# Reasoning with Fuzzy Time Intervals

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Temporal representation and reasoning is a major research topic in Artificial Intelligence, driven by numerous real–world applications. Different approaches differ in the way time is represented (discrete or continuous, totally or partially ordered, etc.), in the ontological primitive that is used (time intervals or time points) and in the nature of the available information (quantitative or qualitative). Our work aims at providing a framework for temporal representation and reasoning to support temporal question answering.

We want a system to be able to answer questions such as "Which wars started just after the Second World War?" and "Who was prime minister of Belgium between the end of the Russian Revolution and the beginning of the Cold War?" based solely on information expressed in natural language (e.g. web documents). In this context, it is usually assumed that the timeline is isomorphic to $\mathbb{R}$, that time intervals are used to represent the time span of events and that the available information is mainly qualitative in nature.

Allen [1] has defined a set of 13 jointly exhaustive and pairwise disjunct qualitative relations between two (time) intervals. These relations are described in terms of constraints on their boundaries. For example *meets* holds between two intervals $[a^-, a^+]$ and $[b^-, b^+]$ iff $a^+ = b^-$, while *before* holds iff $a^+ < b^-$. Although reasoning in Allen's interval algebra is NP–complete in general, very effective heuristics and tractable subalgebras have been defined.

Many historical events, such as the Second World War and the Cold War, are characterized by a gradual beginning and ending, rather than by an exact starting date and ending date. Hence their time span should be represented as a fuzzy set in the universe of time points, which we will call a fuzzy time interval. Unfortunately, this means that we can no longer refer to the beginning and ending of the time span of an event in the same way. Therefore, we have defined a generalization of Allen's interval relations which is suitable for fuzzy time intervals and which, unlike existing generalizations

(e.g. [2], [3]), preserves many of the important properties. Our approach is based on fuzzy orderings of time points, which are lifted to interval relations between fuzzy time intervals through the use of relatedness measures for fuzzy sets [4]. As a consequence, we may also express that, for example, $A$ is *long* before $B$, or that *A more or less* meets $B$. Most of the heuristics and definitions of tractable subalgebras that have been defined in the context of Allen's interval algebra can be generalized to our approach to support reasoning with fuzzy time intervals in polynomial time.

# References

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