongoing" ($\tilde{o}_{tex}$) of the two tasks by the fuzzy constraint: $\tilde{c}_{rev} \cong \mathrm{Dil}(\tilde{o}_{tex})$, where $\mathrm{Dil}(\cdot)$ captures the meaning of hedge "almost".

Regarding the experiment task, it would be reasonable to define that it must be concluded somewhat before the writing task enters its "finishing" phase, since the second author will need to report and discuss the results in the text. This could be specified as $\tilde{c}_{\exp} \precsim \mathrm{Dil}\left(\tilde{f}_{tex}\right)$, where $\tilde{c}_{rev}, \tilde{f}_{tex}$ are linguistic terms representing the fuzzy phases of the tasks and $\mathrm{Dil}(\cdot)$, here, captures the meaning of "somewhat". However, there might be a wide gap between the tasks of the author liable for the experiments and for the final revision. To avoid a long free interval for this author, one might impose a maximum delay between his/her tasks, giving birth to $(\tilde{e}_{\exp} \simeq \tilde{b}_{rev}) \precsim \tilde{\delta}$.

From this example, it is possible to notice the *high expressiveness* and *simplicity* of the proposed fuzzy constraint-based model for temporal tasks coordination. Another important property is that of *generality*, as the applicability of the model is completely unrelated to the way the tasks are divided and allocated among the collaborative peers.

5. Conclusion

The coordination of temporal interdependencies between collaborative tasks in the crisp world brings with it some restrictions, since usually tasks can only be synchronized by their start or finish times. This rigidity limits the modeling of a range of common collaborative scenarios, since it prohibits, for instance, commencing a second task when the first is "almost finished". In this sense, this paper presented a further step towards flexibility in normative coordination models, by means of applying fuzzy concepts to model imprecision and uncertainty.

It is pertinent to mention that the quantitative fuzzy constraints as defined in our temporal model, although interrelating fuzzy concepts (i.e., fuzzy events, delays, deadlines, etc.), do not need to pass through a defuzzification process in order to be deployed within the coordination mechanisms. There are two reasons for this. First, because the set of fuzzy constraints modeling a coordination scenario (we call it a fuzzy coordination script) is not to be interpreted as a fuzzy rule-based system, inasmuch as there is no inferential process occurring here [Pedrycz and Gomide 1998]. Second, because the fuzzy constraints are defined solely in terms of fuzzy ranking operators, which, in our case, are defined in terms of relations between crisp elements (viz., infimum and supremum of support, or core, sets). What is necessary, however, is to translate, by some means, the fuzzy constraints of a coordination script into event-based rules to be triggered by the coordination mechanisms deployed in a certain workflow system. In our case, such coordination mechanisms could be modeled as fuzzy Petri nets [Raposo et al., 2001].

A next step of this work relates to the investigation of some generic consistency analysis rules that could reveal any source of non-congruence among the fuzzy temporal constraints comprising a given temporal specification plan for tasks coordination. The objective is to help the designer of the coordination mechanisms to be deployed in a certain collaborative scenario in avoiding the definition of non-feasible temporal relations, such as task *A* before task *B*, task *B* before task *C*, and task *C* before task *A*. Other forthcoming steps of this research effort include (i) the study of *n*-ary temporal relations among several fuzzy events (or fuzzy linguistic terms); and (ii) the analysis of alternative forms of fuzzification of crisp interval-based and causality-based models towards the more flexible synchronization of collaborative tasks.

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