Towards the Formal Representation of Temporal Aspects of Enemy/Threat Courses of Action

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Outline of Talk

- Problem Statement
  - Is JC3IEDM sufficient as a language for expressing Enemy Courses of Action (ECOA) narratives?
  - If so, what are the semantics for temporal relations?
- Background: ECOAs, JC3IEDM, OWL-TIME
- Representing Temporal Aspects of ECOAs in JC3IEDM
- Conclusions

Background: What is an ECOA?

Associated with each ECOA, there is (are):

- **Situation template** which normally consists of a Modified Combined Obstacle Overlay, depicting the operational environment, together with a doctrinal template or model that shows how the enemy would be expected to act in that environment.
- **Time Phase Lines** (TPLs) are placed on the situation template to depict the expected progress of enemy force movements (such as D+1, D+2, etc.).
- A **Situation Matrix** that depicts the expected progress of enemy activity across time in a spreadsheet format may also be used, especially in land-centric operations.
- An **ECOA Narrative Description** accompanies the situation template and usually addresses the earliest time the ECOA could be executed, location of the main effort, supporting operations, time, and phase lines.
  - Specifies WHO, WHAT, WHEN, WHERE, HOW
- **Decision Points**: critical decisions that the enemy commander must make during implementation of the ECOA are described in terms of their location and space as decision points.
- **High Value Target** list.

Normally at least three ECOAs are briefed: two most likely ECOAs and one most dangerous.

Problem Statement

- Enemy or Threat Courses of Action are produced during Intelligence Preparation of the Battlefield, during the Military Decision Making Process, and as part of the process of Situation Development.
- Due to the overwhelming amount of information involved in these processes and the limited time available to intelligence analysts, significant efforts are underway to develop computer based tools to assist in these processes.
- For these to be successful there needs to be a way to formally represent Enemy/Threat Courses of Action.
- As Courses of Action, ECOAs have (sometimes complex) temporal structures and relations.
- This paper investigates the requirements for and potential solutions to this problem using OWL, elements of JC3IEDM and the OWL Time ontology.

Fusion 2009 Temporal Inference Challenge

Technical Program—Tuesday AM

Pricessa II	Discovery	Portland	Eliza Anderson
Sensor Networks I *Angelia Nedich*	**Situation Awareness I** *Johan Schubert*	**Classification I** *Pramod Varshney*	**Ontology-Based Reasoning** *Mieczyslaw Kokar*
Real-Time Common Awareness in Communication Constrained Sensor Systems *Eelke van Foeken*	Analytic Network Process for Model Elicitation in Nation-Building Simulations *Ying Zhang*	Multi-View Fusion Based on Belief Functions for Seabed Recognition *Hicham Laanaya*	Acoustic Vehicle Classification by Fusing with Semantic Annotation *Baofeng Guo*
Cooperative Relative Localization Using Vehicle-to-Vehicle Communications *Eric Richter*	Evaluation Methods for Distributed Multi-Platform Systems in Electronic Warfare and Information-Warfare Related Missions *Kedar Sambhoos*	GMTI and IMINT Data Fusion for Multiple Target Tracking and Classification *Benjamin Pannetier*	Towards the Formal Representation of Temporal Aspects of Enemy/Threat Courses of Action *Christopher Matheus*
Data Fusion Techniques for Auto Calibration in Wireless Sensor Networks *Maen Takruri*	Evaluation of a Workshop to Capture Knowledge from Subject Matter Experts in Maritime Surveillance *Joeri van Laere*	Maximizing expected Gain in Supervised Discrete Bayesian Classification When Fusing Binary Valued Features *Robert Lynch*	A Multi-Disciplinary Approach to High Level Fusion in Predictive Situational Awareness *Paulo Costa*
Multi-Hop Greedy Gossip with Eavesdropping *Deniz Ustebay*	Situation Assessment for a Centralized Intelligence Fusion Framework for Emergency Services *Dafni Stampouli*	Fusion Technologies for Radar Target Classification Using Dempster-Shafer Rules in Littoral *Guy Kouemou*	Process Refinement Using Biosensor Location Problem *Kedar Sambhoos*
Distributed Consensus Over Network with Noisy Links *Behrouz Touri*	Threat Assessment Using Context-Based Tracking in a Maritime Environment *Jemin George*	Fusing Similarities and Euclidean Features with Generative Classifiers *Luca Cazzanti*	Information Evaluation in Fusion Using Information Correlation *Vincent Nimier*

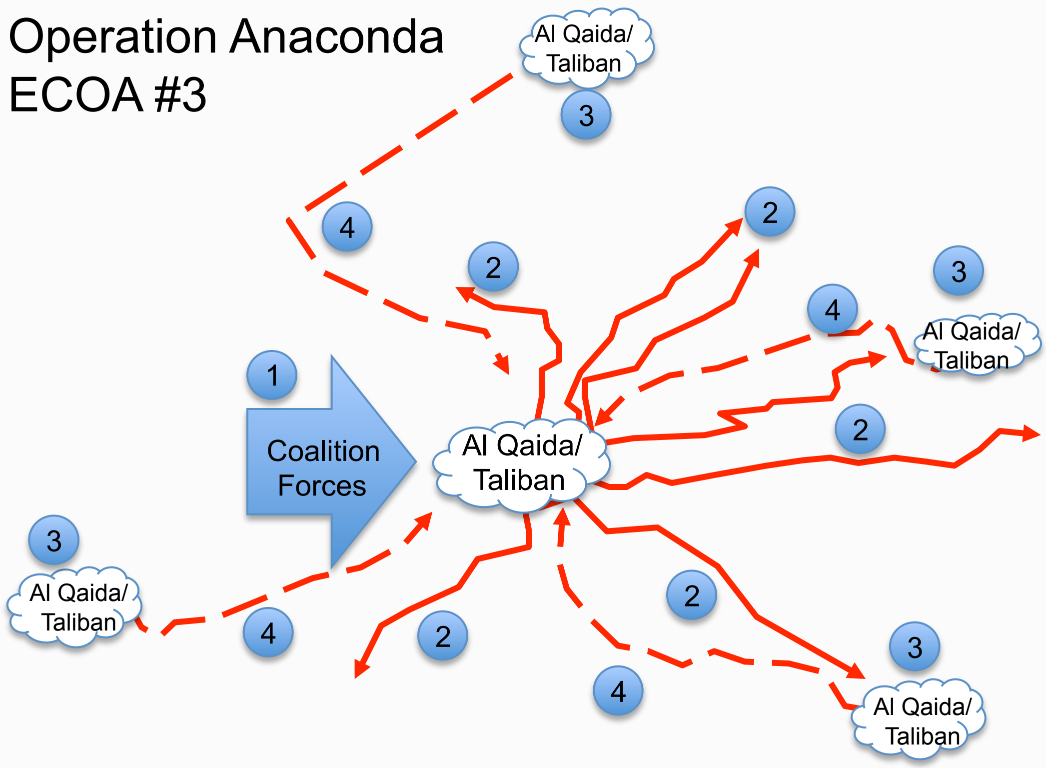
Background: Example ECOA Narrative

REDLAND initially conducts joint operations to disrupt JTF [Joint Task Force] Blue Sword forced entry operations, and upon establishment of the JTF Blue Sword in REDLAND, the REDLAND armed forces disperse into small-unit formations in the mountains and cities and initiate insurgency operations to defeat the JTF ground forces.

-from US Naval War College Training Document

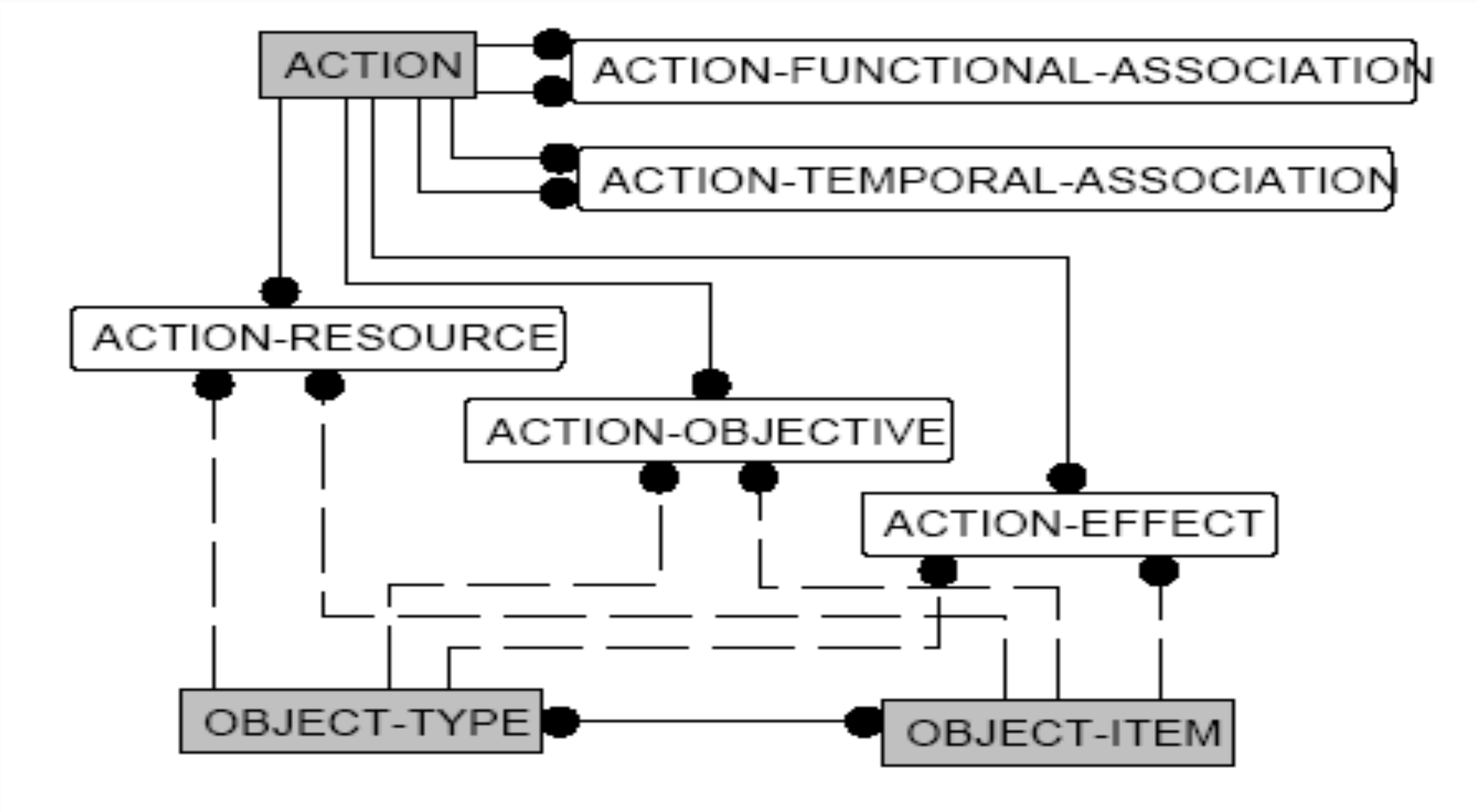
Who What When Where How Why

ECOA Example



Temporal structure: 1) coalition forces attack, then 2) enemy disperses then 3) enemy reconsolidates in order to 4) conduct guerilla attacks.

Basic JC3IEDM ACTION Structure



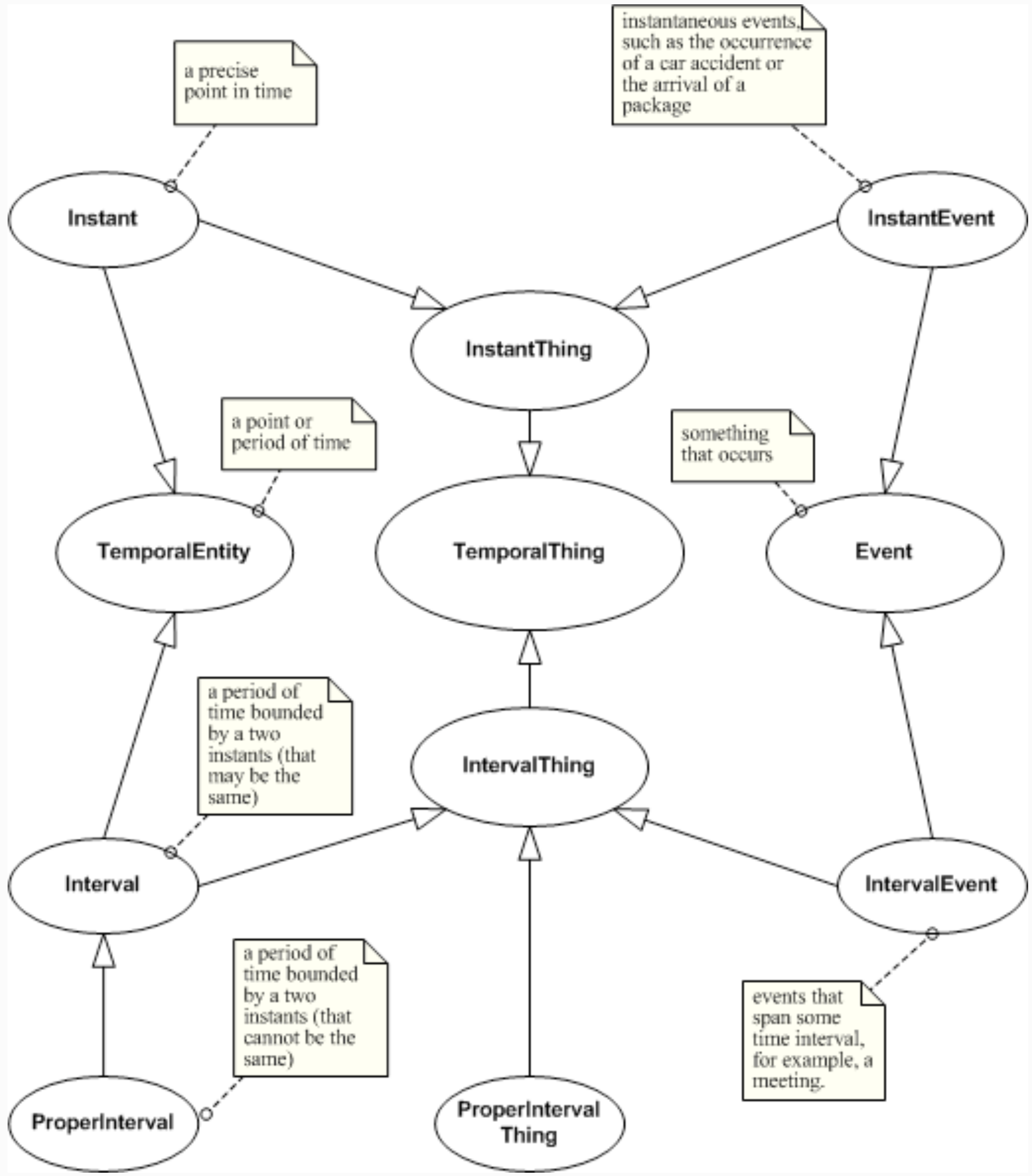
ACTION-TASK Timing

- action-task-minimum-duration
- action-task-estimated-duration
- action-task-maximum-duration
- action-task-planned-start-date
- action-task-planned-start-time
- action-task-start-qualifier-code: *after, as soon as possible, at, before, no later than, not before*
- action-task-planned-end-date
- action-task-planned-end-time
- action-task-end-qualifier-code

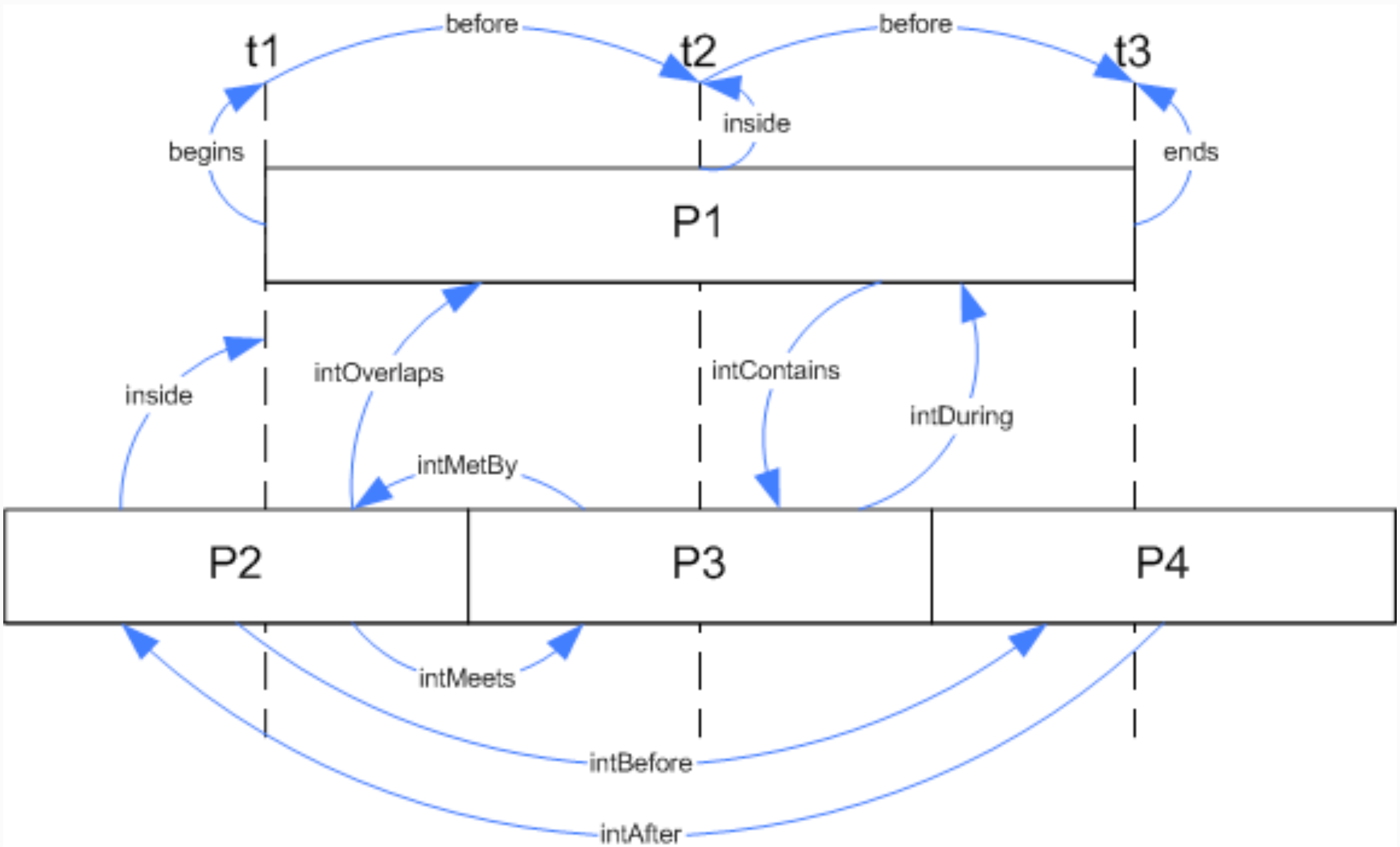
OWL-Time Class Diagram

OWL-Time is an updated version of DAML-Time that permits the representation of point events, interval events and common temporal relationships using OWL and some higher-level axioms.

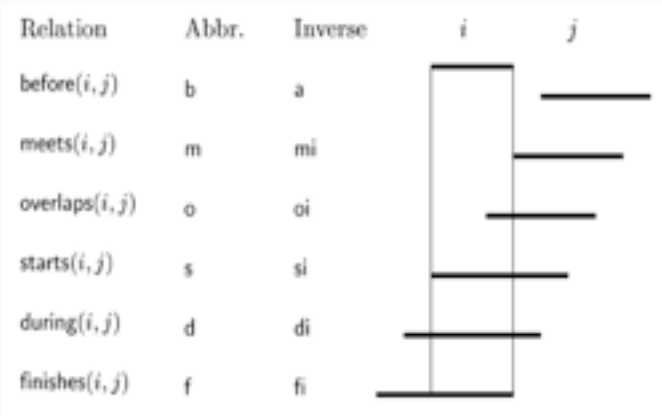
Jerry R. Hobbs and Feng Pan. 2006. Time Ontology in OWL. http://www.w3.org/TR/owl-time



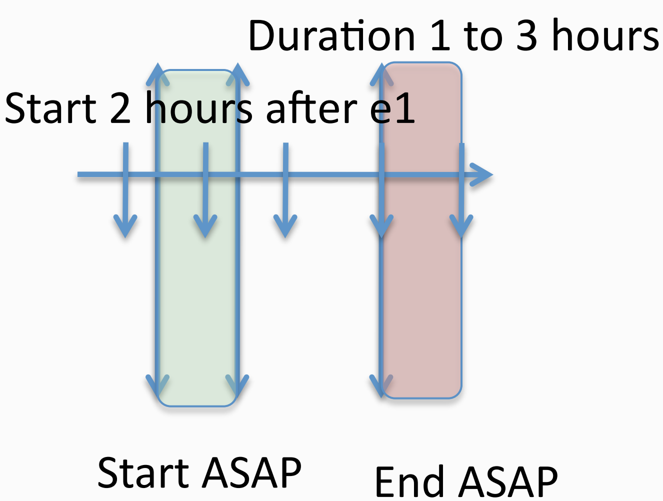
OWL-Time Properties Illustrated



OWL TIME axioms provide ability to make inferences concerning JC3IEDM Temporal Associations

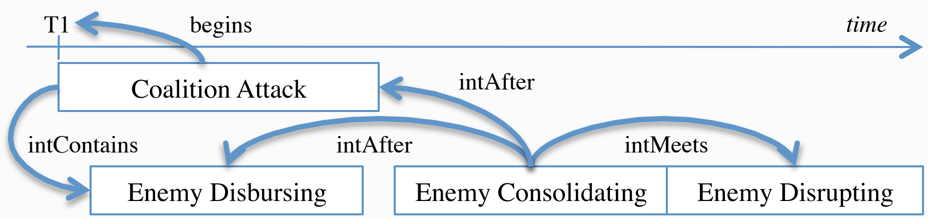


Relation	Abbr.	Inverse
before(i, j)	b	a
meets(i, j)	m	mi
overlaps(i, j)	o	oi
starts(i, j)	s	si
during(i, j)	d	di
finishes(i, j)	f	fi

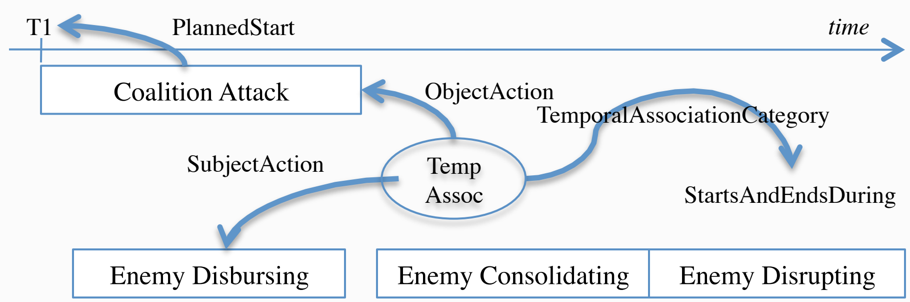


- In JC3IEDM, events can have underspecified start and end times (e.g. 2 hours after end of another event; or H-hour + 2; or ASAP).
- Duration can be encoded as a min-max range with an expected value, or projected via a completion ratio.
- JC3IEDM also allows relationship based on completion ratios: Action A begins … before/after Action B is 1/3 completed.
- OWL-TIME can provide semantics of much of these basic JC3IEDM temporal relations

Temporal Relations in OWL-TIME and JC3IEDM



OWL-TIME



JC3IEDM

JC3IEDM/OWL-Time Equivalents

JC3IEDM	**OWL Time**	Starts at and ends at the same time as	begins(SA) = begins(OA) and ends(SA)=ends(OA)
Ends after end of	after(ends(SA),ends(OA))	Starts at the same time and ends after	begins(SA) = begins(OA) and after(ends(SA),ends(OA))
Ends after start	after(ends(SA),begins(OA))	Starts before and ends before end of	intOverlaps(SA,OA)
Ends no earlier than after end of	after(ends(SA),ends(OA)) or ends(SA) = ends(OA)	Starts during & ends after	intOverlaps(OA,SA)
Ends no earlier than after start of	after(ends(SA),begins(OA)) or ends(SA) = starts(OA)	Starts during & ends at same time as	intDuring(SA,OA) and ends(SA) = ends(OA)
Ends no later than after end of	before(ends(SA),ends(OA)) or ends(SA) = ends(OA)	Starts no earlier than after end of	after(begins(SA),ends(OA)) or begins(SA) = ends(OA)
Starts after end of	after(begins(SA),ends(OA))	Starts no earlier than after start of	after(begins(SA),begins(OA)) Or begins(SA) = begins(OA)
Starts after start of	after(begins(SA),begins(OA))	Starts no later than after end of	before(begins(SA),ends(OA)) or begins(SA) = ends(OA)
Ends no later than after end of	before(ends(SA),ends(OA)) or ends(SA) = ends(OA)	Ends no later than after end of	before(ends(SA),ends(OA)) or ends(SA) = ends(OA)

Conclusions

1. Representing temporal aspects of ECOAs requires the ability to specify

   1) point events; 2) interval events; 3) events with partially constrained time of occurrence;

   4) events that occur in sequence; 5) events that occur in parallel; and

   6) events that are dependent upon other events occur prior to their own occurrence.
2. A formal representation should be grounded in formal ontology and that OWL is a strong candidate as an ontology language for this purpose.
3. In addition, OWL Time is a formal OWL ontology that captures the essence of Allen's interval calculus and provides the representation power required for representing the temporal elements we've encountered in our sample of ECOAs and is capable of expressing the temporal relationships that are part of the JC3IEDM data model.
4. While the OWL-Time ontology goes a long way towards providing a basis reasoning about time it does not afford a complete solution as it does not address the problems of representing uncertainties regarding the accuracy and precision of times, nor does it attempt to align itself with a command and control language such as JC3IEDM.
5. We have auto-translated JC3IEDM into OWL; reasoning with JC3IEDM is ***theoretically*** possible.

Thank You!

Questions?

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