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# Natural Language Knowledge Graphs

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Gabriel Stanovsky, Rachel Wities, Iryna Gurevych

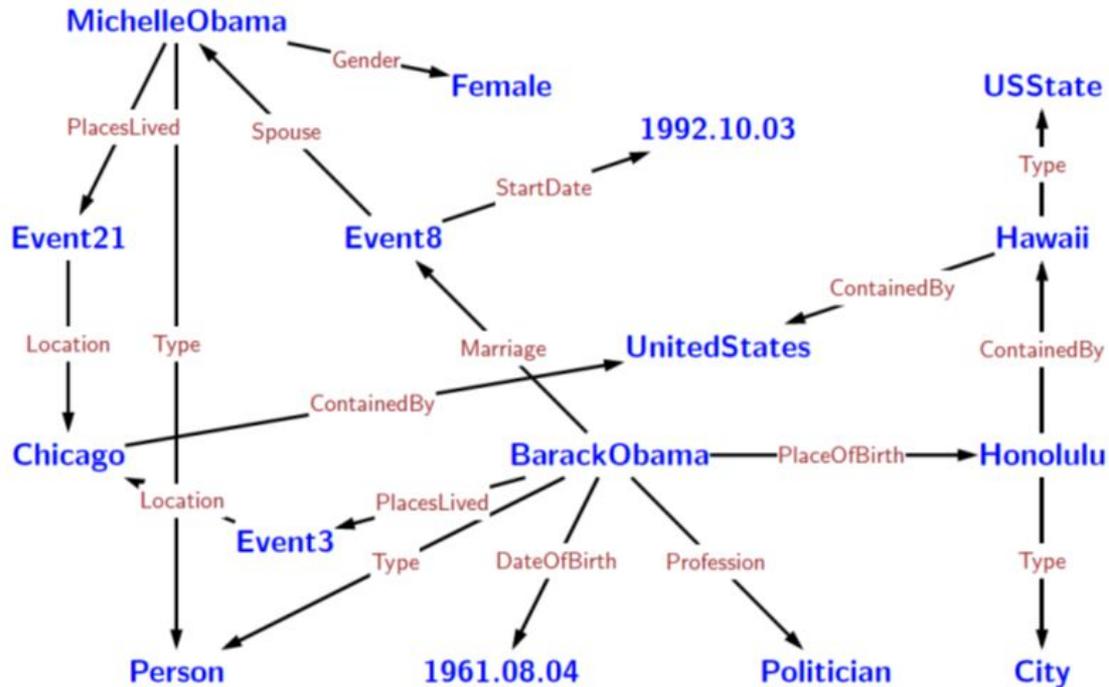
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*Work in progress*

# A Perspective: Structured Knowledge Graphs

Freebase knowledge graph



# Structured Knowledge Graphs (KG)

- Encode selected facts about the world
- as propositions - asserted relations (predicates) between entities
- Allow structured presentation and querying
- Consolidating many facts about the encoded entities
- Relations and entities are pre-specified

# Our Motivation: NL-based KG (NLKG)

- How can we capture unbounded information in collections of text?
- How can we communicate it efficiently to users, or applications?
- An “open” NL-based representation
  - Vs. formal KG
- This talk:
  - Defining the graph structure & dataset annotation
  - Illustrating application potential
  - No algorithms...

**Illustrating Example:  
Consolidating Event Tweets -  
Stand-alone Sentences**

# What is said here?

Turkey forces a plane from Russia to land in Ankara.

Syrian jet grounded by the Turkish military was carrying munitions.

Intercepted Syria-bound plane carried ammunition from Russia to Syria.

Russia angry at Turkey about grounded Syrian jet and Russian passengers

Turkey Escalates Confrontation with Syria, forcing Syrian plane flying from Russia to land in Turkey

Turkey forces down suspect Syrian plane

Turkish PM says plane from Moscow forced to land in Turkey was carrying ammunition for Syria government.

Turkish F16s force Syrian passenger plane enroute from Moscow land in Ankara.

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# Characteristic 1: Redundancy

Turkey forces a plane from Russia to land in Ankara.

Syrian **jet** grounded by the Turkish military **was carrying munitions**.

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...

# Characteristic 2: Complementary scattered info

Turkey forces a plane from Russia to land in Ankara.

Syrian **jet** grounded by the Turkish military **was carrying munitions**.

Intercepted Syria-bound **plane carried ammunition from Russia to Syria**.

Russia angry at Turkey about grounded Syrian jet and Russian passengers

Turkey Escalates Confrontation with Syria, forcing Syrian plane flying from Russia to land in Turkey

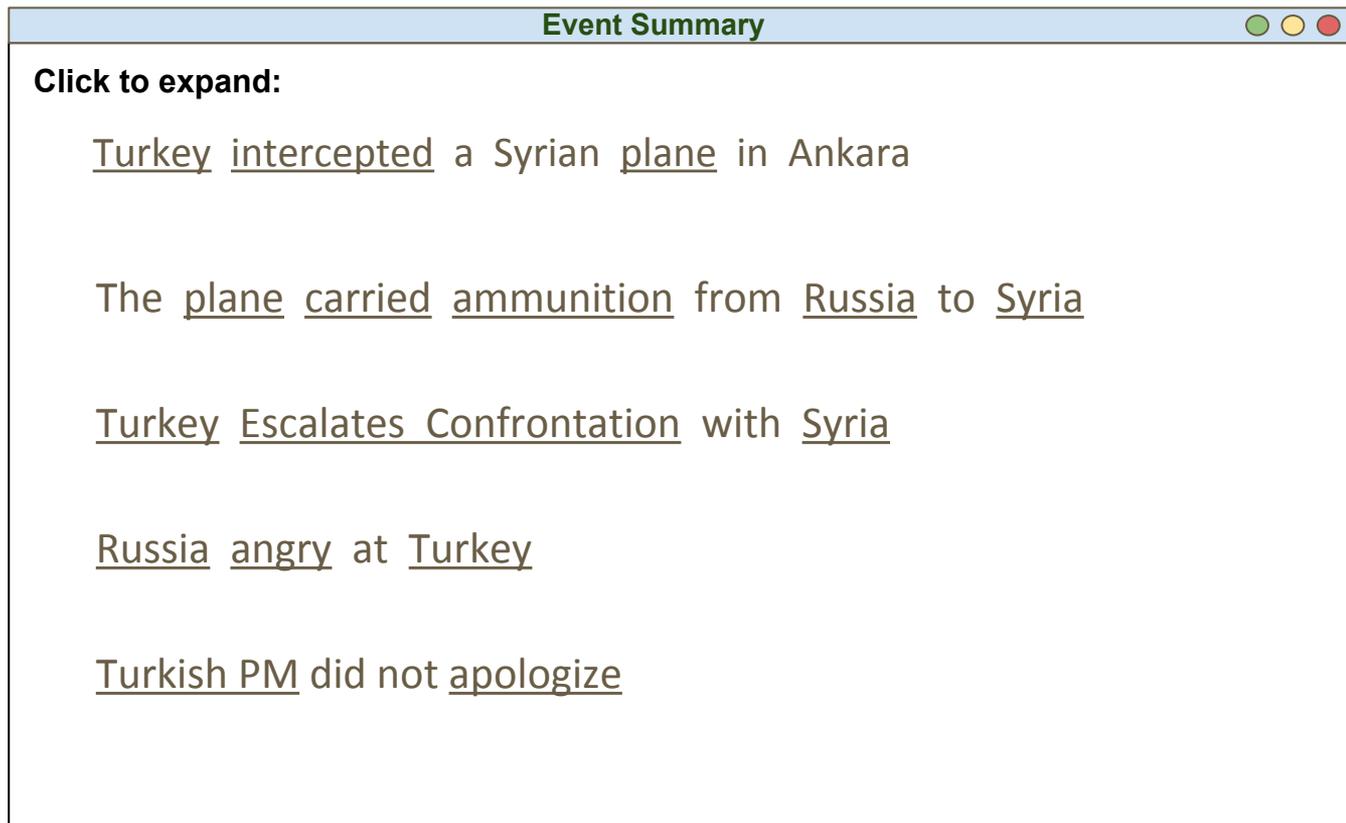
Turkey forces down suspect Syrian plane

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Turkish F16s force Syrian passenger plane enroute from Moscow land in Ankara.

...

# Illustration: Consolidated Event Summary View



The image shows a browser window titled "Event Summary" with three window control buttons (green, yellow, red) in the top right corner. The main content area contains a list of news snippets, each with several words underlined to indicate expandable links.

**Click to expand:**

- Turkey intercepted a Syrian plane in Ankara
- The plane carried ammunition from Russia to Syria
- Turkey Escalates Confrontation with Syria
- Russia angry at Turkey
- Turkish PM did not apologize

# Event Summary View

Event Summary

Click to expand:

Turkey intercepted a Syrian plane in Ankara

Turkey military  
Anti-aircraft unit ▶

The plane carried ammunition from Russia to Syria

Turkey Escalates Confrontation with Syria

Russia angry at Turkey

Turkish PM did not apologize

# Event Summary View

Event Summary

Click to expand:

Turkey intercepted a Syrian plane in Ankara

Turkey military  
Anti-aircraft unit  Turkish F-16s

The plane carried ammunition from Russia to Syria

Turkey Escalates Confrontation with Syria

Russia angry at Turkey

Turkish PM did not apologize

# Event Summary View

Event Summary

Click to expand:

Turkey intercepted a Syrian plane in Ankara  
force to land  
grounded

The plane carried ammunition from Russia to Syria

Turkey Escalates Confrontation with Syria

Russia angry at Turkey

Turkish PM did not apologize

# Event Summary View

Event Summary

Click to expand:

Turkey intercepted a Syrian plane in Ankara

passenger plane ▶

The plane carried ammunition from Russia to Syria

Turkey Escalates Confrontation with Syria

Russia angry at Turkey

Turkish PM did not apologize

# Event Summary View

Event Summary

Click to expand:

Turkey intercepted a Syrian plane in Ankara

passenger plane    passenger jet plane

The plane carried ammunition from Russia to Syria

Turkey Escalates Confrontation with Syria

Russia angry at Turkey

Turkish PM did not apologize

**Background:**

**Build NLKG (mostly) from *known* component tasks**

# Single Sentence Representations (1)

- SRL - annotating predicate-argument structure of sentences.

*Danny arrived to the restaurant to meet Sarah*

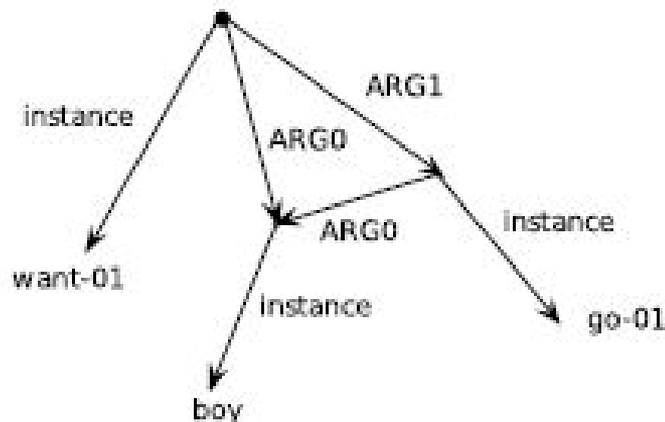
	☐ SRL	☐ SRL
Danny	entity in motion / 'comer' [A1]	achiever, agent [A0]
arrived	V: arrive.01	
to	end point, destination [A4]	
the		
restaurant		
to	proper noun component [AM-PNC]	
meet		V: meet.01
Sarah		goal [A1]

\* V. Punyakanok et al., 2008

- QA-SRL - an argument role is a natural language question which the argument answers
- Open IE - Isolates “atomic” propositions as predicate-argument tuples
  - (Danny, arrived, at restaurant, to meet Sarah)
  - (Danny, meet, Sarah)

# Single Sentence Representation (2)

- **AMR** (Banarescu et al., 2013)
  - Represents sentence semantic structure as a labeled graph.
  - Assigns same AMR structure to sentences with the same meaning.



# Cross-document Consolidation - Pre-defined IE

- **Rich ERE** (DEFT) - Entities, Relations, and Events
- Annotating a small predefined set of entity, relation and event types.
  - 5 Entity types: PER, ORG, GPE, LOC, FAC
  - 20 relation types: member, family, founder, ...
  - 38 event types: attack, marry, appeal, ...
- Consolidation via coreference between mentions of same entity/relation/event

# Cross-document - Open Pred-arg Alignment

- Roth and Frank (2012), PARMA (2013), ECB+ (2014) - Cross-document alignment of events and entities

*T1: On Monday Lindsay Lohan checked into rehab in Malibu, California after car crash.*

*T2: Ms. Lohan entered a treatment facility.*

*T3: The 26 year old actress checked into Betty Ford Center.*

- Each of these efforts is limited/partial in certain respects
- No consolidation

# Coreference-based inference

- Lexical substitution of co-referring elements
  - I saw a **boy**. **He** was running  $\Rightarrow$  A **boy** was running
- Used in question answering, RTE, etc.
- DRT (Kamp 1988, Kamp et al., 2011)
  - In formal semantics - a proposition applies to all co-referring (equal) entities

# Our Positioning and Novelty

- Rely on extended *QA-SRL extractions* and *entity/predicate coreference*
- **Merge pred-arg extractions** into a consolidated structure
- **Trace redundancies** - through *entailment* relations

# NLKG Scope & Requirements

# Setting: Natural Language Propositions

- Assumption: textual information can be represented by NL propositions
  - Natural language predicate and arguments
  - Expressing an assertion, to which a truth value can be assigned
  - Typically specifies an event, relation or property
- Similar to Open-IE rationale

# Scope of Represented Propositions

- “*Verbatim*” natural language propositions: only mentioned lexical elements
  - Lexical inference is left for a separate module
    - E.g. if only *apple* mentioned, avoid representing *fruit*
- *Coreference-based* inference: the basis for merging information
  - a **plane** from Russia + a Syrian **jet** => a jet from Russia.
  - The plane **flew** from London+The plane **flew** to Paris. => The plane flew from London to Paris.

# Requirements

1. Represent the NL propositions conveyed jointly by the texts
  - *Completeness*: capture all propositions - verbatim + coref-based
  - *Soundness*: all represented propositions are indeed conveyed by the texts
  - Trace original mentions for each information component
    - Frequency - indicates salience & certainty
2. Redundancy modeling
  - Model redundancy between the represented NL propositions, such that -
  - Support incremental communication
    - Use cases: hierarchical presentation, updates
    - A communicated proposition should add new information

# Graph Specification & Construction

# Overview

*Knowledge graph of consolidated propositions:*

*a **novel structure** based (mostly) on **known NLP tasks***

1. Consolidating *entities & propositions*
  - Via coreference chains
2. Modeling redundancy via entailments

# Entities

- *Entity mention*
  - A word or multi-word term in a sentence, referring to a real world object or concept
- *Entity*
  - A coreference chain of entity mentions, all referring to the same object/concept
    - A cross-document “discourse entity”

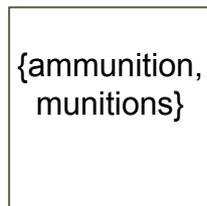
# Entity mentions & co-reference chains

1. Intercepted plane carried ammunition to Moscow.
2. Syrian jet grounded by the Turkish military was carrying munitions from Russia to Syria.
3. Turkey uses military to force a plane from Russia to land in Ankara.

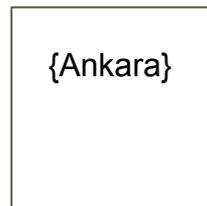
E1 (plane)



E2 (ammunition)



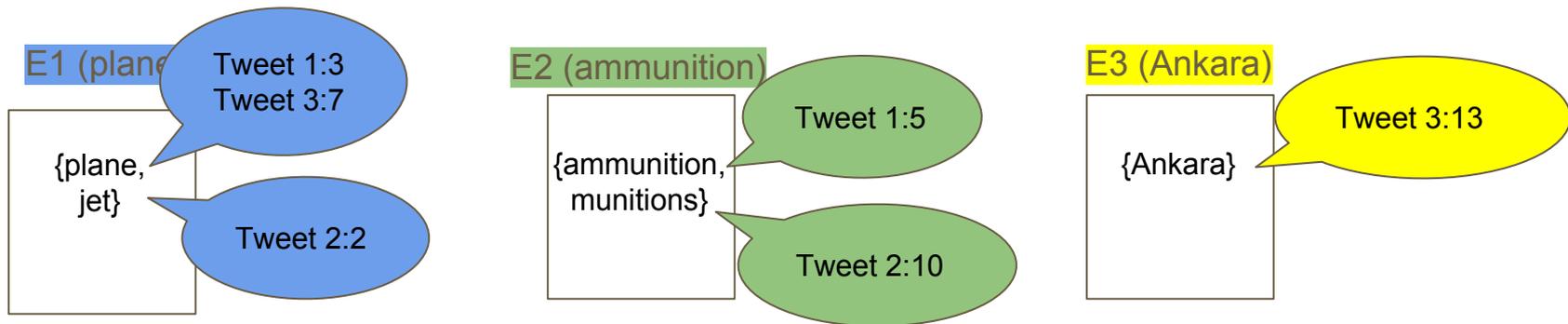
E3 (Ankara)



...

# Tracking Supporting Mentions

1. Intercepted plane carried ammunition to Moscow.
2. Syrian jet grounded by the Turkish military was carrying munitions from Russia to Syria.
3. Turkey uses military to force a plane from Russia to land in Ankara.

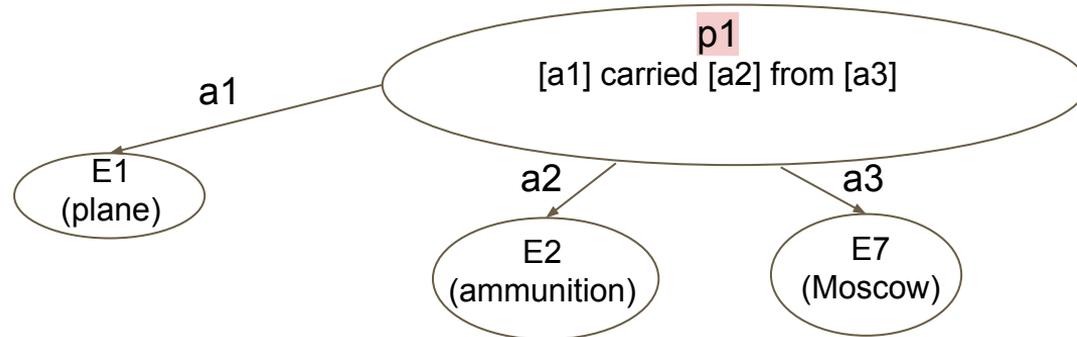


# Propositions

- *Proposition mention*
  - A fragment in the text, referring to a single event, relation or property.
- *Proposition*
  - A coreference chain of proposition mentions that refer to the same real-world fact.

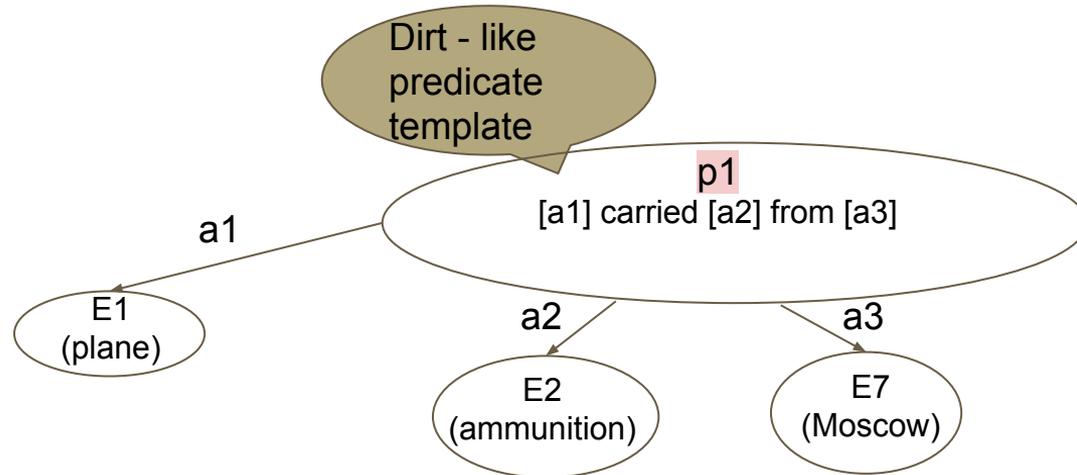
# Propositions as a graph

1. Intercepted plane **carried** ammunition from Moscow.
2. Syrian jet grounded by TURkey was carrying munitions from Russia to Syria.



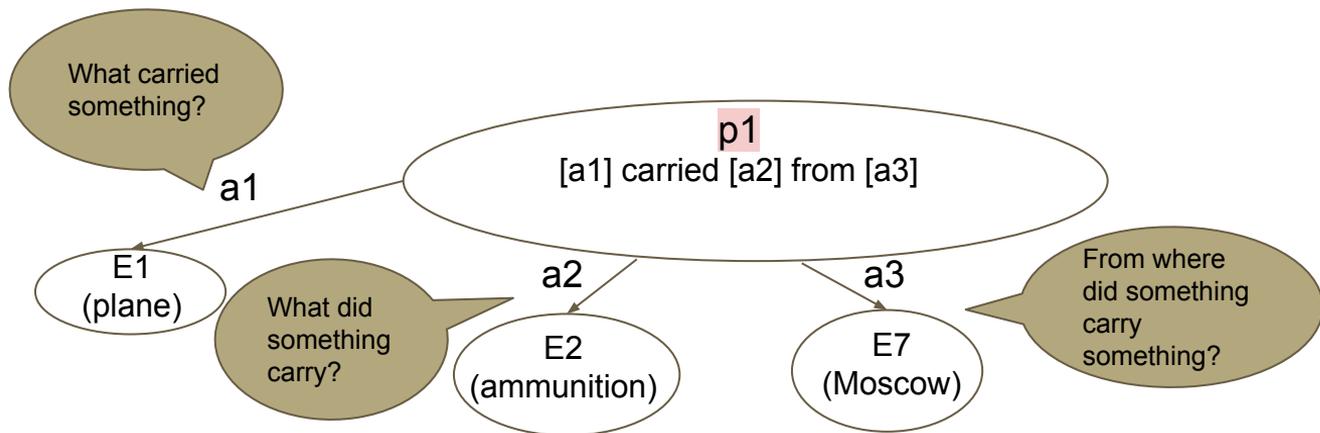
# Predicate templates

1. Intercepted plane **carried** ammunition from Moscow.
2. Syrian jet grounded by TURkey was carrying munitions from Russia to Syria.



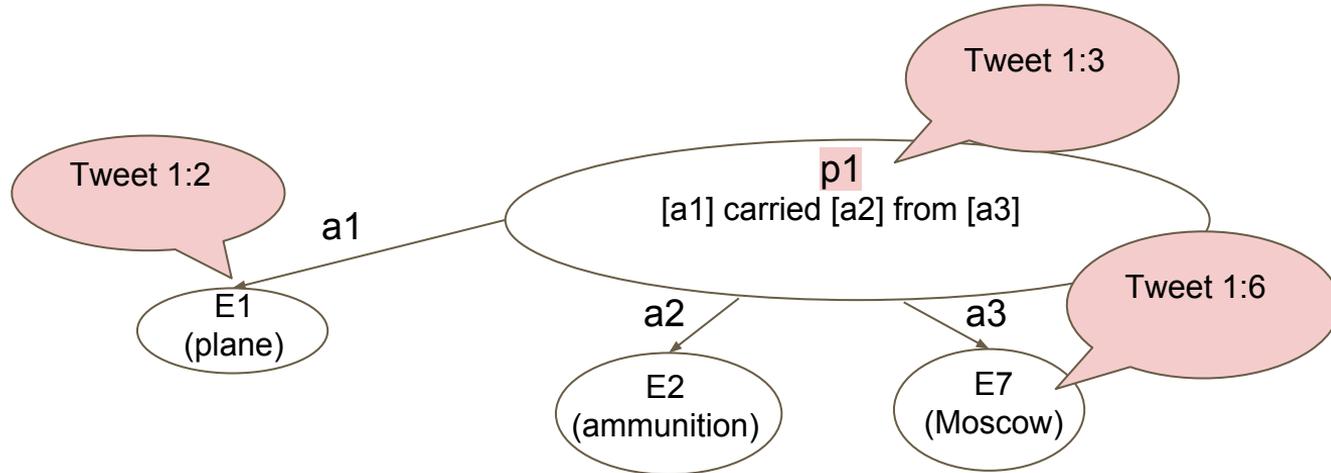
# QA-SRL based argument annotation

1. Intercepted plane **carried** ammunition from Moscow.
2. Syrian jet grounded by TURkey was carrying munitions from Russia to Syria.



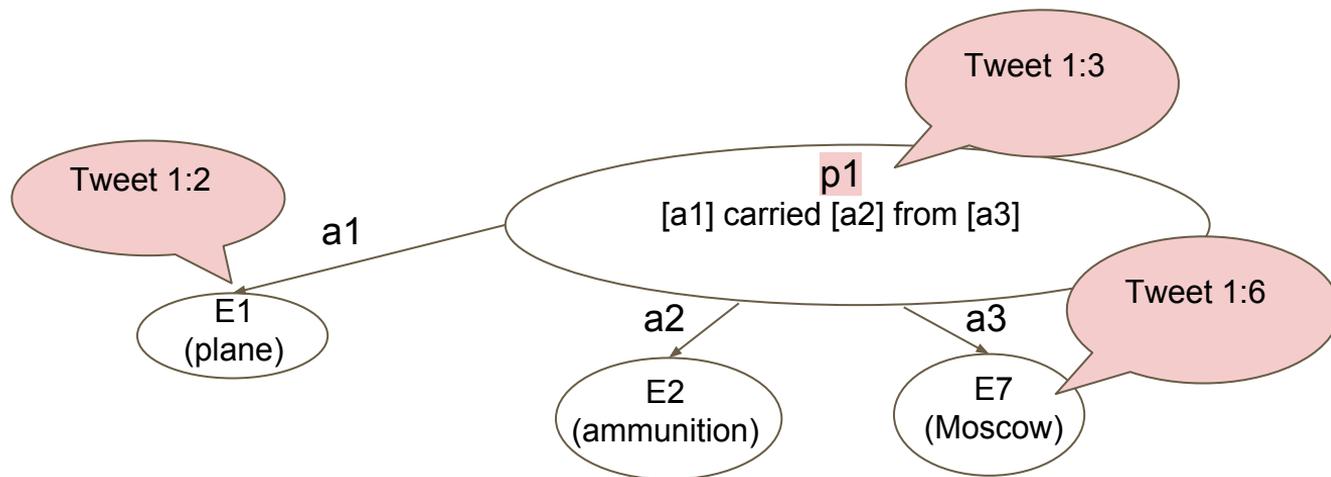
# Keep track of support

1. Intercepted plane **carried** ammunition from Moscow.
2. Syrian jet grounded by Turkey was carrying munitions from Russia to Syria.



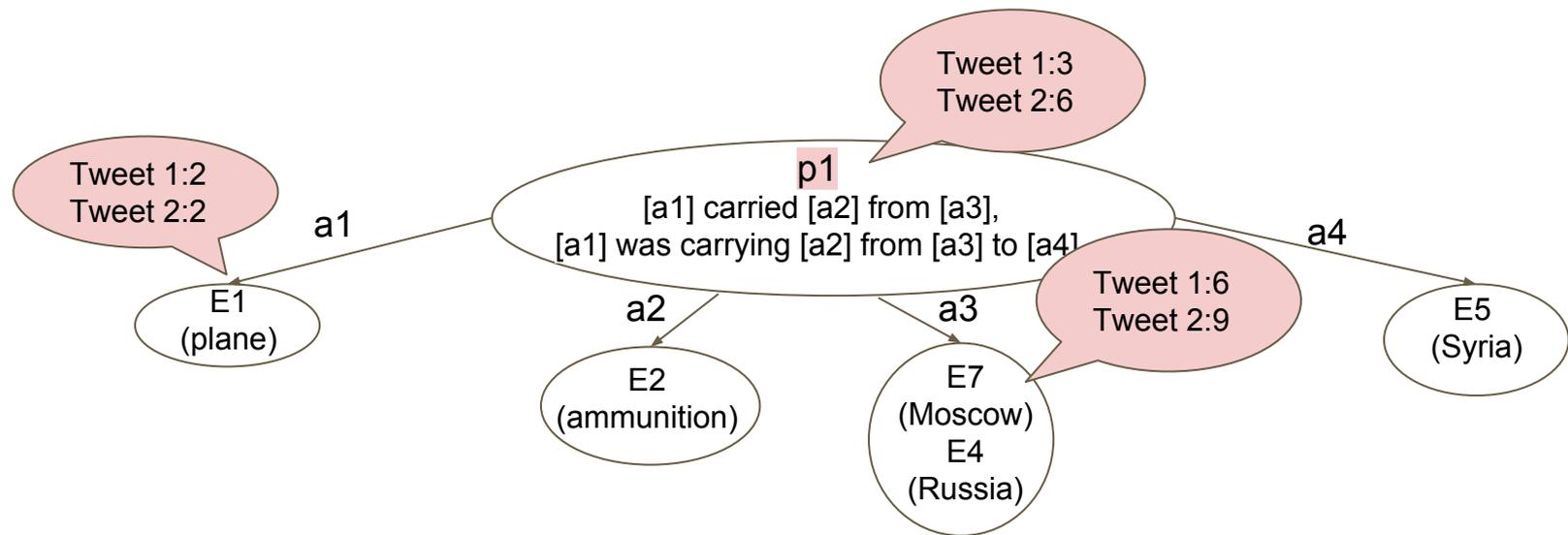
# Merge complimentary info

1. Intercepted plane **carried** ammunition from Moscow.
2. Syrian jet grounded by Turkey **was carrying** munitions **from** Russia **to** Syria.



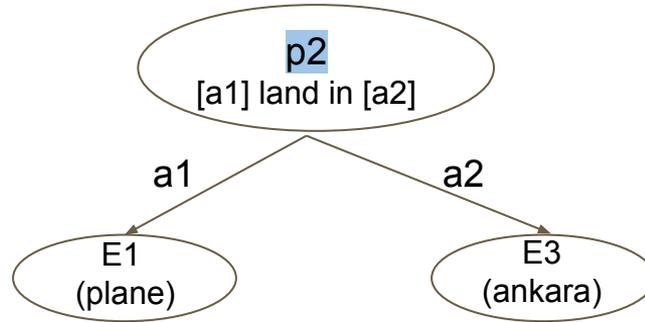
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1. Intercepted plane **carried** ammunition from Moscow.
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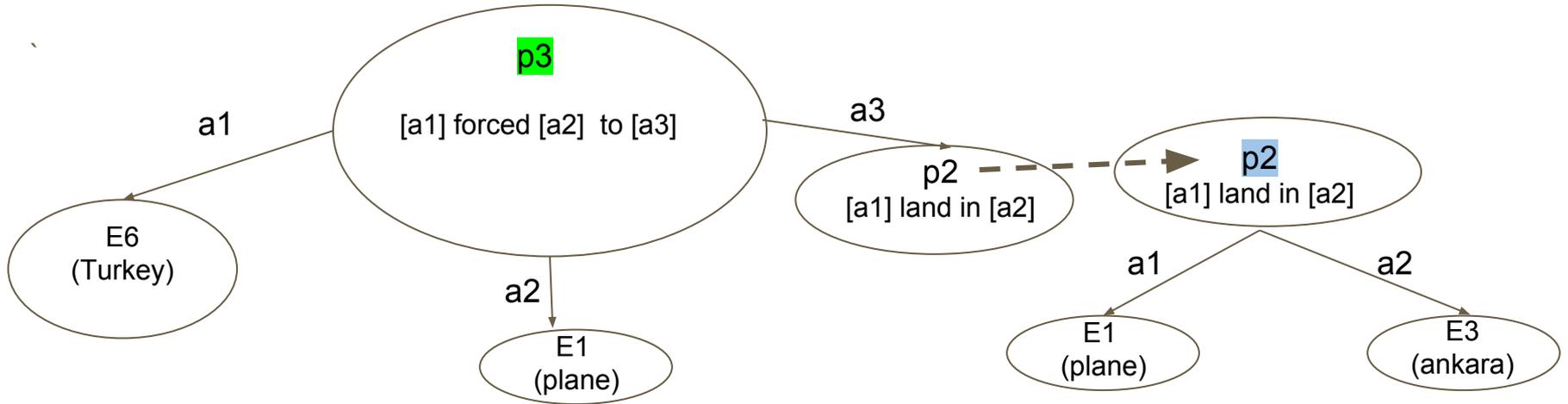
# Embedded propositions

Turkey uses military to force a plane from Russia to land in Ankara.



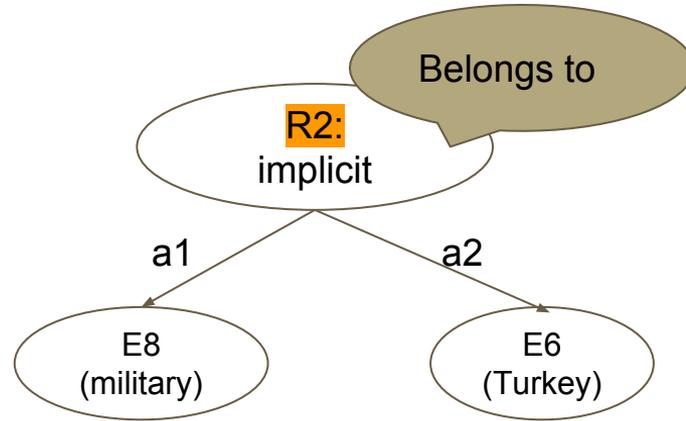
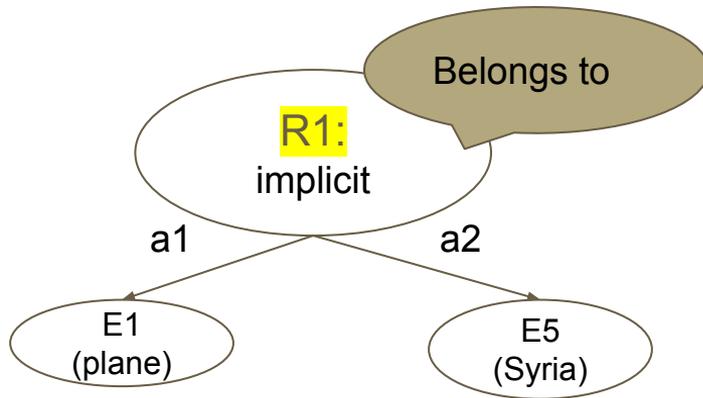
# Embedded propositions

Turkey uses military to force a plane from Russia to land in Ankara.



# Implicit propositions

Syrian jet grounded by the Turkish military was carrying munitions from Russia to Syria.



# Entailment

- Textual Entailment (between propositions):

*Proposition A entails proposition B if a human reading A would infer that B is true.*

- In our graph, we encode entailment between terms or predicate templates :

*Term/predicate entailment holds iff textual entailment holds when substituting one phrase for the other **within the given contexts** in the graph.*

- jet  $\Rightarrow$  plane
  - “Jet landed in Ankara”  $\Rightarrow$  “plane landed in Ankara”
  - “Jet carried ammunition”  $\Rightarrow$  “plane carried ammunition”
  - ...
- A1 grounded A2  $\Rightarrow$  A1 intercept A2
  - “Turkey grounded plane”  $\Rightarrow$  “Turkey intercepts plane”
  - ...

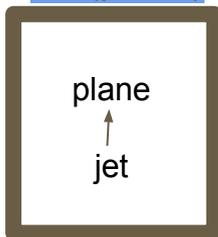
# Entailment graph for entity terms

Intercepted plane carried ammunition to Moscow.

Syrian jet grounded by the Turkish military was carrying munitions from Russia to Syria.

Turkey uses military to force a plane from Russia to land in Ankara.

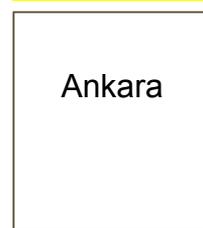
E1 (plane)



E2 (ammunition)



E3 (Ankara)

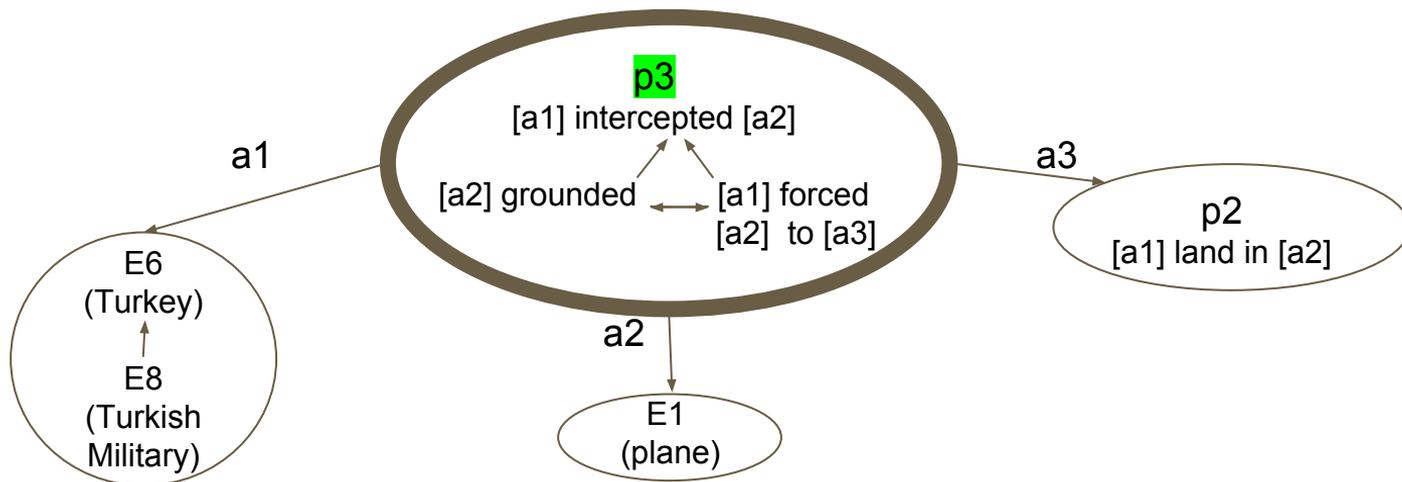


# Entailment for predicate templates

**Intercepted plane** carried ammunition to Moscow.

Syrian **jet grounded by** the Turkish **military** was carrying munitions from Russia to Syria.

**Turkey** uses military to **force a plane** from Russia **to land** in Ankara.

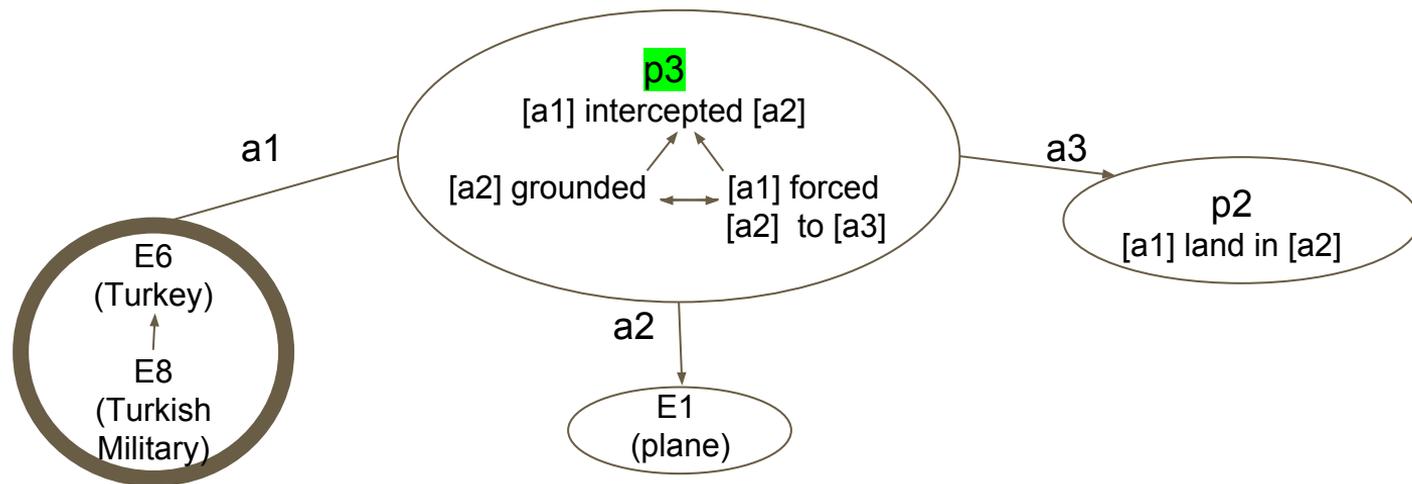


# Entailment between entities in argument

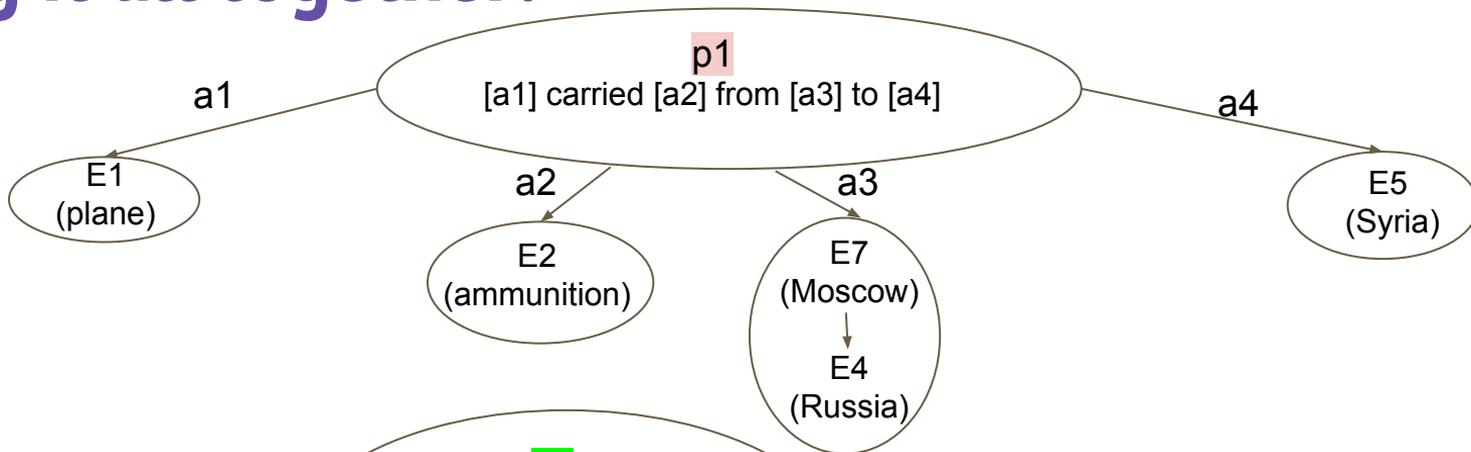
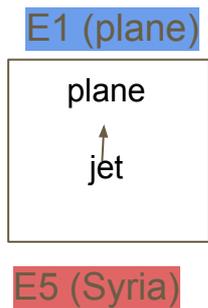
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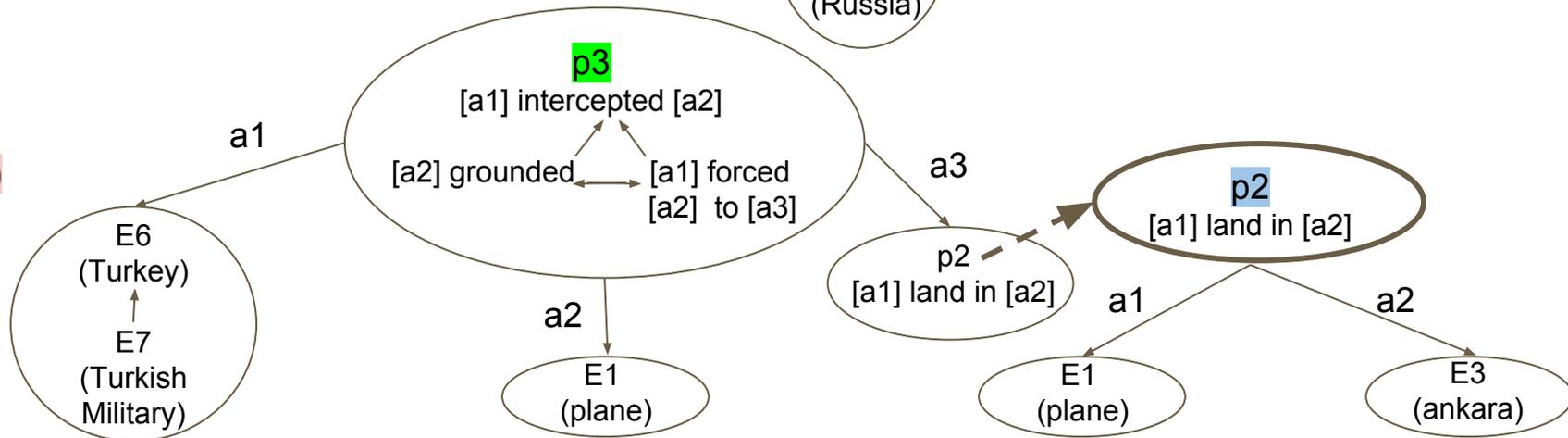
**Turkey** uses military to **force a plane** from Russia **to land** in Ankara.



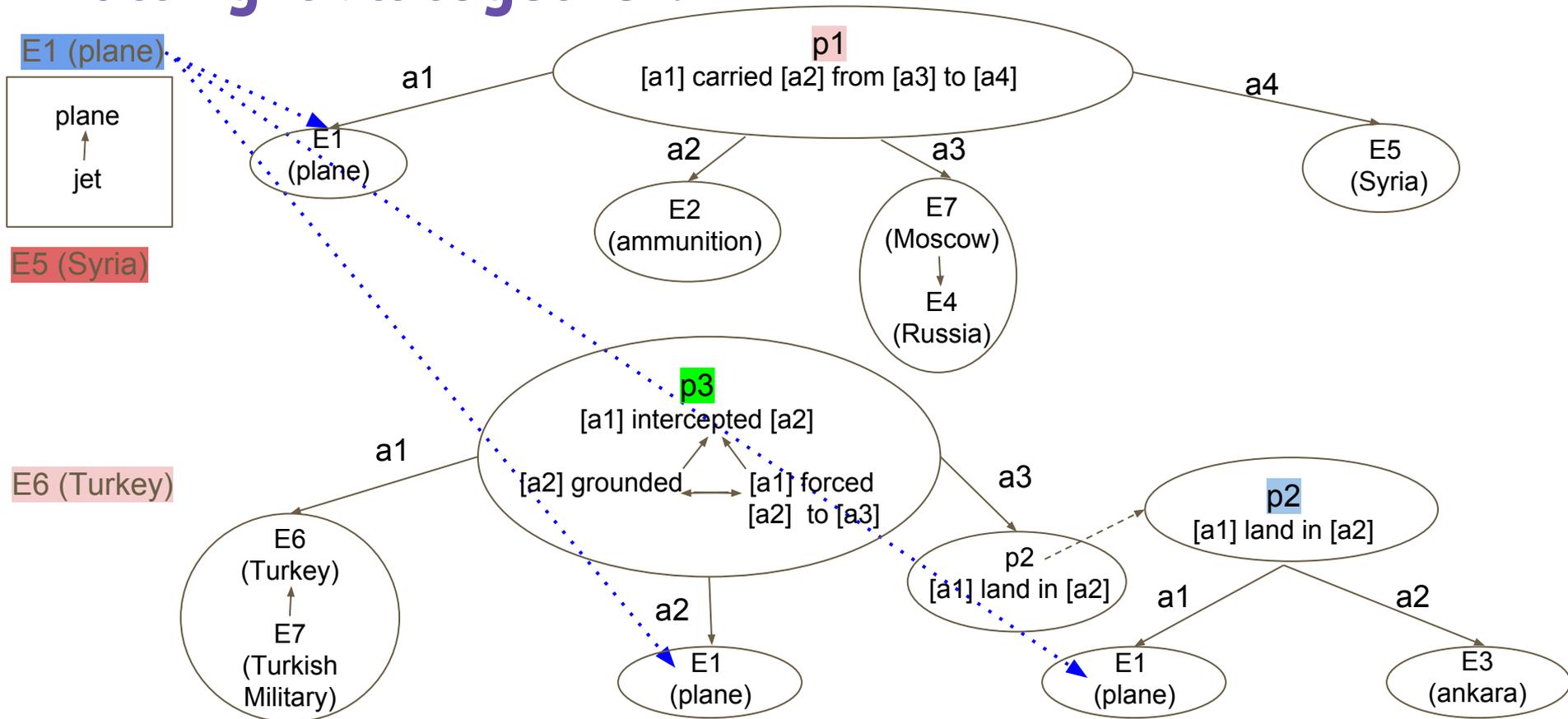
# Putting it all together:



**E6 (Turkey)**



# Putting it all together:



# Summary: building on (mostly) known tasks

1. Extracting extended **predicate-argument structures**
  2. **Coreference chains** for entities and predicates
  3. **Merging** co-referring propositions
  4. **Entailment graphs** for entities/arguments/predicates
- ⇒ *Can be seen as a **cross-text semantic representation** -  
extending Open-IE / QA-SRL to the cross-text level*

# Fulfilling the Requirements

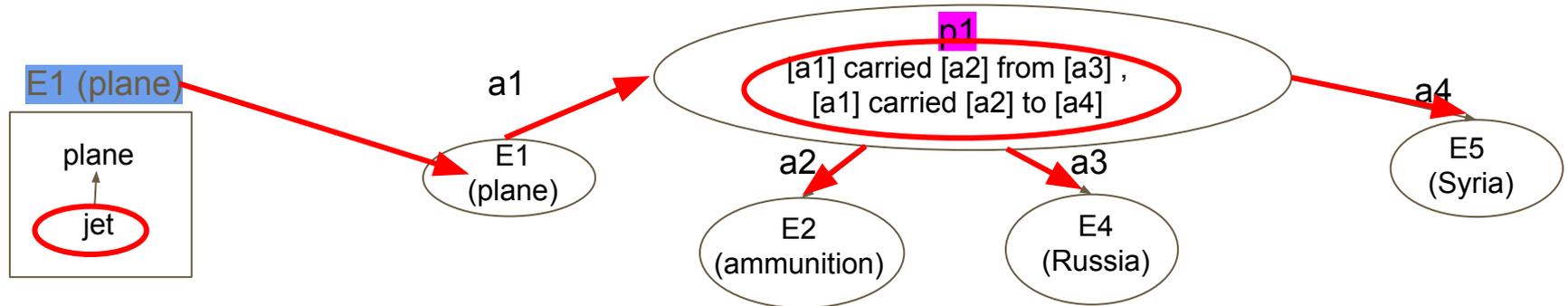
# Fulfilling requirements - merging

Original propositions:

1. Plane carried ammunition from Russia
2. Jet carried ammunition to Syria

Generated propositions:

- ❖ Plane carried ammunition from Russia
- ❖ Jet carried ammunition to Syria
- ❖ Plane carried ammunition to Syria
- ❖ Jet carried ammunition from Russia
- ❖ Jet carried ammunition from Russia to Syria



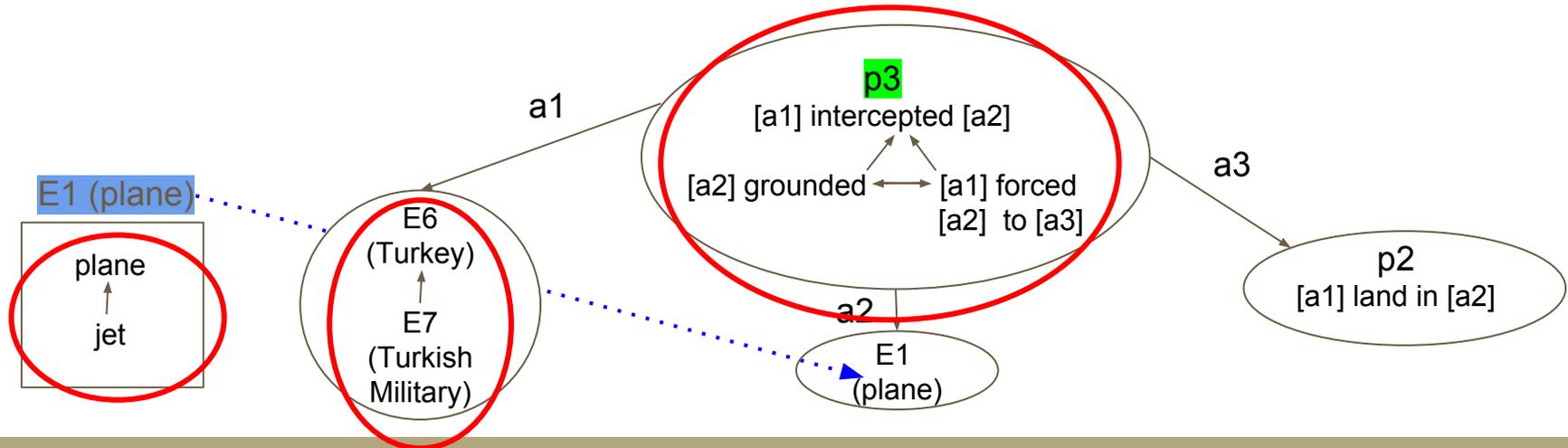
# Fulfilling requirements - modeling redundancy

Generated sentences:

1. Turkish military forces jet to land
2. Plane intercepted by Turkey

Entailments:

- ❖ plane  $\Rightarrow$  jet
  - ❖ Turkish military  $\Rightarrow$  Turkey
  - ❖ Forces to land  $\Rightarrow$  intercepted
- >> ***Turkish military forces jet to land  $\Rightarrow$  Plane intercepted by Turkey***



# Tracing Supporting Mentions - Illustration

Event Summary

Click to expand:

Turkey intercepted a Syrian plane in Ankara

Turkey military  
Anti-aircraft unit — Turkish F-16s

The plane carried ammunition from Russia to Syria

Turkey Escalates Confrontation with Syria

Russia angry at Turkey



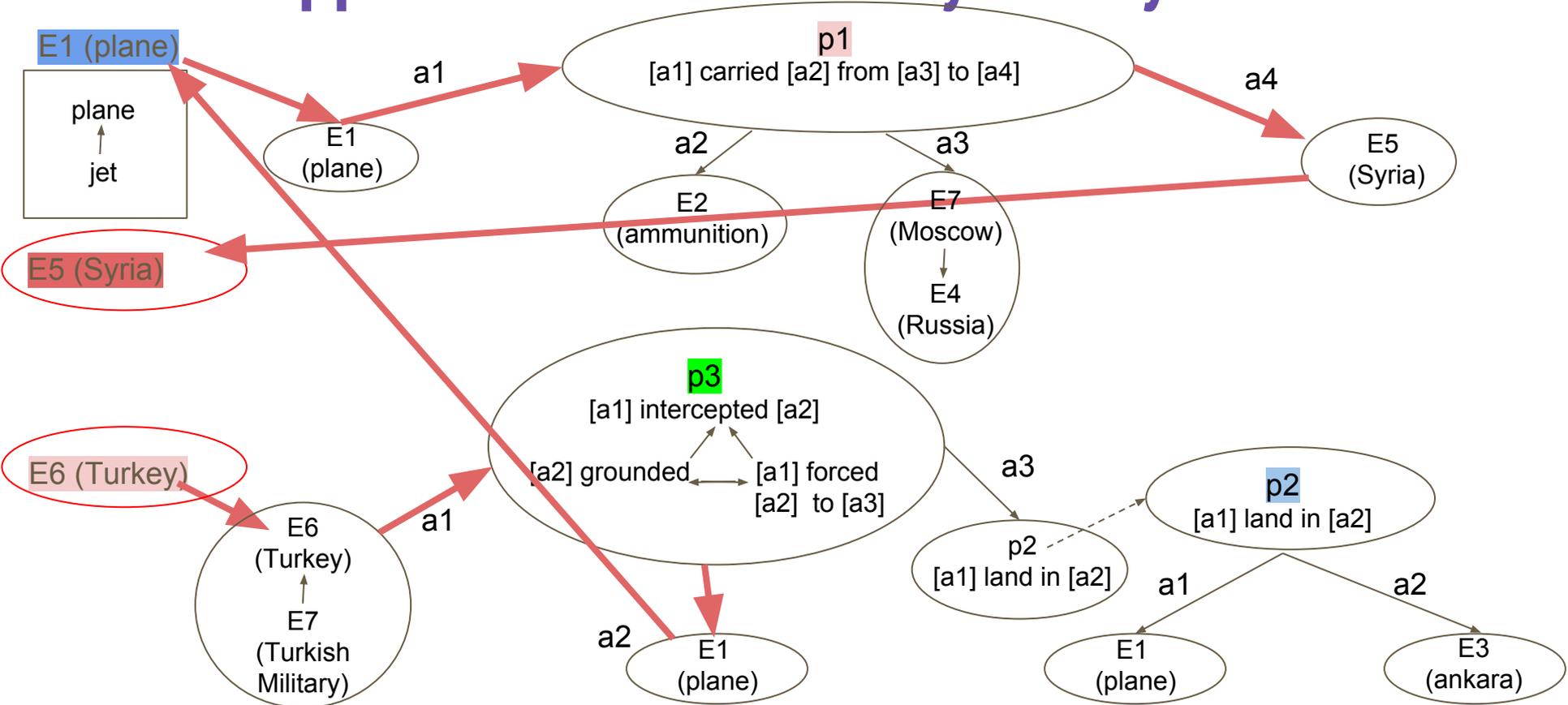
# Potential Applications - Content Presentation

- **Interactive text exploration** - “What is said here?”
  - Dynamic - salience, detail level, length
    - *F-16 vs. Turkish army vs. Turkey*
  - Hierarchical
  - Incremental
  - Bullet style vs. continuous text
- Improving abstractive multi-document summarization

# Potential Applications - Querying

- Querying applications
  - Complex questions, requiring aggregated information from multiple texts
  - E.g.: *Grounding Syrian planes*
- Combining queries and content presentation: show all information about
  - An entity
  - Relations between entities

# What happened between Turkey and Syria?



# Graphical Tools

# Manual Annotation Tool - Entities & Propositions

Tweets Annotation Tool 3.1 - C:\Users\ido.ido-THINK\Documents\Rachel Wities\MLKG\Fuel\_tank\_vered.xml

Done Cancel Choose tokens and Right click

Sentence 1 of 32 (ID: 1) Fuel\_tank\_explosion\_event\_short\_tokenized.txt

Current Sentence Annotation

P0: containing [a2: e0: gas] [a1: e1: tanker]  
P1: [a1: e6: around 14 ppl] killed P2: [a1: e5: more than 60] injured  
P3: [a1: e2: National Guard Bridge] in [a2: e3: Riyadh]  
P4: [a1: e1: tanker] exploded [a2: e2: National Guard Bridge] e0: gas  
e1: tanker e2: National Guard Bridge e3: Riyadh e5: more than 60  
e6: around 14 ppl

A gas tanker exploded under the National Guard Bridge in Riyadh -  
around 14 ppl killed , and more than 60 injured

Proposition

P0: containing  
1: What contains something?  
2: What does something contain?  
(25)

P1: killed  
1: Who was killed?  
2: How was someone killed?  
3: Where was someone killed?  
4: When was someone killed?  
(26)

P2: injured  
1: Who was injured?  
2: How was someone injured?  
3: Where was someone injured?  
4: When was someone injured?  
(6)

P3: located in  
1: What is located somewhere?  
2: Where is somewhere located?  
(1)

P4: exploded  
1: What exploded?  
2: Where did something explode?  
4: When did something explode?

P9: hospitalized  
1: Who is hospitalized?  
2: Where is someone hospitalized?  
(1)

Entity

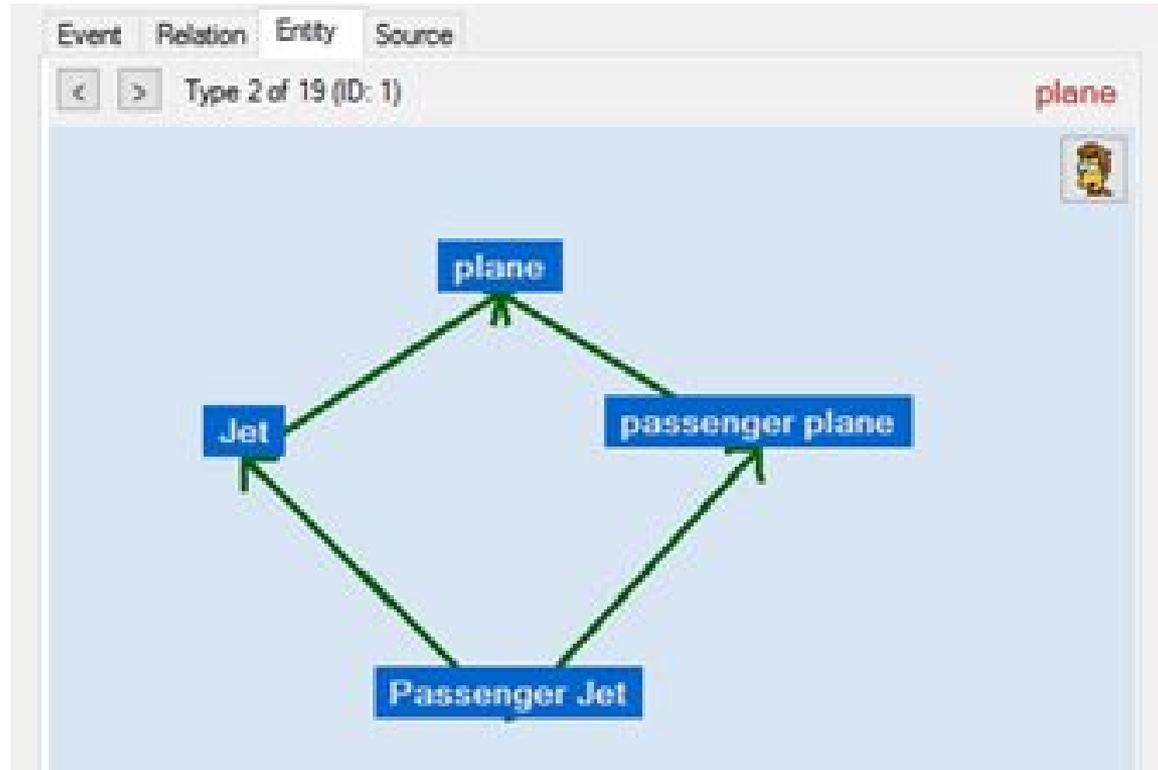
e0: gas (26) e1: tanker (28) e2: National Guard Bridge (1) e3: Riyadh (25)  
e5: more than 60 (1) e6: around 14 ppl (4) e7: At least 23 (3) e8: Saudi Arabia (12)  
e9: at least 22 (12) e10: World (3) e11: The Star Online (1)  
e12: PH Embassy in Saudi (1) e13: 1 Filipino (1) e14: 9 (1) e15: hospitals (1)  
e16: 3 (1) e17: Reuters (1) e18: Building (3) e19: 10 (2) e20: Damamm (1)  
e21: Egypt (1) e22: Jan25 (3) e23: -Saudi State TV (1) e24: 111 (1)  
e25: BBC News (1) e26: UAE President (1) e27: King Abdullah (1)

Source

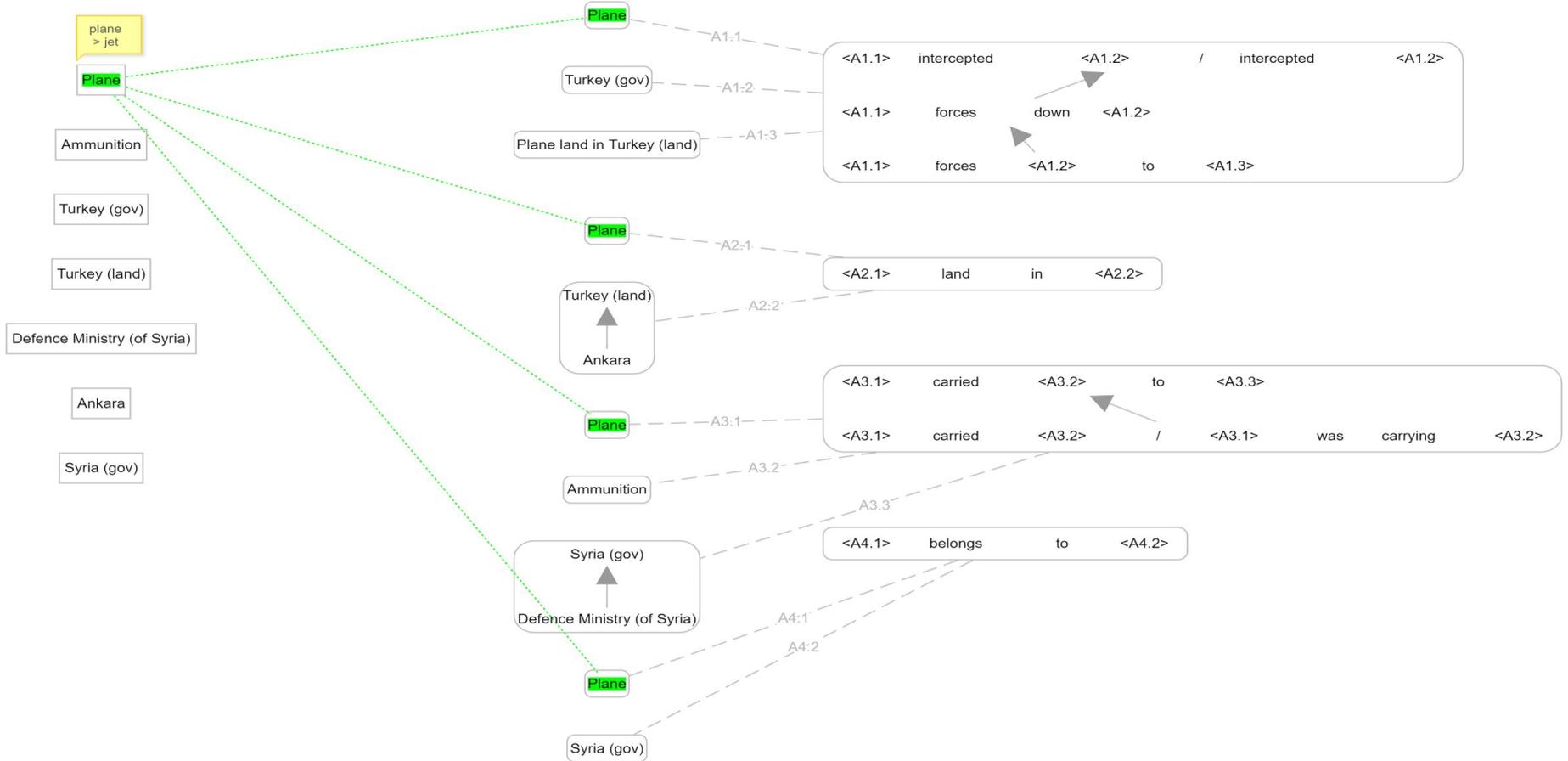
S0: World (2) S1: The Star Online (2)  
S2: PH Embassy in Saudi (1)  
S3: Reuters (1) S4: Saudi Arabia (1)  
S5: Egypt (1) S6: -Saudi State TV (1)  
S7: BBC News (1) S8: The Hindu (1)  
S9: Yahoo News (1)  
S10: khawadd news (1)

Don't forget to save. (Ctrl-S) Ctrl-R to refresh types 02:38:45

# Manual Annotation Tool - Entailments



# Interactive Visualization



# Future Enhancements & Conclusion

# Lots of things to add

- Contradiction & factuality (partly in 1st version)
- Modeling sub-events - partial argument alignment
  - *ISIS attacks Syria, 5 killed* - shared agent for attacking and killing
- Non-verbatim lexical inference
  - For generalization - in presentation and in queries
  - E.g. *Russia **criticized** the grounding, Which **countries** criticized the grounding?*
- Inter-proposition relations
  - Causal, temporal, ...
- Tying to general knowledge bases
- ...

# Conclusion

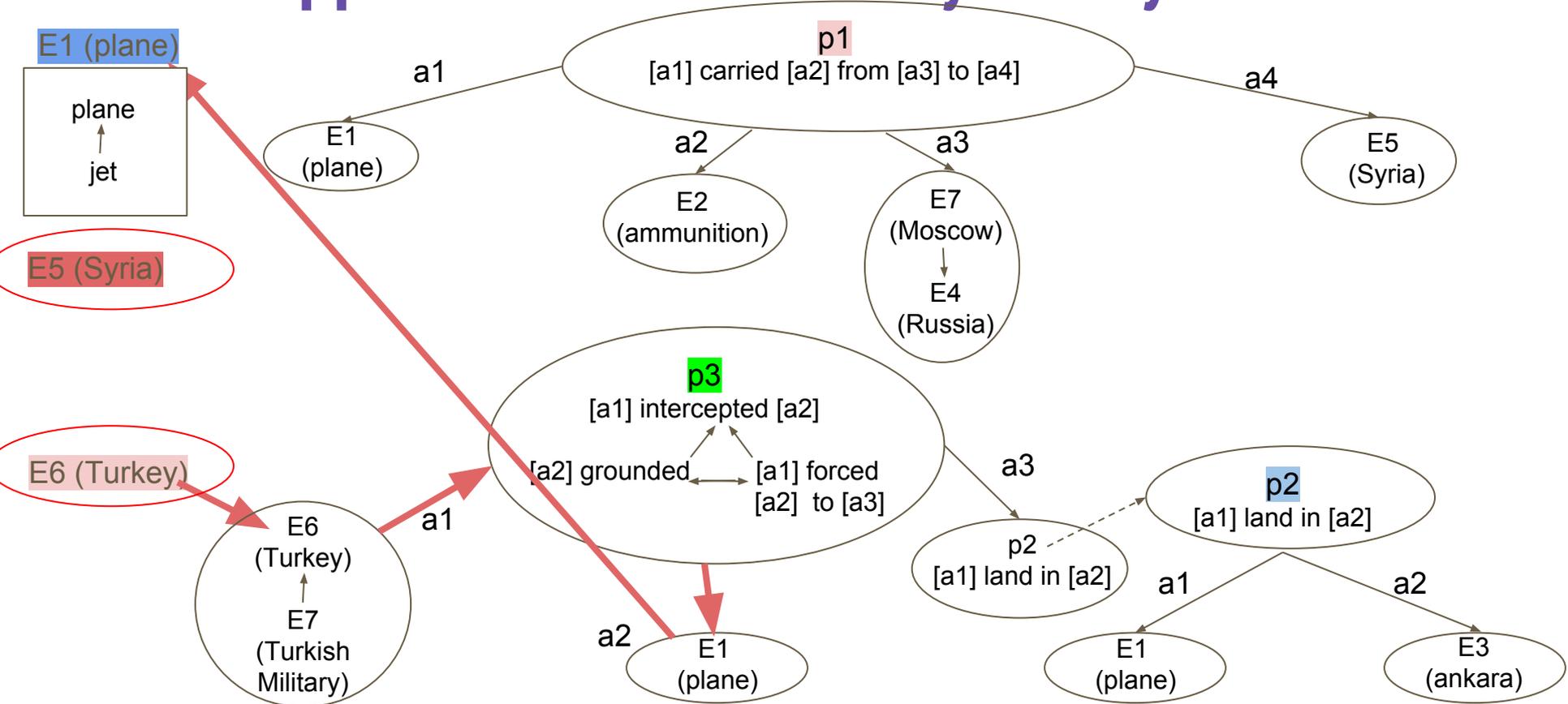
- A consolidated representation of propositions across texts
- Modeling:
  - Coreference-based inference (merging)
  - Information redundancy/overlap via textual entailment
- Yielding a cross-text extension of Open-IE / QA-SRL representations
- Driving application - interactive text exploration
- Potential for semantic applications over aggregated content
- Lots of ways to go...      ***thank you!***

# References

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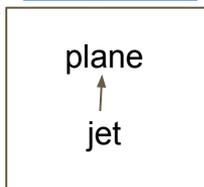
# Unused slides

# What happened between Turkey and Syria?

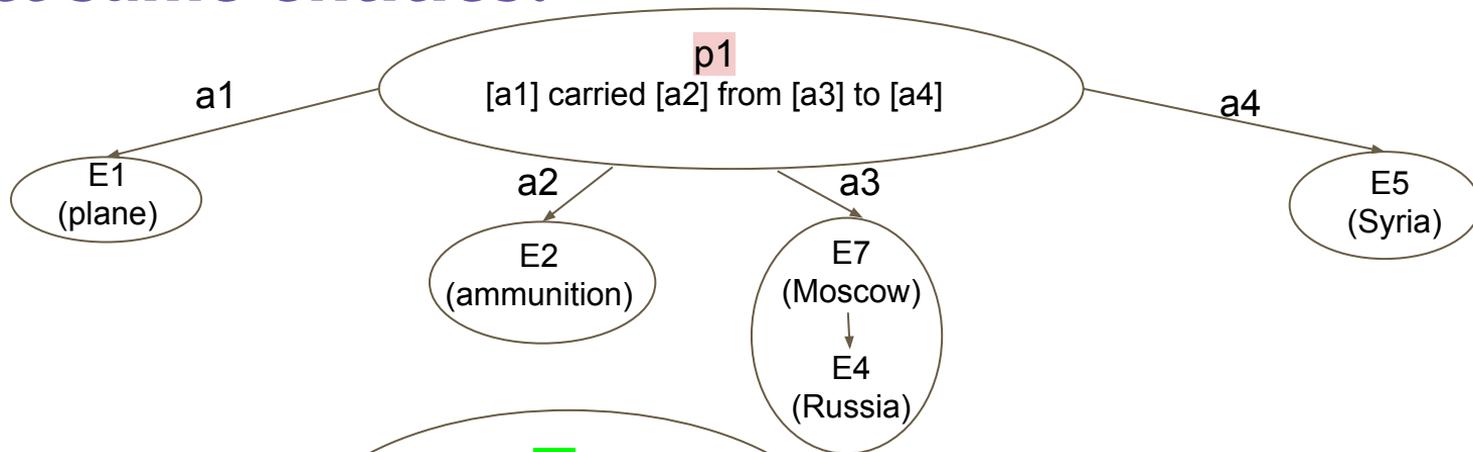


# Connect same entities:

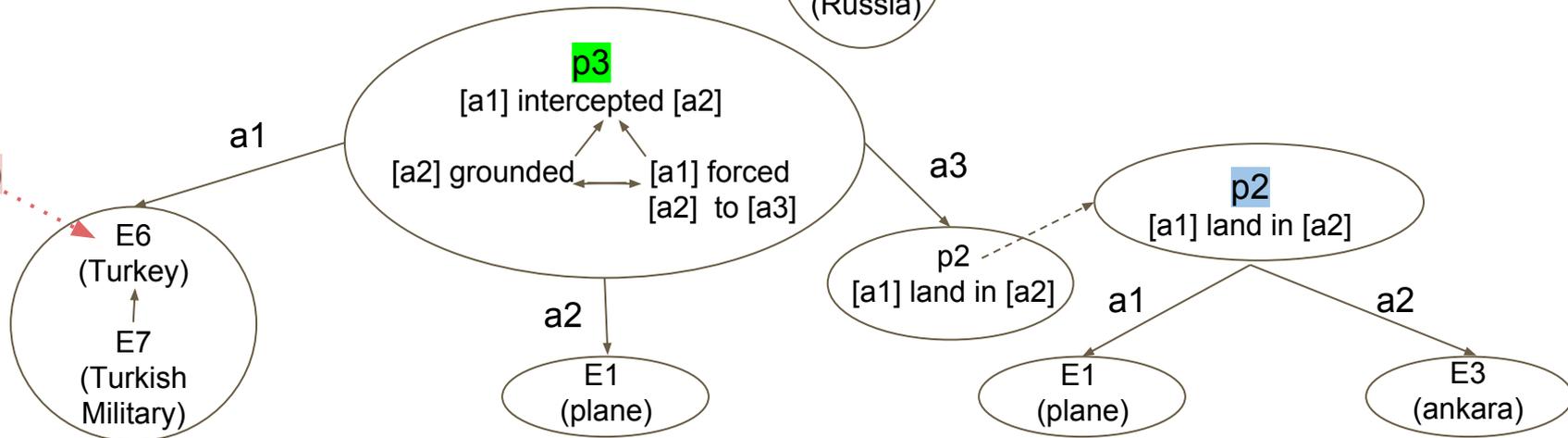
E1 (plane)



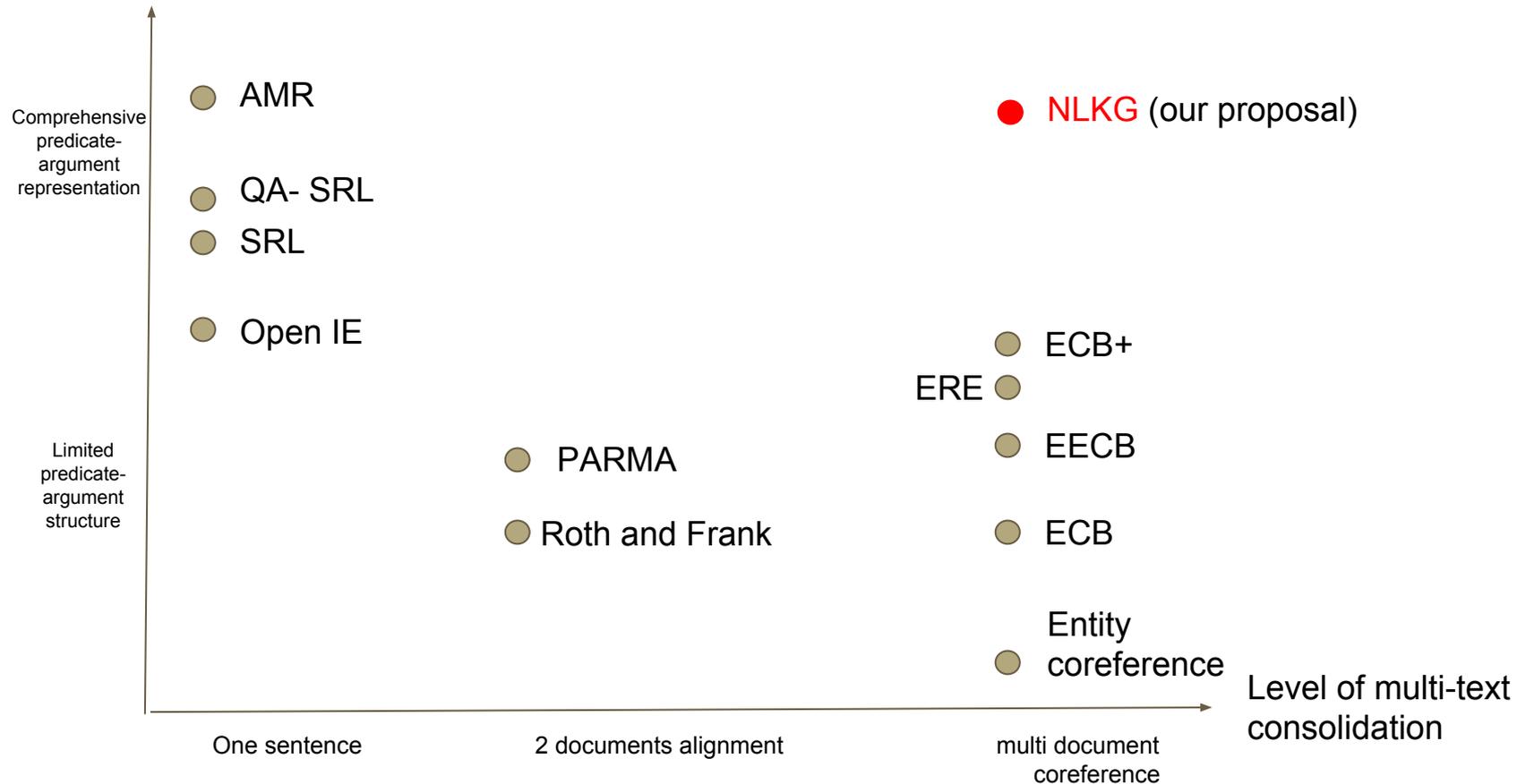
E5 (Syria)



E6 (Turkey)



# Expressiveness of semantic structure



# Takeout: Characteristics of Textual Information

- Identifying and modeling **redundancy**
  - Plane to Syria  $\Leftrightarrow$  Syria-bound plane
  - forced plane to land  $\Rightarrow$  intercepted plane
  - jet  $\Rightarrow$  plane
- Merging **complementary scattered info** about the same the same entity or event
  - “Turkey forced a jet from Russia to land”  
“Turkish military intercepted a Syria-bound plane”  
 $\Rightarrow$  “Turkish military forced a Syria-bound jet from Russia to land”

# ~~ Multi-document Summarization

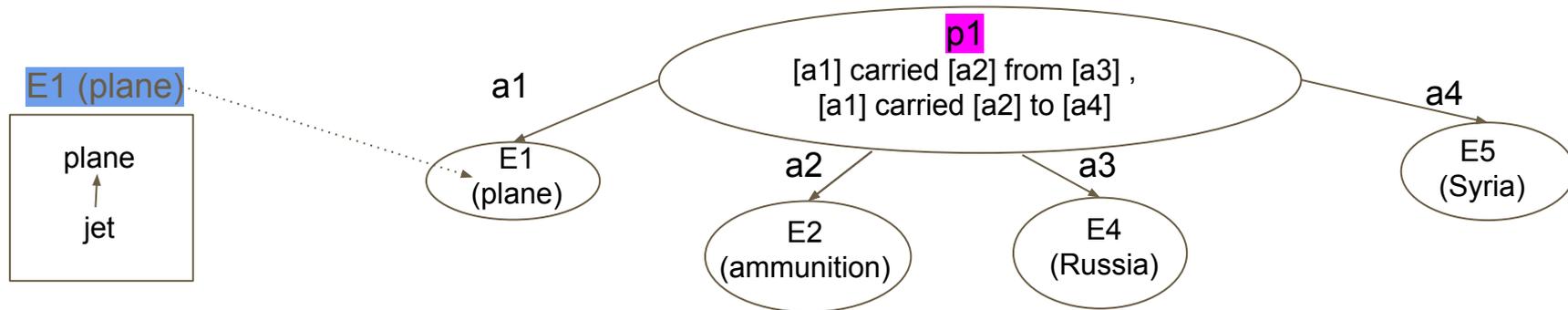
- Focusing only on salient sentences
- Identifying redundant sentences
  - Typically selecting one representative sentence
- Abstractive summarization
  - Aims to merge some parts of different sentences - hasn't matured
- Heuristic - Vs. systematic semantic representations

# Fulfilling requirements - merging

Original sentences:

1. Plane carried ammunition from Russia
2. Jet carried ammunition to Syria

Generated sentences:



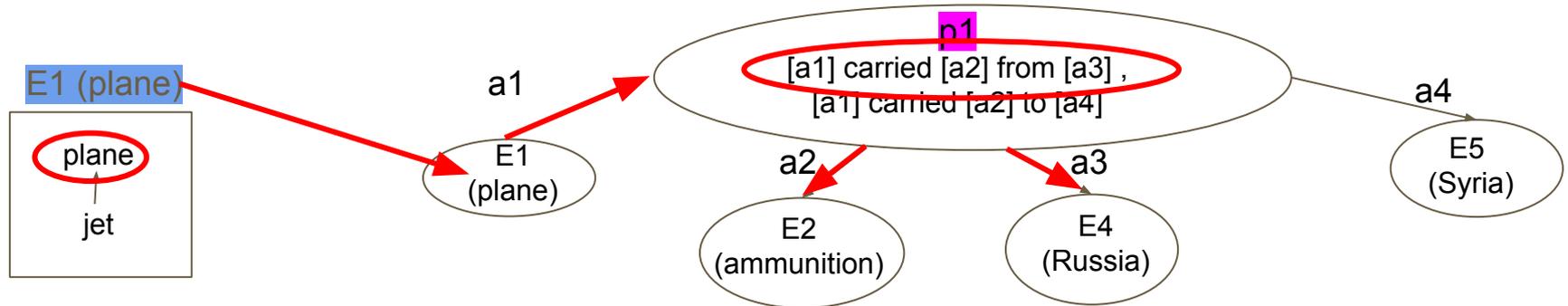
# Fulfilling requirements - merging

Original sentences:

1. Plane carried ammunition from Russia
2. Jet carried ammunition to Syria

Generated sentences:

- ❖ Plane carried ammunition from Russia



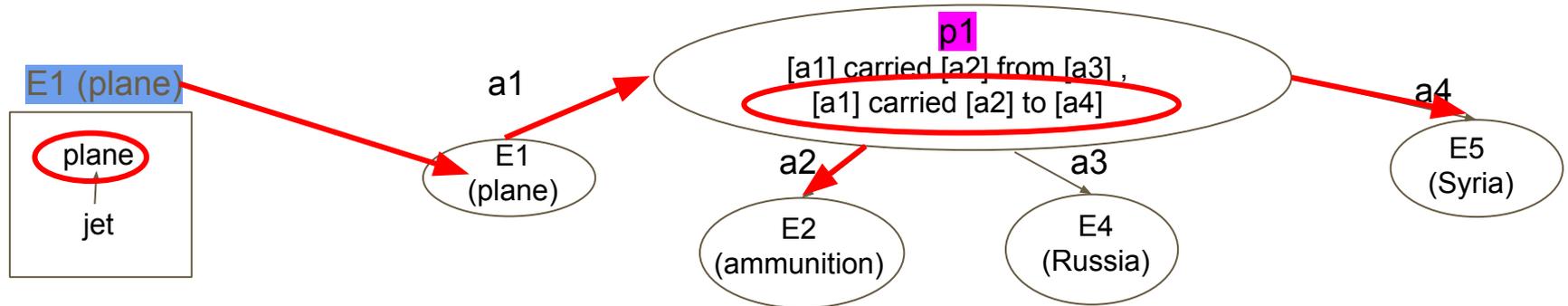
# Fulfilling requirements - merging

Original sentences:

1. Plane carried ammunition from Russia
2. Jet carried ammunition to Syria

Generated sentences:

- ❖ Plane carried ammunition from Russia
- ❖ Jet carried ammunition to Syria
- ❖ Plane carried ammunition to Syria



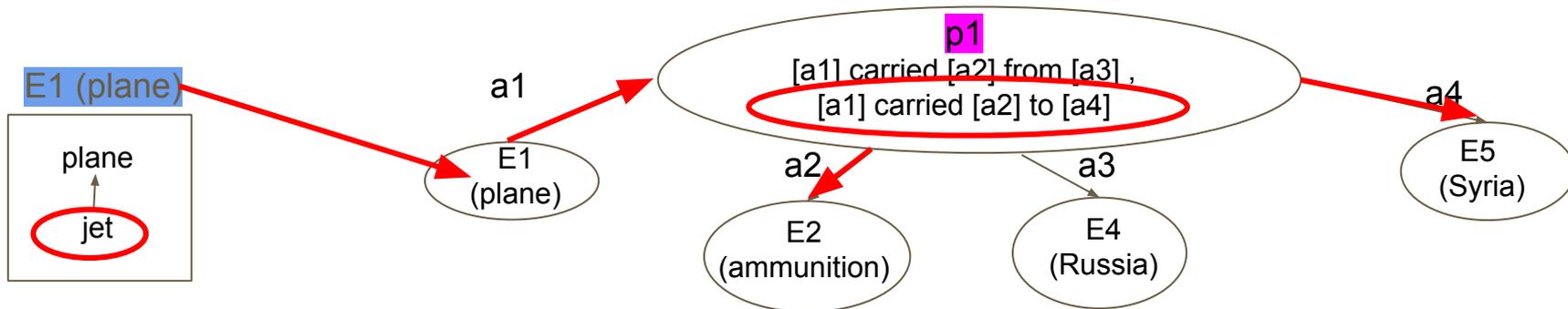
# Fulfilling requirements - merging

Original sentences:

1. Plane carried ammunition from Russia
2. Jet carried ammunition to Syria

Generated sentences:

- ❖ Plane carried ammunition from Russia
- ❖ Jet carried ammunition to Syria



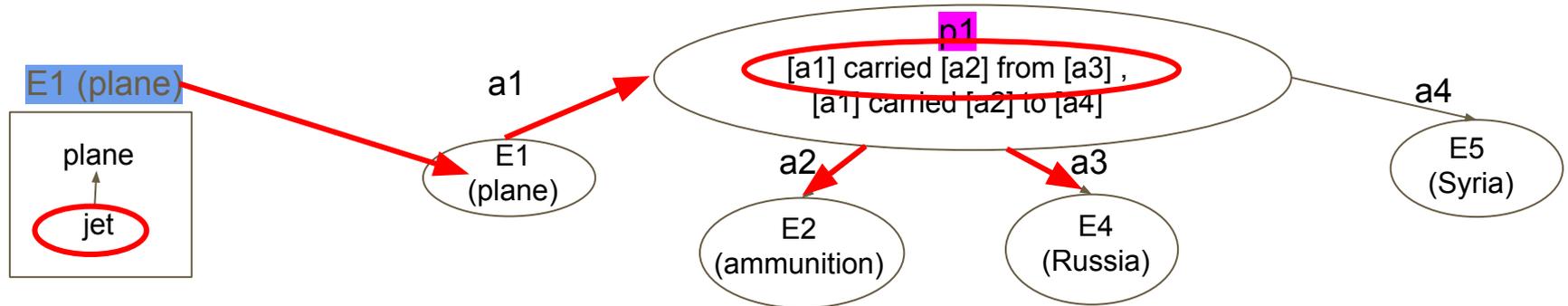
# Fulfilling requirements - merging

Original sentences:

1. Plane carried ammunition from Russia
2. Jet carried ammunition to Syria

Generated sentences:

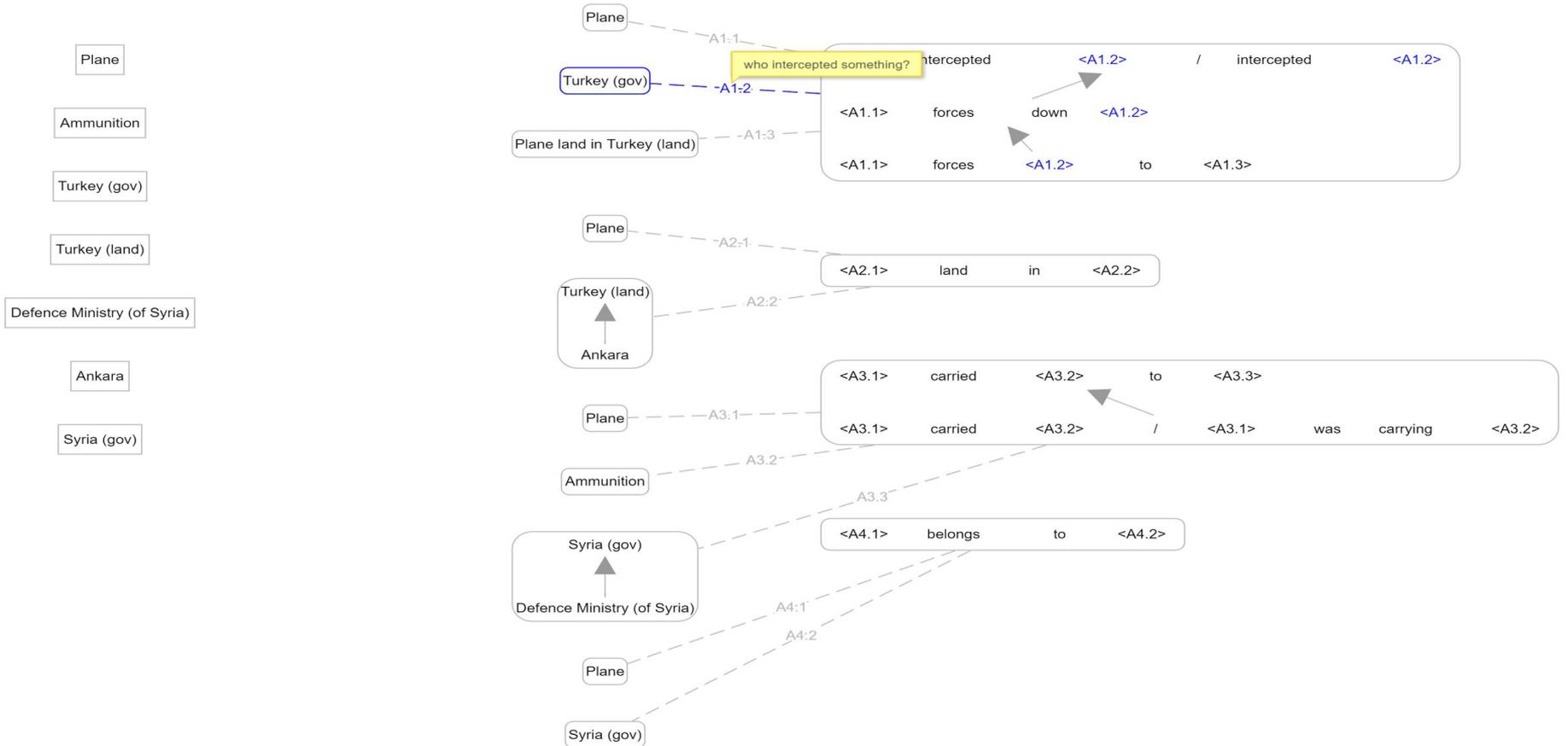
- ❖ Plane carried ammunition from Russia
- ❖ Jet carried ammunition to Syria
- ❖ Plane carried ammunition to Syria
- ❖ Jet carried ammunition from Russia



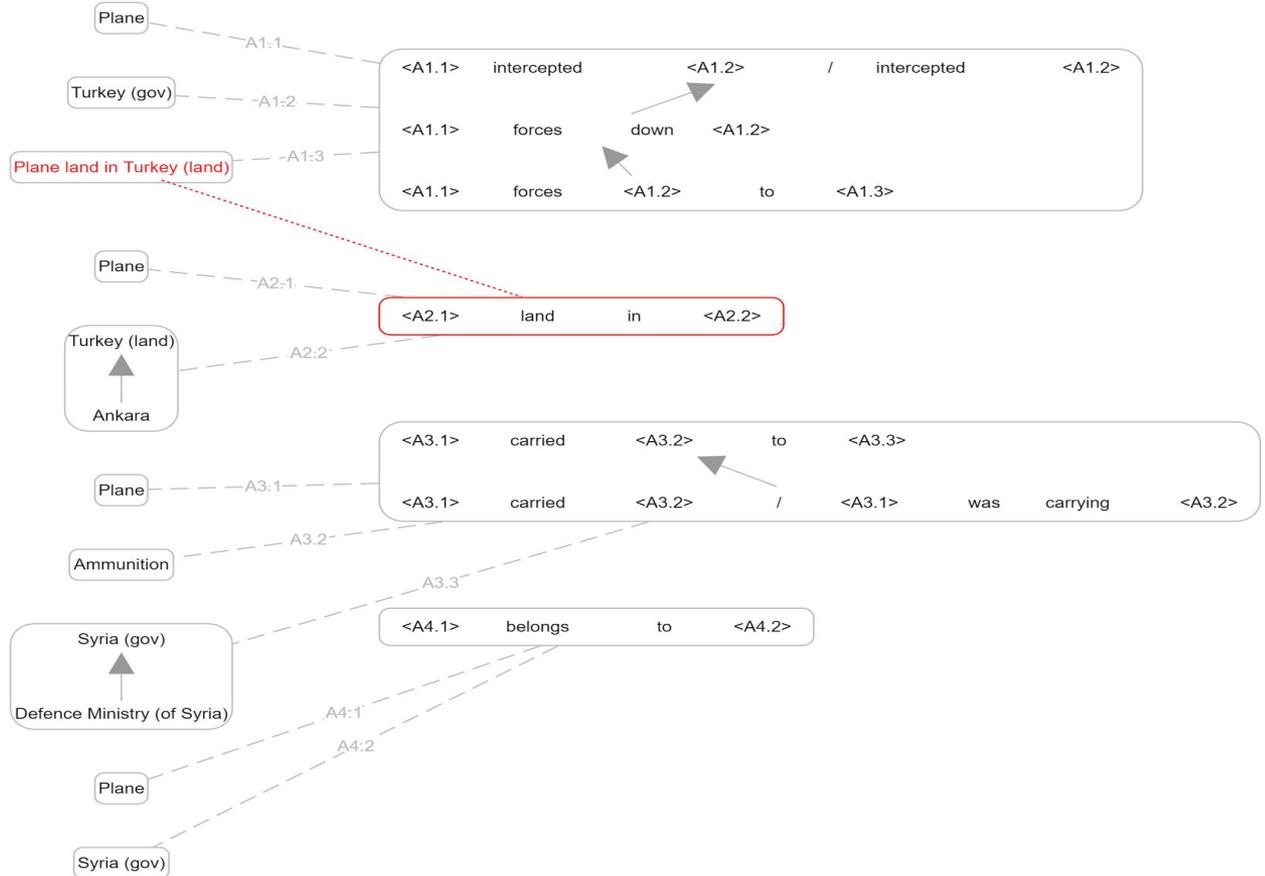
# Fulfilling requirements - Supporting Mentions

- Support Tracking & Frequency
  - Salience
    - “Turkey attacks Syria” vs “Turkish PM did not apologize”
  - Certainty
    - Frequently mentioned facts are more likely to be true.

# Interactive Visualization



# Interactive Visualization



Plane

Ammunition

Turkey (gov)

Turkey (land)

Defence Ministry (of Syria)

Ankara

Syria (gov)