Using Propositional Graphs for Soft Information Fusion

Michael Prentice and Stuart C. Shapiro

Department of Computer Science and Engineering,
Center for Cognitive Science,
Center for Multisource Information Fusion
University at Buffalo, Buffalo, NY 14260
{mjp44,shapiro}@buffalo.edu

Outline

Soft Information Fusion

Combine information from multiple natural language messages.
Counterinsurgency domain.

Message 12: 01/13/07 — Cell phone call from unidentified male in
Adhamiya to unidentified male in Ramadi lasted just five
seconds with the words "my brother sends greetings" spoken
by originator of call.

Message 14 extract: 01/14/07 — Originator of 1/13/07 cell phone call
to Ramadi from Adhamiya has now been identified as Sufian
Mashhadan. The recipient has been identified as Ziyad
al-Obeidi.

Some problems:

- Embedded in many messages.
- Same cell phone calls?
- from *vs.* originator
- to *vs.* recipient

Tractor

1. Syntactic Processing
   - Produce dependency graph
2. Propositionalizer
   - Map dependency graph to propositional graph
3. Contextual Enhancement
   - Add relevant ontological and other background information
4. Fuse contextually enhanced propositional graphs

Dependency Structure of Sentences

- Clauses

    Head: Verb
    Dependents:
    - Adverbs
    - Noun phrases
    - Prepositional phrases
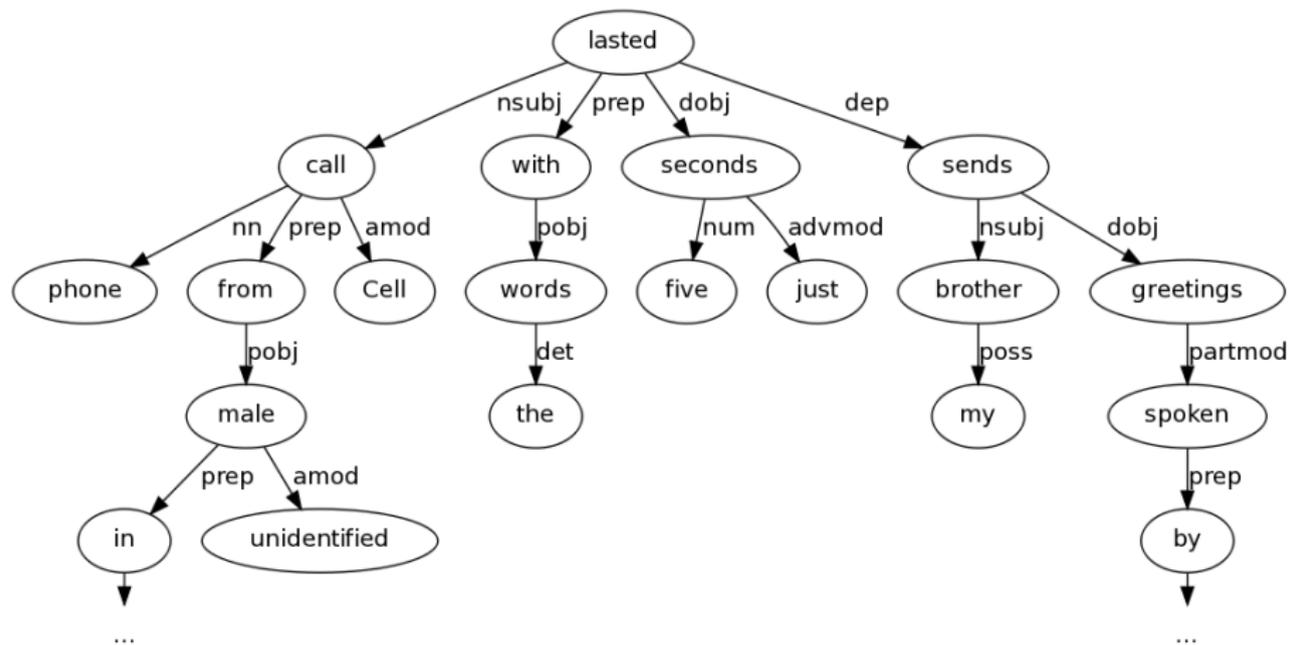
- Prepositional Phrases

    Head: Preposition
    Dependents: Noun phrase

- Noun Phrases

    Head: Noun
    Dependents:
    - Determiner
    - Adjectives
    - Nouns
    - Prepositional phrases

Dependency Parse for Message 12

Caseframes for Semantics

- Based on "The Case for Case" [Fillmore, 1968]
  and The Berkeley FrameNet Project [Baker, Fillmore, & Lowe, 1998]
- Frame
  - schematic representation of a situation
    with a set of participants
    and conceptual roles.
- Eliminates syntactic differences.
- E.g.
  - Sufian called Ziyad.
  - Ziyad was called by Sufian.
  - a call from Sufian to Ziyad

Structure of Frames

- Frame
    - set of frame elements
    - semantic roles filled by entities of certain types.
- Filler can be another frame.
- Core Frame Elements:
    - "conceptually necessary component"
- Non-Core (Peripheral) Frame Elements:
    - Does not "introduce additional, independent or distinct events"

Contacting Frame

- Core Elements
    - Communicator, type: Sentient
    - Addressee, type: Sentient
    - Communication
    - ...
- Non-Core Elements
    - Medium
    - Time, type: Time
    - ...
- E.g.
    - Time: 2007-01-13
    - Medium: cell phone
    - Communicator: Sufian Mashhadan
    - Addressee: Ziyad al-Obeidi
    - Communication: "My brother sends greetings."

Frame for Message 12

Time: 2007-01-13

Communicator: Some Sentient

Message: Duration: 5 seconds
            Entity: Medium: Cell phone
                    Communicator: Some male in Adhamiya
                       Addressee: Some male in Ramadi
                    Communication: "My brother sends greetings."

Propositional Graphs

- A Knowledge Representation (KR)
    - labeled directed acyclic graph
    - with formal syntax
    - and formal semantics
- Atomic Node
    - Corresponds to individual constant
    - No outgoing arcs
    - Denotes entity in domain
- Molecular Node
    - Corresponds to functional term
    - Outgoing arcs labeled with argument position (role)
    - Compositional semantics
    - Denotes
        - Entity in domain
        - Possibly a proposition

Basic Principles

- Comprehensiveness
  - Every entity, person, category, property, value, etc.
    Every proposition, belief, fact, etc.
    is represented by a node.
- Uniqueness Principle
  - No two nodes with same ID.
  - No two molecular nodes with same labeled arcs to same nodes.
  - No two nodes representing the (obviously) same domain entity.
 - Base case for fusing propositional graphs

SNePS KR System

- Logic-based
- Frame-based
- Propositional graph-based
- Each view supports a different style of inference
  (not covered in this talk)
- Uses Arbitrary and Indefinite terms [Shapiro, 2004]
    - E.g.,
      ```
      (some ind1 () (Instance ind1 Male)
                    (Location ind1 Ramadi))
      ```

SNePS Graph::Frame::Logic

- Atomic node :: atomic symbol :: individual constant
    - Node ID = atomic symbol
- Molecular node :: frame :: functional term
    - Node ID = wft$i$[!]
- Arc label :: frame slot :: argument position
- Uniqueness Principle
    - No two nodes with same ID
    - No two molecular nodes with same labeled arcs to same nodes
    - Base case for fusing SNePS propositional graphs

Lowest Parts of Propositional Graph for Message 12
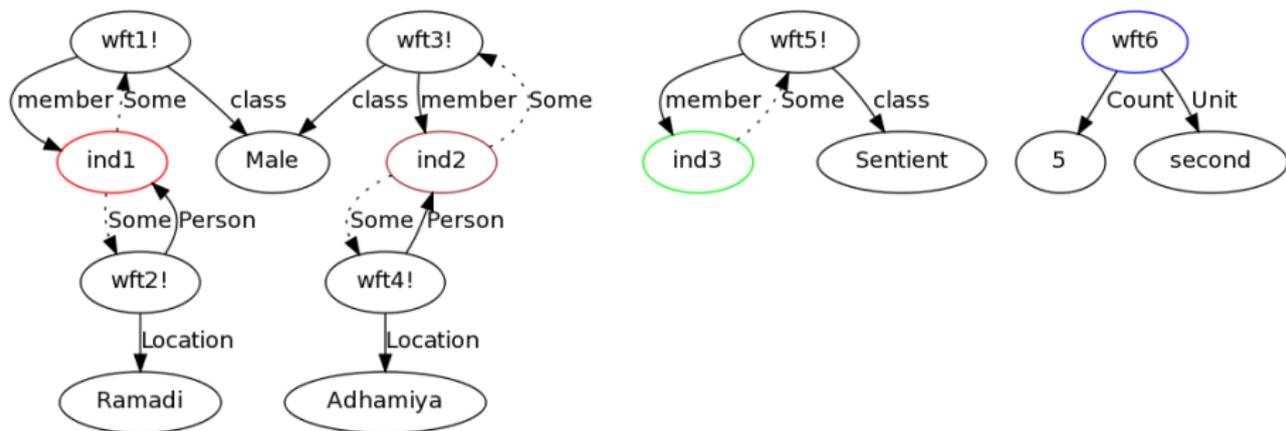
some Male in Ramadi; some Male in Adhamiya; some Sentient; 5 seconds

Contacting in Propositional Graph for Message 12
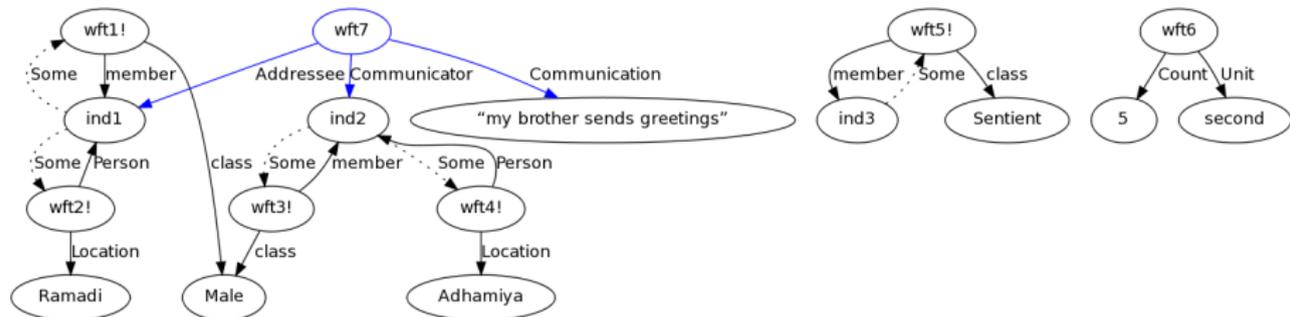
Some Male in Ramadi communicated "my brother sends greetings" to some Male in Adhamiya.
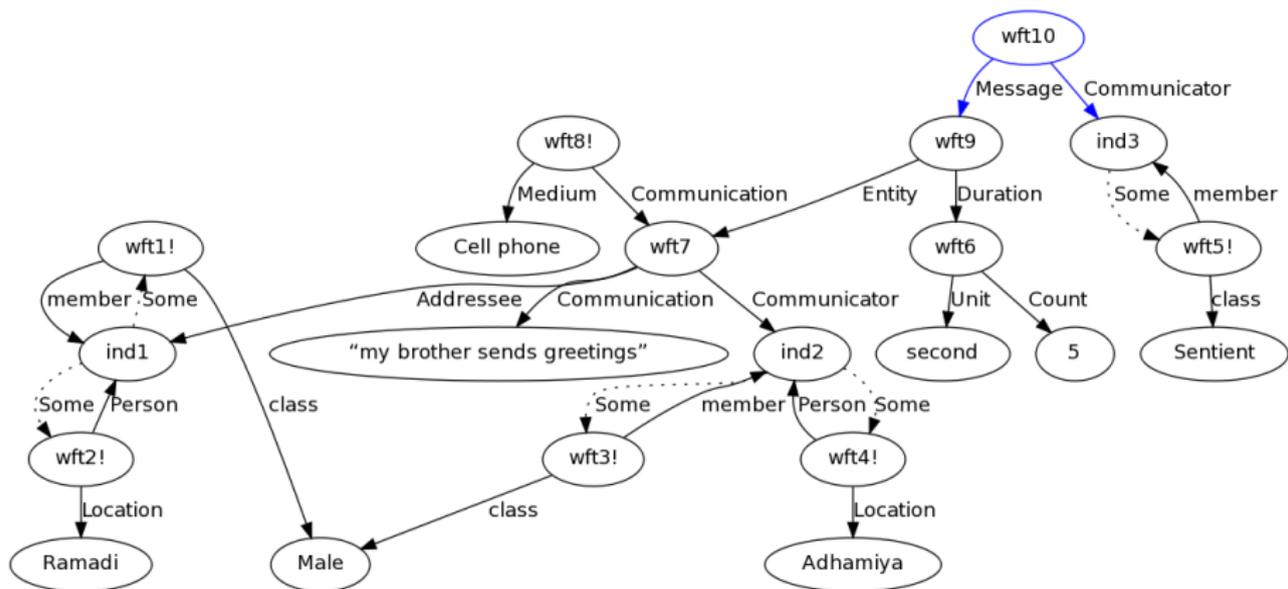
Note 3-ary relation.

Cell Phone in Propositional Graph for Message 12
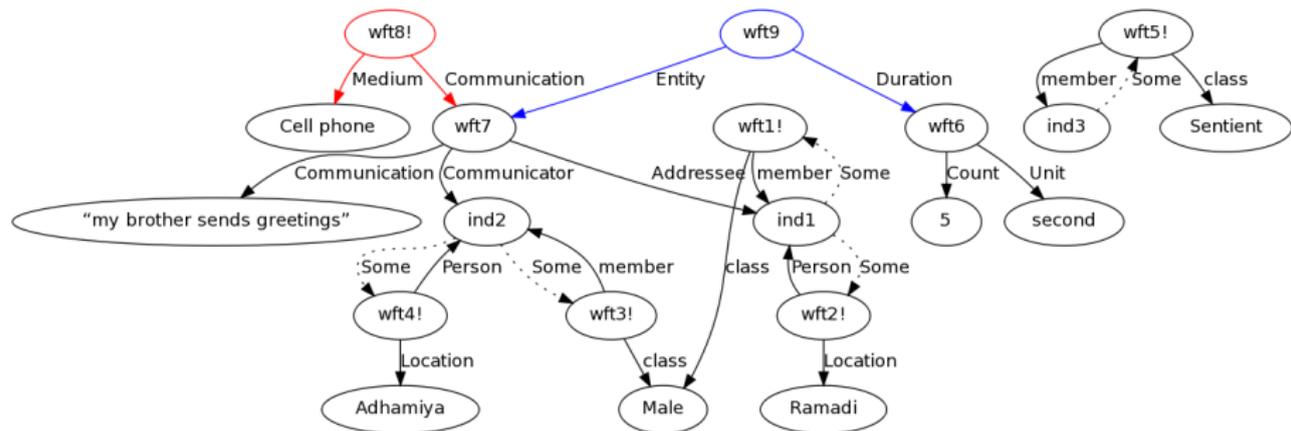
The contacting was via cell phone and lasted 5 seconds.
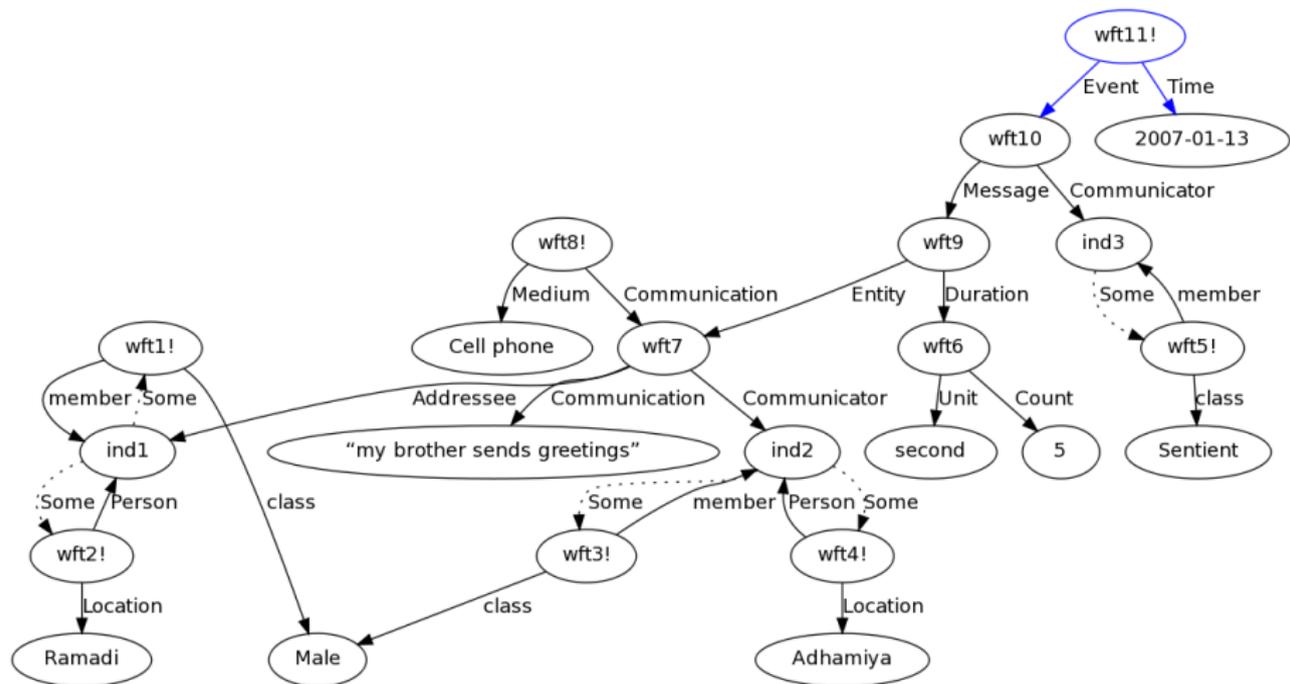
Note nesting of functional terms.

Propositional Graph for Sender of Message 12
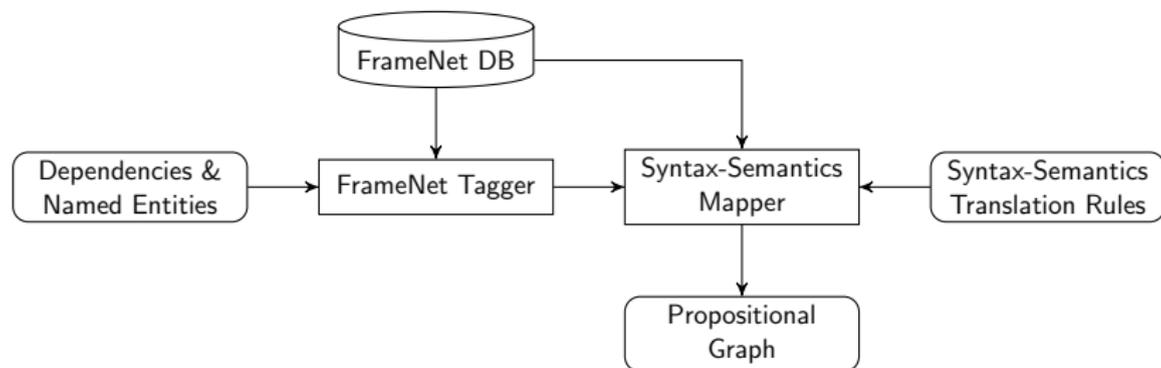

Some Sentient said that it lasted 5 seconds.

Note pedigree information.

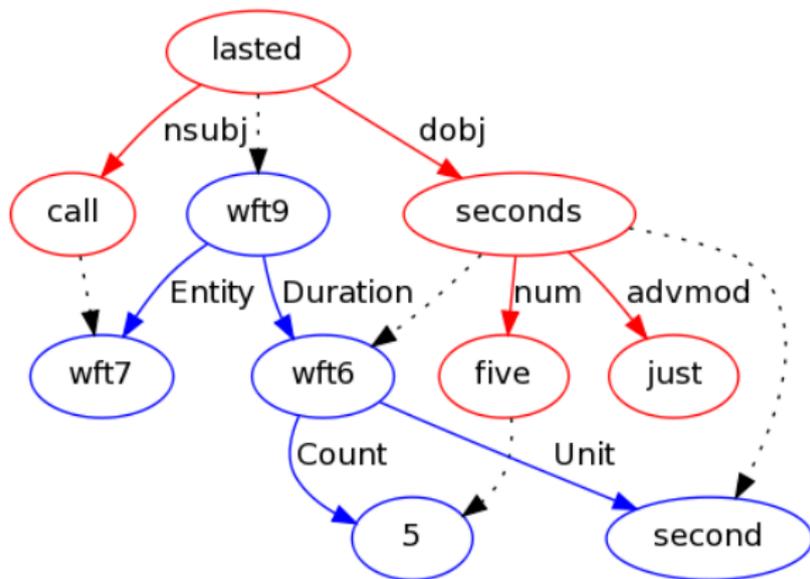# Final Propositional Graph for Message 12

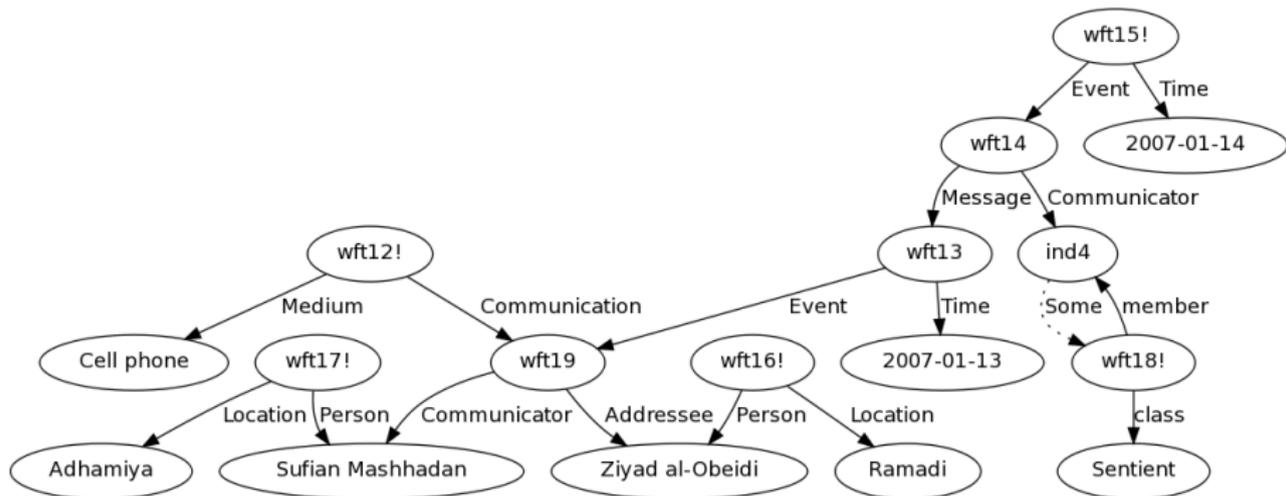Message 12 was sent on 2007-01-13

Propositionalizer

Example Syntax-Semantics Mappings

Sample mappings from dependency graph to propositional graph.

Propositional Graph for Message 14

Fused Propositional Graph

Given common Medium, Time, Locations,
Data Association should fuse calls, communicators, and addressees.

Conclusions

- Tractor
  - analyzes an English message
  - builds a dependency graph
  - and then a propositional graph.
- Propositional Graphs
  - Are a Knowledge Representation
  - Based on FrameNet frames
  - Can represent n-ary relations
  - Can represent meta-information
  - Can represent pedigree
  - Support Data Association by graph matching

Future Work

- Automating tagging of words with FrameNet frames
- Automating Syntax-Semantics Mapper
- Designing test and evaluation measures

Acknowledgements