Meta-Model Driven Construction of Timed Influence Networks

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A meta-model driven approach is presented that can be used to generalize existing Timed Influence Net (TIN) models into meta models for a class of problems.

Many subject matter experts have difficulty in expressing their knowledge in a formal analytical representation, e.g., Bayesian Nets, TINs, etc.

The ontology-based, meta-modeling approach provides potential assistance to these modelers in developing quick (and possibly incomplete) models for new situations using the meta models. These models can be further refined.
Influence Nets (IN) are variants of Bayesian Networks

The Graph Representation

- A set of random variables that make up the nodes of an IN. All the variables in the IN have binary states.
- Each directed link has associated with it a pair of parameters that shows the causal strength of the link.

Situational and Behavioral Assessment Modeling

- Nodes with propositional statements representing PMESII* aspects of a domain
- Links represent causal influences from one (affecting) proposition to another (affected)

Analysis

- Given evidence (states) on some nodes, what is the effect of the evidence on other nodes?

* PMESII: political, military, economic, social, infrastructure, and information
Timed Influence Nets

- Timed Influence Nets (TINs) are an extension of Influence Nets (IN).
- A TIN models situations where the impact of events (actions or effects) takes some time to reach and be processed by the affected events or conditions.
- The temporal constructs allow a system modeler to specify delays associated with nodes and arcs.
  - These delays may represent the information processing and communication delays present in a given situation.
- Time Stamps become associated with each node including the “input” nodes that represent potential actions within a course of action.
- Any particular Course Of Action triggers a timed sequence of changes in the probability values of the effect nodes. The result can be represented graphically with what is called a probability profile.
Timed Influence Nets

- Courses of Action (COA) Analysis
  - Given inputs with time stamps, what is the timed sequence of effects of the input on an objective node?
  - Given a desired effect on an objective node, what is the timed sequence of inputs (i.e., COA) that achieves it or maximizes/minimizes it?

$d$ is the delay
@t1 is the ‘time stamp’ on input A

Country B Agrees to Withdraw
Leader of Country B Believes He Can Succeed
Diplomatic Mission in Country B
Country G Employs Successful Cover Operation
Int'l Community Threatens Sanctions

timeline
Example Applications

• We have been using TINs for 12 years, mostly in war games, modeling adversary behaviors, and to support the Air Force Research Laboratory.
  – Global 2000, 2001
  – Millennium Challenge 02
  – JEFX 04
  – AFRL/IF Dynamic Air and Space Effects Based Assessment (DASEA Critical Experiment)
  – …

• TINs have been used at the Strategic, Operational, and Tactical Level

• They can support COAs that integrate kinetic and non-kinetic operations and mixes of Diplomatic, Information, Military, and Economic (DIME) actions
An Example TIN

Timed Influence Net developed in 2001 to capture some aspects of East Timor conflict.
TIN developed as part of a socio-political study of Diyala, in 2005.
A domain specific Timed Influence Net is a representation of a SME’s understanding of the causal influences between domain concepts (events, actions, beliefs, etc.).

- Example: “If the Kurd population in the Northern provinces of Iraq finds its rights respected in the new administration, then it will be more cooperative for the new development plans.”

The causal influences can be generalized into Template (Meta) Influences using generic domain concepts.

- Example:
  “If an <ethnic minority> in a <geographic administrative unit> finds its rights respected, then it will <participate> in the <development activity>.”

A Template Influence can be instantiated with values taken from new domains/situations.
Architecture of the Approach

Domain Modeling

Template Ontology

Template TIN

Mapping Box

Situation Modeling

Ontology

TIN Generator

TIN
• **Template Timed Influence Net** describes generalized cause-effect relations characterizing the domain.

• **Template Ontology** describes the abstract concepts and relations characterizing a domain.

• **Mapping Box** defines abstract concepts in Template Influence Net in terms of abstract concepts and relations present in Template Ontology.
• **Ontology** describes a situation in terms of abstract concepts and relations in Template Ontology.

• **TIN Generator** uses Mapping Box and instance ontology to generate Timed Influence Net specialized for the situation. The specialized Influence net will only contain concepts and cause-effect relations relevant for the situation.
Tool Support

Protégé
Ontology

Pythia
Influence Net

Castalia
Mapping Box Specification, Influence Net Generation and Ontology Evaluation
• An Analysis of Kenya and Tanzania Embassy Bombings was performed with the developed approach.

• An instance TIN was developed by an expert using the data on Kenya incident only. A Template Timed Influence Net was derived from it by generalizing the propositions in the Kenya-TIN.

• Mapping Rules developed for the generalization variables used in the Template TIN.
A sample mapping rule

• The values of these variables can be queried from a given ontology.

Select ?leader, ?funding
Where
{( ?leader instanceOf KnownTerrorist)
 ( ?leader leadershipRank high)
 ( ?observationL instanceOf C2Observation)
 ( ?observationL hasParticipant ?leader)
 ( ?funding instanceOf FinancialSource)
 ( ?observationF instanceOf FinancialAquasitionObservation)
 ( ?observationF hasFinancialSource ?funding)}
Bombing Analysis Application
Template Ontology (OWL)
Bombing Analysis Application
Generated Influence Net for Tanzania
Instance Ontology
Conclusions

• The approach can be used to generalize situation and behavioral assessment models in the form of Template TINs.

• A set of mapping rules define generalized concepts in a Template TIN to concepts in an ontology.

• The generalized TIN models can be instantiated with data in domain ontologies for a quick (and possibly incomplete) development of domain-specific situational models.

• A library of Template TINs provides an analyst with an ability to choose and merge several domain models from different sources and/or experts.