行为意图识别/规划识别

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心智盲.

Inferring Others and Mindblindness

- *Mindblindness* (in humans): Being blind to others' minds
  - *Not representing and reasoning about other*
  - A specialized module in the brain doing modeling of others
  - Develop when we are *3-4* years old
  - Experiments can reveal dramatic shifts in behavior in children pre- and post- development of this module in the brain

- Presented as an explanation to *autism*
  - They have mindblindess 认知障碍.
  - Findings by Simon Baron-Cohen and others

Agent Modeling: Example Environments

- Battlefield and training simulations, virtual environments
- Multi-agent robotics, robotic soccer, future space missions
- Integrated distributed applications, intelligent user interfaces

Intention/Plan Recognition (IR)

- Wide applications in many fields:
  - Natural language understanding
  - Multi-agent interactive systems
  - User modeling & user-adaptive interface
  - Intrusion detection
  - Security informatics
  - Human computer/robot team
  - Pervasive smart environments
  - Game AI …… ……

Imagine that you are watching a soccer game….

角度问题（用自己认为的模型）

(Modeling from *multiple* perspectives)

- As a player…
  - Trying to see if a teammate needs help
  - Trying to predict if there is threat from an opponent
- As a coach…
  - Trying to assess the state of players
  - Trying to figure out strategy and tactics of opponents

是一个过程

Intention/Plan Recognition (IR):
The Key Agent Modeling Technique

- The task of inferring the *most likely* plan (or goal) from the observed behavior of the actor

  Inferring the *plans* and *goals* of the observed agent based on *a sequence of observations*, usually with the help of a set of predefined *recipes* (called *plan library*)

  先验

- Types and assumptions

  锁孔识别　最一般

  Keyhole recognition: the observed agent does not attempt to impact

  合作识别　对抗识别

  Intended recognition **vs.** *Adversarial recognition*

  Fully-observable **vs.** *Partially-observable*

（核心：消歧）

Related Research on IR

（基于 Bayesian）
贝叶斯网络

- Psychological experiment & AI [Schmidt *et al*, 1978]
- *Bayesian* reasoning [Charniak & Goldman, 1993; Huber *et al*, 1994]
- *Parsing* based approach [Pynadath *et al*, 2000; Geib & Goldman, 2009]
- *HMM* based approach [Bui *et al*, 2003]
- *Decision-theoretic* approach [Mao *et al*, 2004, 2012]
- Plan recognition as *planning* [Ramírez & Geffner, 2010; E-Martín *et al*, 2015; Sohrabi *et al*, 2016]

C. F. Schmidt, N. S. Sridharan and J. L. Goodson. The Plan Recognition Problem: An Intersection of Psychology and Artificial Intelligence. *Artificial Intelligence*, 11(1,2), 1978.

C. F. Schmidt. Understanding Human Action: Recognizing the Plans and Motives of other Persons. In: J. Carroll & J. Payne (Eds.), *Cognition and Social Behavior*. Lawrence Erlbaum Associates, 1976.

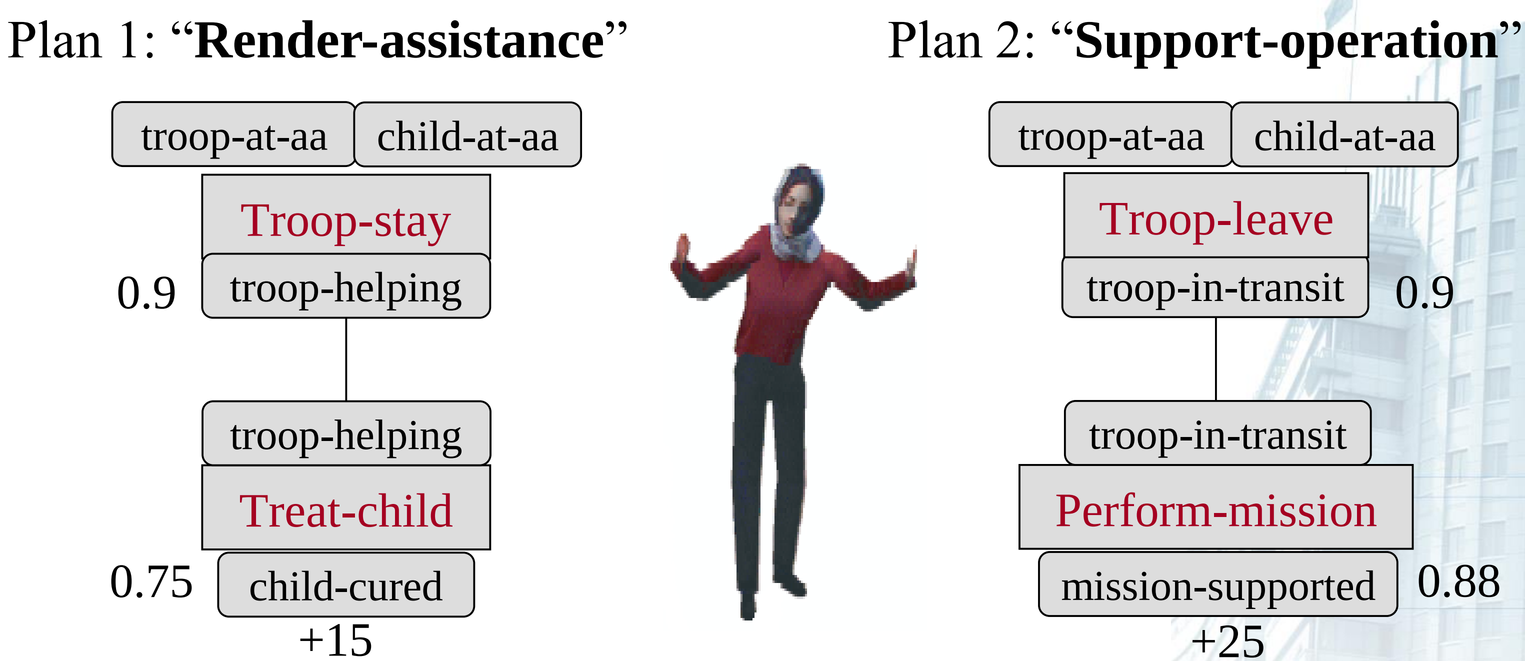
Key Challenges of IR

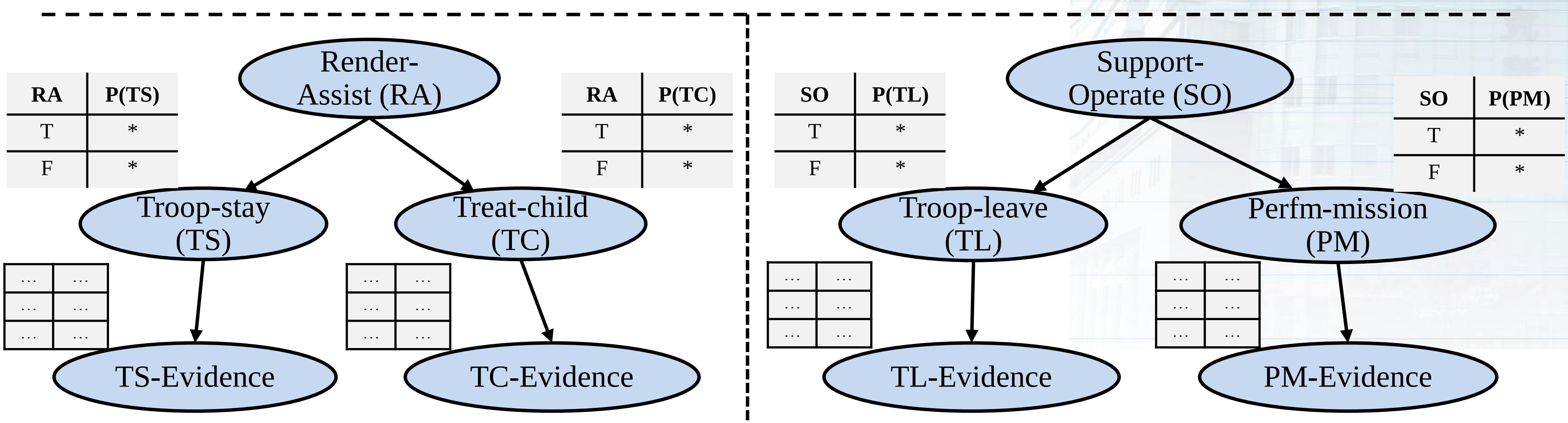
- Need criteria for ***disambiguation*** 消歧
  - Multiple plans possible to explain the observed actions
  - Problematic to maintain all possible hypotheses
- Rely on *handcrafted plan library* 依赖手工建造规划库.
- Lack of *human experimental studies*
- Other issues
  - Computational *complexity* (HMM)
  - *Flexibility* and easy to use (Bayesian)
  - Compatibility with *human intuitions*

Illustrative Example

- A human ***trainee*** was in command of a troop in peacekeeping ***operation to support*** another unit
- One of the troop's vehicles severely injured a civilian ***child (w/ mother)***
- The *trainee* must balance whether to continue mission or ***render assistance***

IR Using Bayesian Reasoning





Decision-Theoretic Approach to IR

In many real-world applications, utilities of different outcomes are clearly known. When an agent makes decisions and acts on the world, it needs to explicitly take this information into account and balance between different possible outcomes.

- View plan recognition as inferring the *decision-making strategy* of the observed agent

状态偏好

- Explicitly take the observed agent's *state preferences* into consideration

期望效用值

- Compute *Expected plan utility* as criterion for disambiguation

W. Mao, J. Gratch and X. Li. Probabilistic Plan Inference for Group Behavior Prediction. *IEEE Intelligent Systems*, 27(4):27-36, July/August, 2012.

Decision Theory / Expected Utility Theory

- Decision Theory

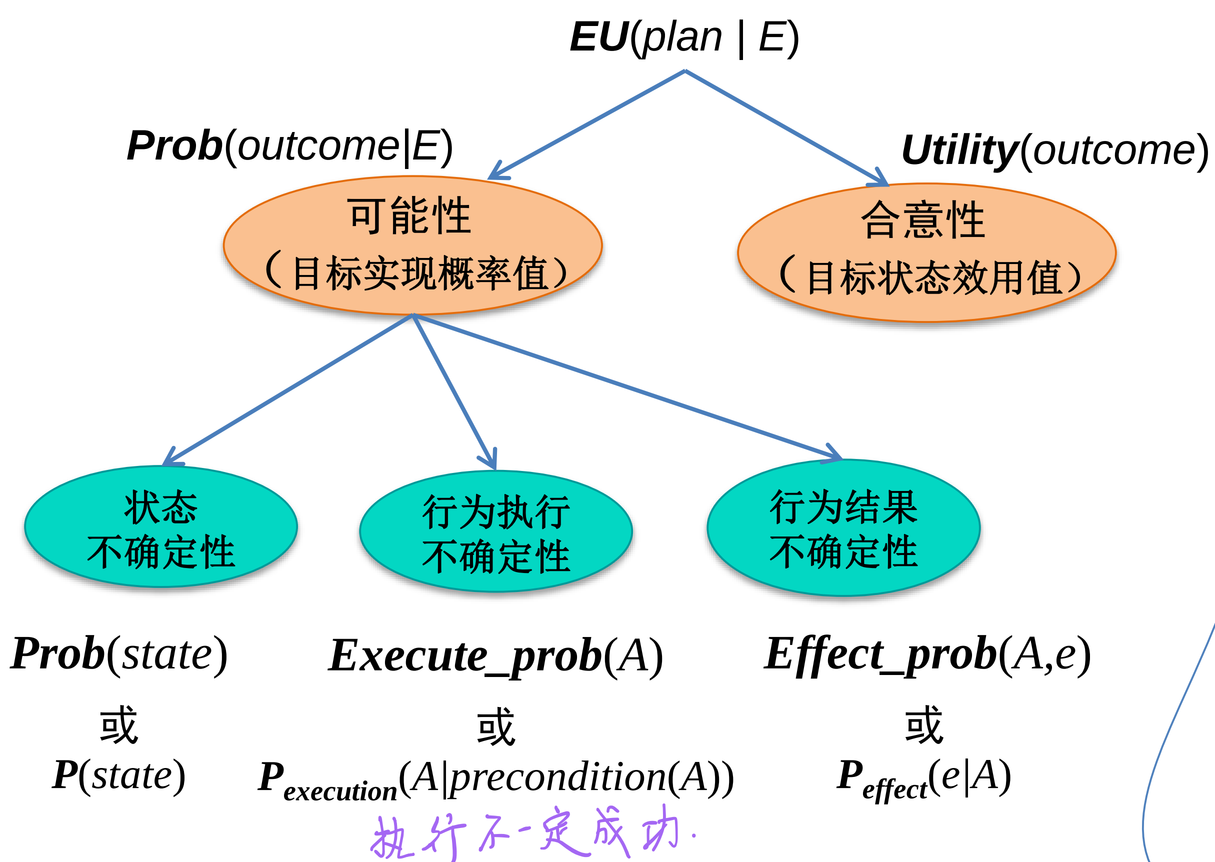
  = **Probability Theory** + **Utility Theory**

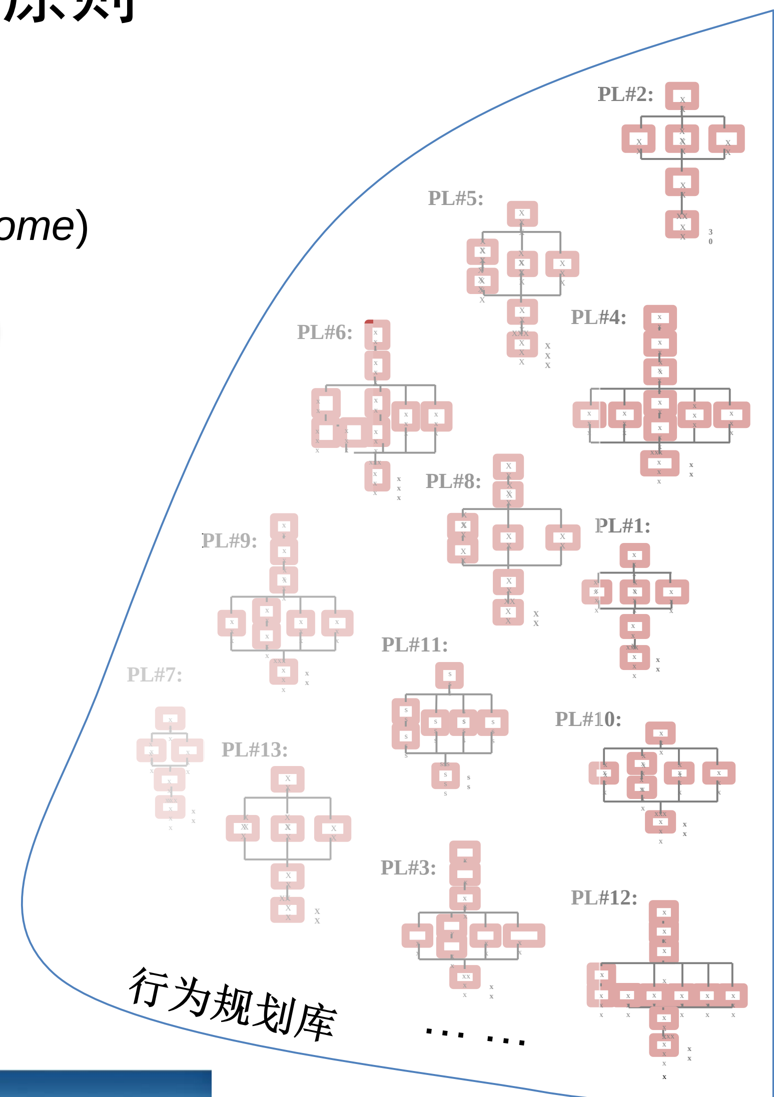
  (deal with ***chance***) (deal with ***outcomes***)

- Fundamental ideas
  - The *MEU (Maximum expected utility) principle*
  - Agent is *rational* if and only if it chooses the action that yields the *highest expected utility*, evaluated over all possible outcomes of the action
  - Weigh the utility of each outcome by the *probability* it occurs

意图识别方法

- 基于决策理论和期望效用最大化原则





Probabilistic Plan Representation

- **Execution probability *Execute_prob*(*A*):**

  Probability of successful execution of action *A* given its preconditions are true.

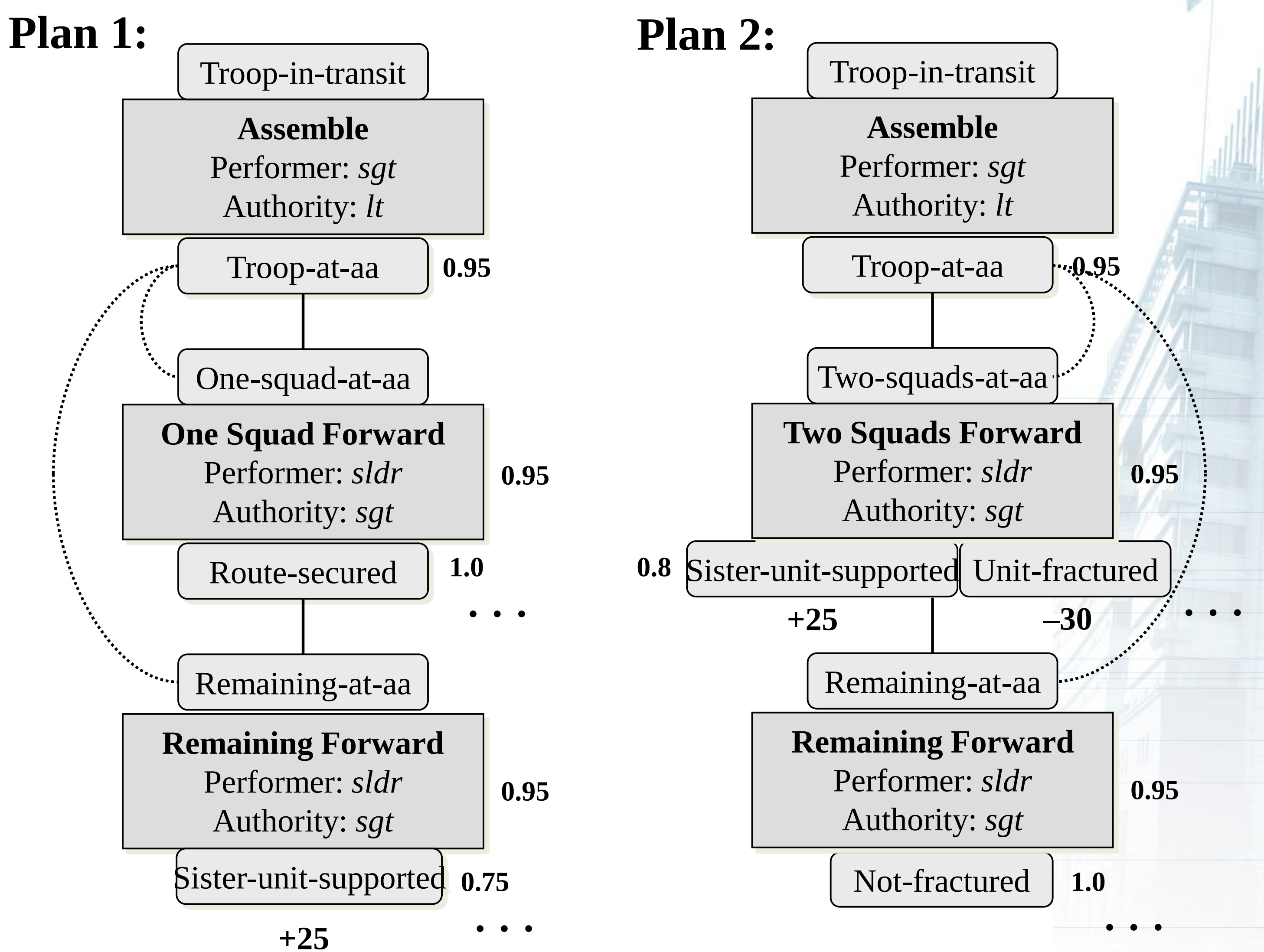
- **Effect probability *Effect_prob*(*A*, *e*):**

  Probability of the occurrence of its effect *e* given action *A* is successfully executed.

- **Conditional probability *Cond_prob*(*Antecedent*(*e*), *c*):**

  Probability of the occurrence of its consequent *c* given conditional effect *e* and its antecedents are true.

Probabilistic Plans



Probabilistic Inference

- Observations change state probabilities
- State probabilities change probabilities of action execution
- Action execution probabilities affect the probabilities of outcome occurrence
- Outcome probabilities affect expected plan utilities

Computation: Change State Probability

Observations change state probabilities, e.g.

- If a state x is observed, $P(x|E) = 1$
- If an action A is observed

  If $x \in \mathit{Precondition}(A)$, $P(x|E)=1.0$

  If $x \in \mathit{Effect}(A)$, $P(x|E)=\mathit{Effect\_prob}(A, x)$

  If $x \in \mathit{Consequent}(\mathit{Cond\_effect}(A))$,

  $$P(x|E)=\mathit{Cond\_prob}(\mathit{Antecedent}(\mathit{Cond\_effect}(A)), x) \times P(\mathit{Antecedent}(\mathit{Cond\_effect}(A)))$$

Changing State Probability

Prob(*two-squads-at-aa*|*E*)=*1*

Two-squads-at-aa

Two Squads Forward
Performer: *sldr*
Authority: *sgt*

Observed

Effect_prob: 0.8 **Sister-unit-supported** **Unit-fractured**

…

…

Changing State Probability

Prob(*two-squads-at-aa*|*E*)=*1*

Two-squads-at-aa

Two Squads Forward
Performer: *sldr*
Authority: *sgt*

Observed

Effect_prob: 0.8 **Sister-unit-supported** **Unit-fractured**

… **…**

Prob(*sister-unit-supported*|*E*)=*0.8*

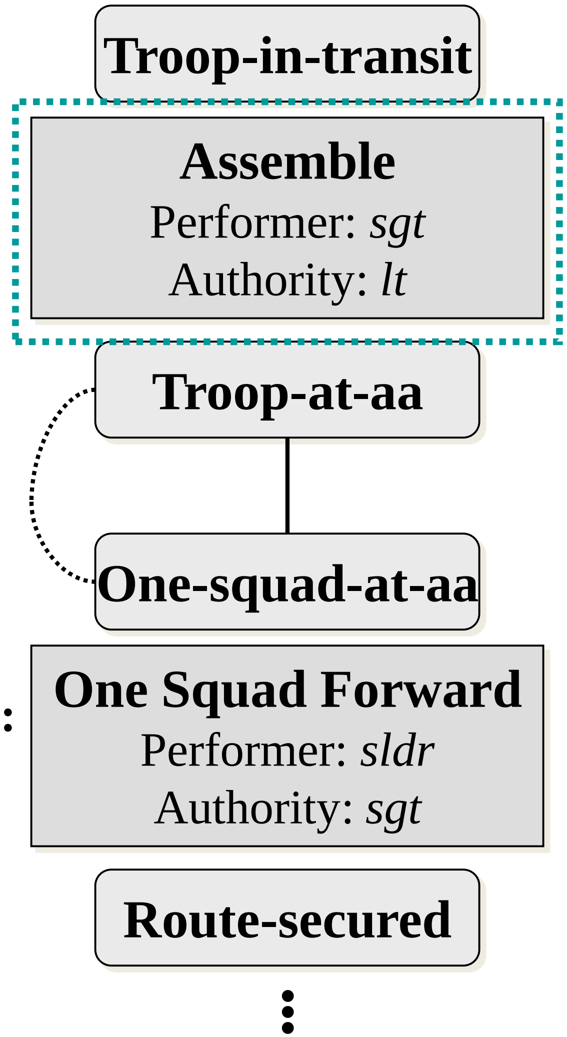
Compute Probability of Action Execution

Observations and state probability change the probabilities of action execution

- If an action A is observed, $P(A|E) = 1$
- Otherwise

$$P(A \mid E) = \left(\prod_{x \in precondition(A)} P(x \mid E)\right) \times Execute\_prob(A)$$

Probability of Action Execution



Observed

Prob(*assemble*|*E*)=*1*

Execute_prob: 0.95

Prob(*one-squad-fwd*|*E*)= Prob(*one-squad-at-aa*|*E*)*0.95

… **…**

Compute Outcome Probability and Plan Utility

Action execution probabilities affect the probabilities of outcome occurrence

- Primitive plan $P_i = \{A_1, \ldots, A_k\}$. Action sequence leads to the outcome o_j

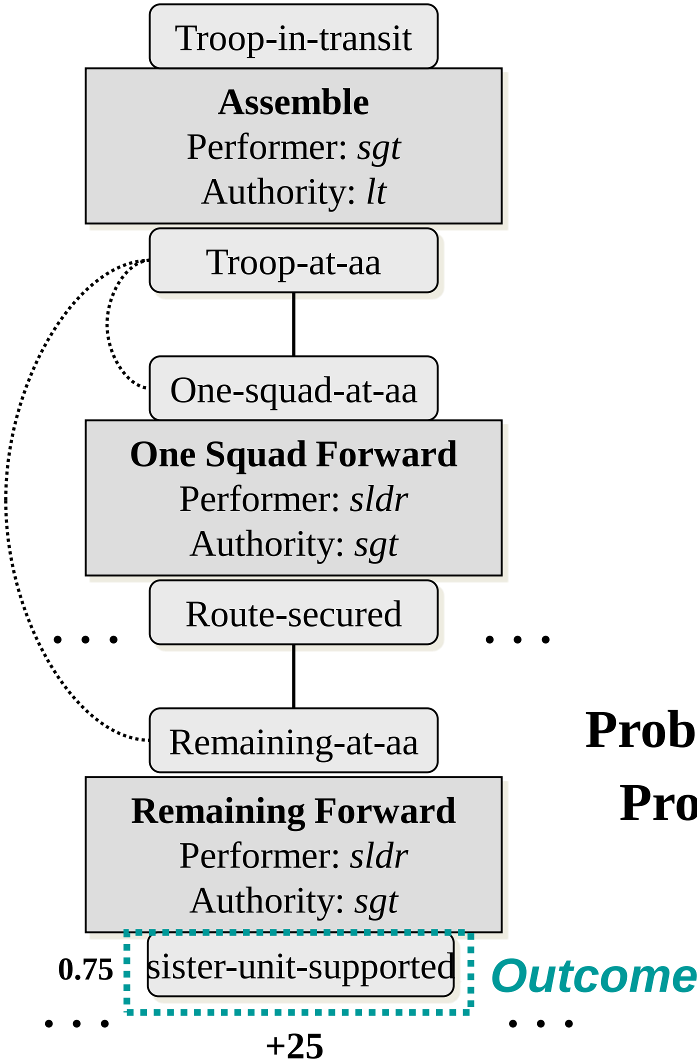
$$P(oj \mid E) = \Big(\prod_{i=1,\ldots,k} P(Ai \mid E)\Big) \times Effect\_prob(Ak, oj)$$

Outcome probabilities affect expected plan utilities

- The estimated expected utility of P_i

$$EU(Pi \mid E) = \sum_{o_j \in O_i} \big(P(oj \mid E) \times Utility(oj)\big)$$

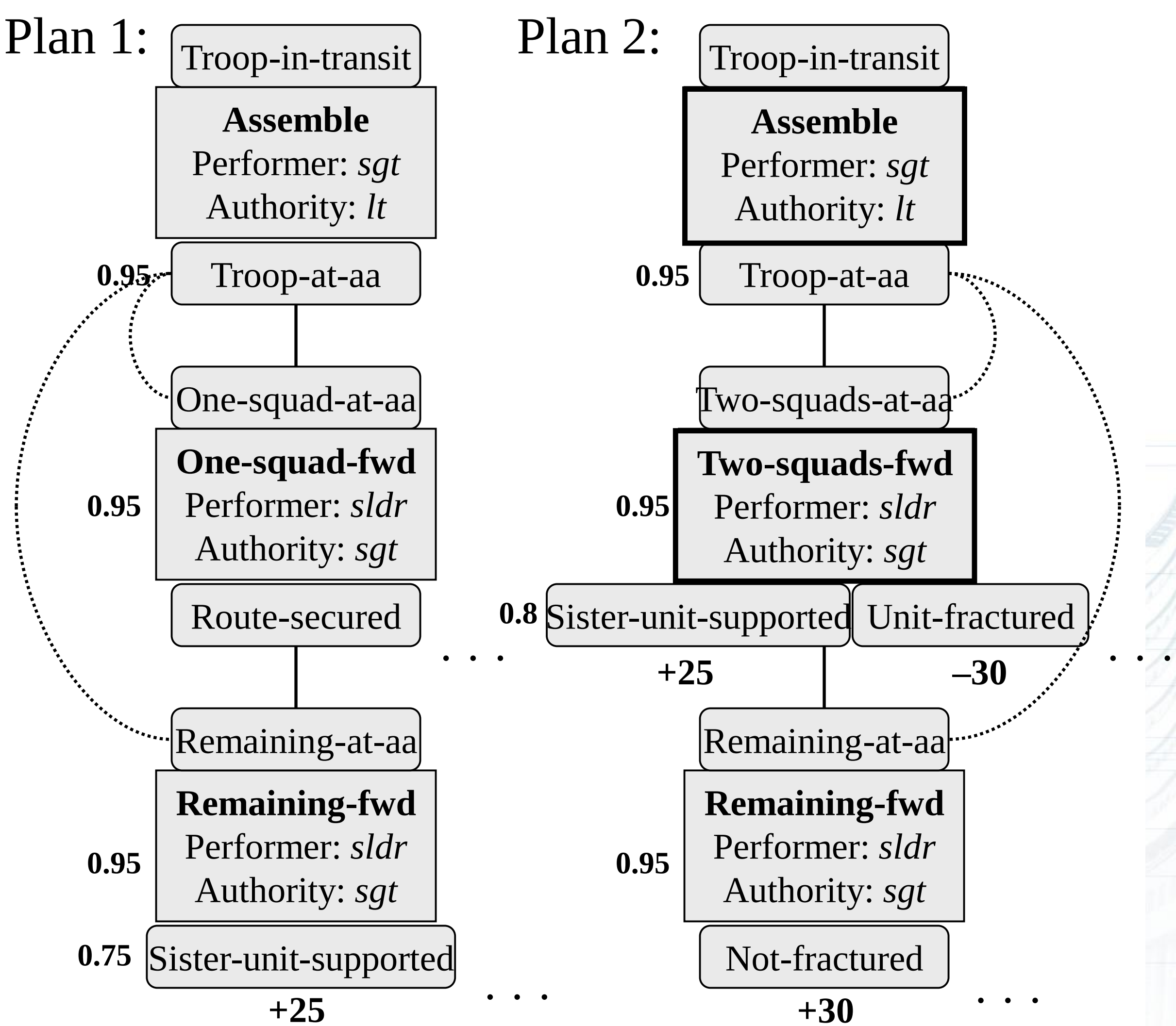
Outcome Probability & Plan Utility

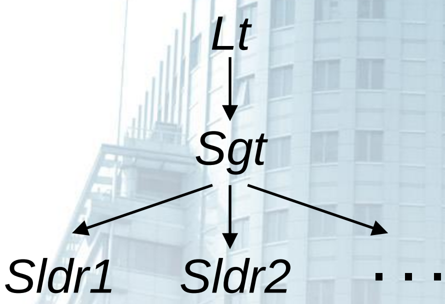


Expected-Utility(*plan*|*E*)=
Prob(*sister-unit-supported*|*E*)*25

Prob(*sister-unit-supported*|*E*)=Prob(*assemble*|*E*)*
Prob(*one-squad-fwd*|*E*)*Prob(*remaining-fwd*|*E*)*0.75

Illustrative Example





$$EU\,(Plan_{1}|E) = 15.25$$

$$EU\,(Plan_{2}|E) = 17.075$$

Illustrative Example: Computation

Based on the *1st* observation, $P(Assemble|E)$=1.0:

$P(troop\text{-}in\text{-}transit|E) = 1.0$
$P(troop\text{-}at\text{-}aa|E) = P(one\text{-}squad\text{-}at\text{-}aa|E) = P(two\text{-}squads\text{-}at\text{-}aa|E) = P(remaining\text{-}at\text{-}aa|E) = 0.95$

Based on the *2nd* observation, $P(Two\text{-}squads\text{-}forward|E)$=1.0:

$P(two\text{-}squads\text{-}at\text{-}aa|E) = 1.0$
$P(sister\text{-}unit\text{-}supported|E) = 0.8$ (*Plan 2*)
$P(unit\text{-}fractured|E) = 1.0$

So given the evidence,

$P(One\text{-}squad\text{-}forward|E) = P(Remaining\text{-}forward|E) = 0.95 \times 0.95 = 0.9025$

Illustrative Example: Computation

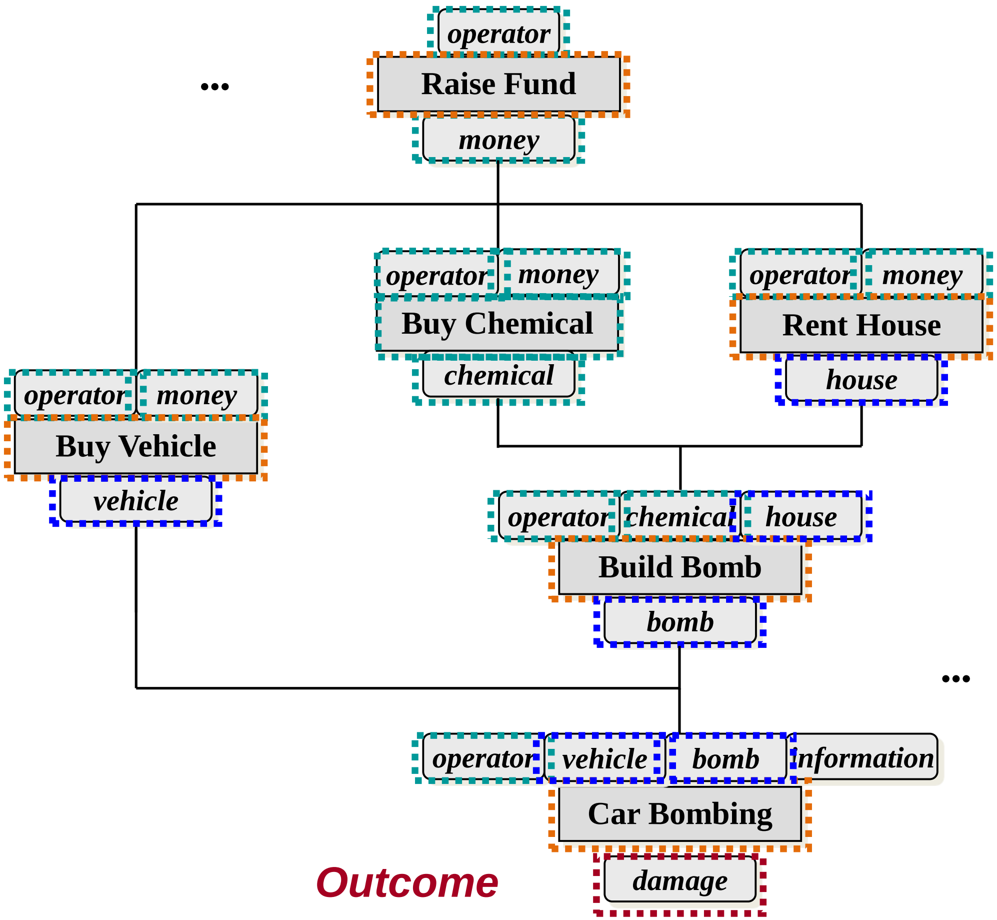
The probabilities of plan outcomes:

$P_{plan}(\textit{sister-unit-supported}|E) = 0.9025 \times 0.9025 \times 0.75 = 0.61$ (*Plan 1*)
$P_{plan}(\textit{sister-unit-supported}|E) = 0.8$ (*Plan 2*)
$P_{plan}(\textit{unit-fractured}|E) = 1.0$
$P_{plan}(\textit{not-fractured}|E) = 0.9025$

The expected utilities of *Plan 1* and *Plan 2*:

$EU(Plan_1|E) = 0.61 \times 25 = 15.25$
$EU(Plan_2|E) = 0.8 \times 25 + 1 \times (-30) + 0.9025 \times 30 = 17.075$

意图推理过程



$$P(A \mid E) = P_{execution}(A \mid precondition(A)) \times \prod_{e \in precondition(A)} P(e \mid E)$$

$$P(e \mid E) = P(A \mid E) \times P_{effect}(e \mid A)$$

$$P_{plan}(o_j \mid E) = \Big(\prod_{i=1,\dots,k} P(A_i \mid E)\Big) \times P_{effect}(o_j \mid A_k)$$

$$EU(P \mid E) = \sum_{o_j \in O_p} \big(P_{plan}(o_j \mid E) \times Utility(o_j)\big)$$

Experimental Study: Dataset

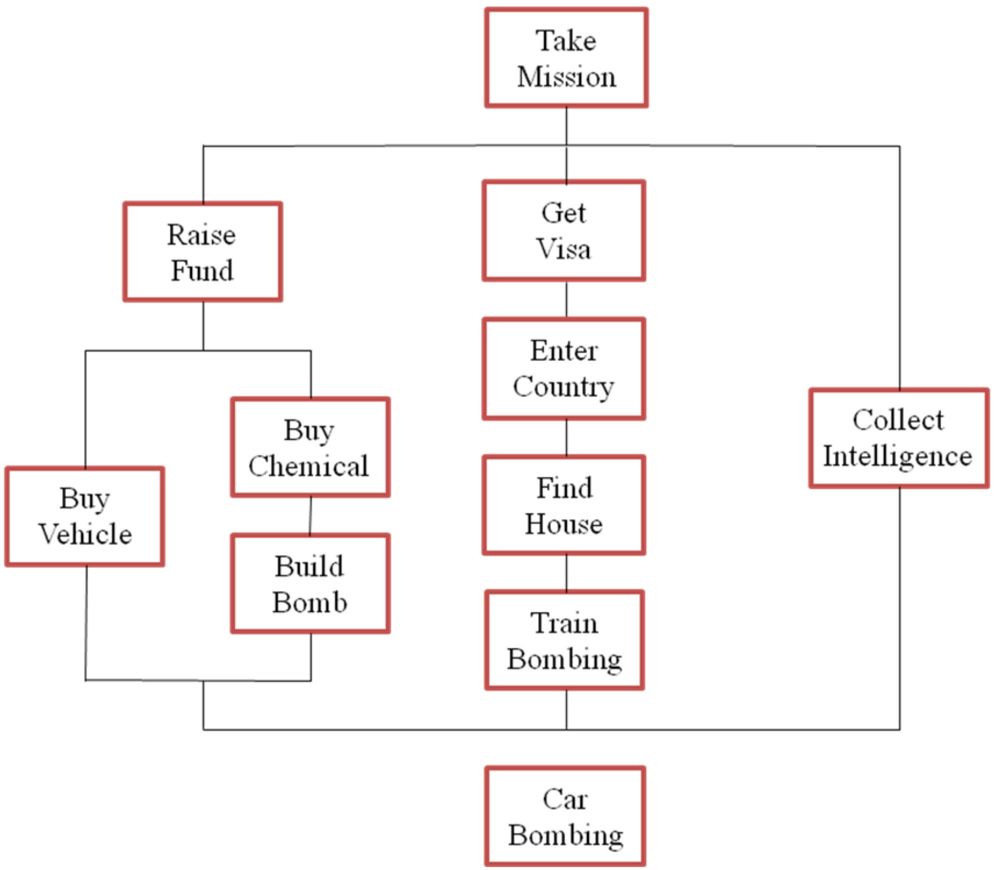
- Experiment in security informatics domain and choose *Al-Qaeda* as a representative radical group for our study
- Employ computational methods to automatically generate group attack plans from relevant open source textual data
  - Relevant news reported about this group's historical events in *The Times Online* (www.thetimes.co.uk) and *USATODAY* (www.usatoday.com)
  - Employ planning algorithm to automatically generate attack plans of the group

Constructing Plan Library

- Plan library
  - Among official investigation reports, *13* real attacks perpetrated by *Al-Qaeda* have relatively complete descriptions
  - Based on the generated plans, intelligence analyst helped choose *13* plans that match the reported real attacks
- Outcome utilities
  - Normalized values calculated based on the *GTD* (*Global Terrorism Database*) of the actual attacks by this group in history
- Probabilities assigned by intelligence analyst
  - State probabilities, action execution probabilities and effect probabilities in our approach
  - Prior and conditional probabilities for Bayesian reasoning

A Group Attack Plan

PR #6: The 1993 World Trade Center bombing



Action: take mission (1.0)
 Precondition: have authority, have operator
 Effect: have mission (1.0)
Action: raise fund (0.75)
 Precondition: have mission, have operator
 Effect: have money (0.5)
Action: buy vehicle (0.95)
 Precondition: have operator, have money
 Effect: have vehicle (0.95)
Action: buy chemical (0.75)
 Precondition: have operator, have money
 Effect: have chemical (0.5)
Action: build bomb (0.75)
 Precondition: have operator, have chemical
 Effect: have bomb (0.75)
Action: get visa (0.95)
 Precondition: have mission, have operator
 Effect: have visa (0.5)
Action: enter country (0.95)
 Precondition: have operator, have visa
 Effect: in country (0.95)
Action: find house (0.95)
 Precondition: have operator, in country
 Effect: have house (0.75)
Action: train bombing (0.95)
 Precondition: have operator, have house
 Effect: master bombing (0.95)
Action: collect intelligence (0.75)
 Precondition: have mission, have operator
 Effect: have intelligence (0.5)
Action: car bombing (0.5)
 Precondition: have vehicle, have bomb,
 master bombing, have intelligence
 Effect: have damage (0.1)
 Utility: 11

The Test Set

- Randomly generate *95 lines of evidence* using the combination of actions and initial states in plan library
  - Two observations: *49%*; Three observations: *51%*
- Four human raters experienced in security informatics participate in the experiment
- Each rater examined the evidence set line by line and predicted the most likely plans based on the plan library
- The test set is composed of each rater's predictions with corresponding evidence
  - Inter-rater agreement (*Kappa*): *0.764*

Experimental Result (1)

Kappa Agreements between Algorithms and Human Raters

Rater	Plan Inference						Bayesian Reasoning					
	2-Observation			*3-Observation*			*2-Observation*			*3-Observation*		
	P(*A*)	**P(*E*)**	***K***	**P(*A*)**	**P(*E*)**	***K***	**P(*A*)**	**P(*E*)**	***K***	**P(*A*)**	**P(*E*)**	***K***
1	0.826	0.108	0.805	0.878	0.106	0.861	0.436	0.078	0.388	0.469	0.106	0.406
2	0.696	0.090	0.666	0.837	0.105	0.818	0.435	0.086	0.382	0.469	0.107	0.405
3	0.609	0.096	0.567	0.776	0.097	0.752	0.435	0.098	0.374	0.490	0.102	0.432
4	0.652	0.088	0.618	0.694	0.101	0.660	0.370	0.089	0.308	0.388	0.092	0.326
AVG			**0.664**			**0.773**			**0.363**			**0.392**

W. Mao, J. Gratch and X. Li. Probabilistic Plan Inference for Group Behavior Prediction. *IEEE Intelligent Systems*, 27(4):27-36, July/August, 2012.

Experimental Results (2)

Comparison of Algorithms' *1-Best* and *2-Best* Results and Human Answers

Rater	Plan Inference				Bayesian Reasoning			
	1-Best		*2-Best*		*1-Best*		*2-Best*	
	#Match	#Error	**#Match**	#Error	**#Match**	#Error	**#Match**	#Error
1	81	14	91	4	43	52	58	37
2	73	22	85	10	43	52	56	39
3	66	29	84	11	44	51	64	31
4	65	30	83	12	36	59	57	38
Percentage	**75%**	25%	**90.26%**	9.74%	**43.68%**	56.32%	**61.84%**	38.16%

W. Mao, J. Gratch and X. Li. Probabilistic Plan Inference for Group Behavior Prediction. *IEEE Intelligent Systems*, 27(4):27-36, July/August, 2012.

Discussions

- **Criterion for disambiguation**
  - Expected plan utility & human intuition
  - 行为支持假设
  - How well the observed actions support hypotheses
- **Inference/Recognition process**
  - Action knowledge involved
  - Utilizing state information/preferences
- **Inputs/Flexibility**
  - Automatically generated vs. handcrafted plan library
  - Numbers of priors and conditional probabilities
  - How difficult to obtain probabilities

Discussions

- **Observations**
  - Both actions and states
  - Partially observable environment
- **Computational complexity**
  - Incremental intention recognition
  - Exactness vs. approximation 近似方法 先验知识
- **Multi-goal/Multi-agent recognition**
  - 并发 交叉规划
  - Concurrent plans vs. interleaved plans
  - Multi-agent/multi-occupant plan recognition

Plan-Based Approach for Behavior Prediction

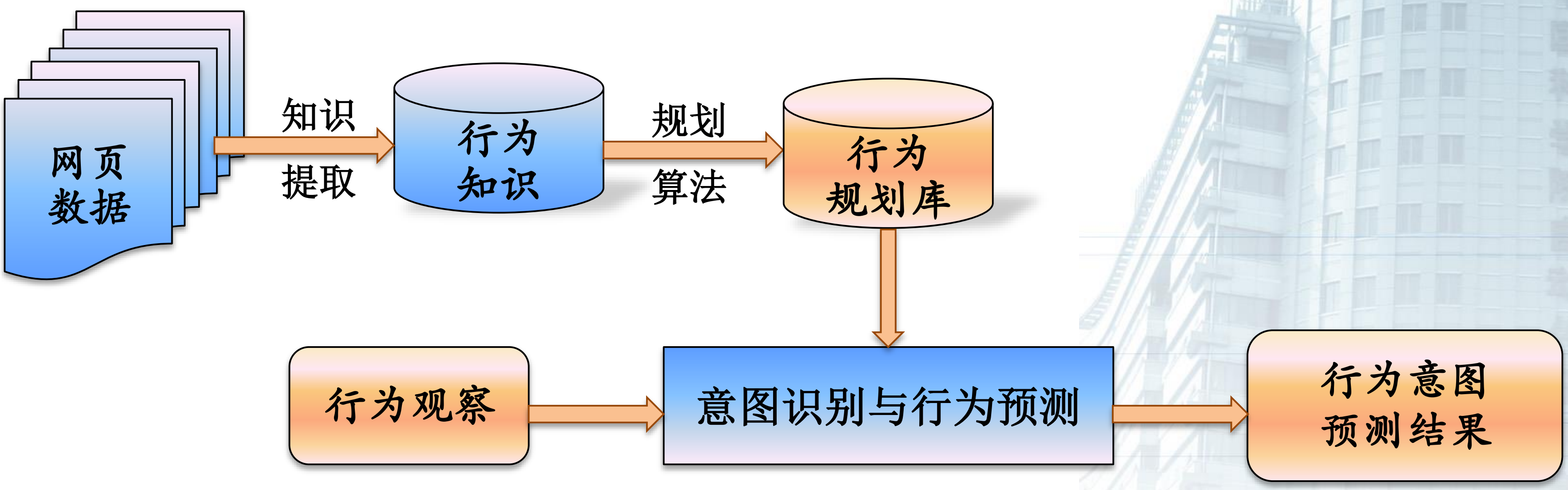
- Recent progress has made it possible to extract plan knowledge from online textual data and construct group plans via planning algorithm
- Advantageous for representing, analyzing and explaining behavior prediction results:
  - Plans are more expressive in representing behavioral patterns, group strategies and alternative courses of actions
  - Can not only come up with prediction results, but also inform group goals and intentions

行为预测方法比较

	数据驱动的方法（ML-based）	基于规划的方法（Plan-based）
对数据/知识需求	结构化数据集	行为规划库
任务类型	分类	溯因（Abduction）
表达程度	较弱	较丰富
可解释性	较差	较好
领域知识的嵌入	较困难	较容易

面向个体/组织的行为知识自动提取

行为建模、分析与预测



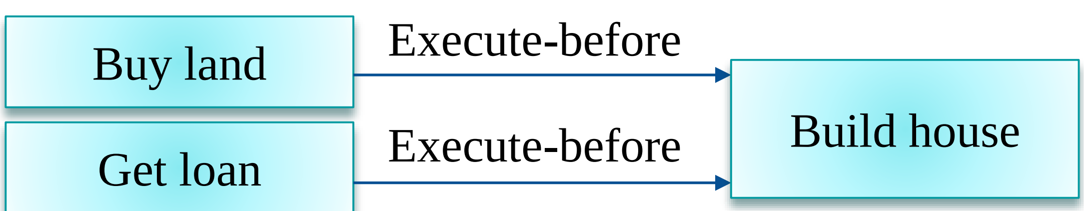
Action Knowledge from Text

S_1	Jack builds a new house to have more living space.
S_2	"You can make a bomb from fertilizers."
S_3	Before building a new house, the man bought the land and got some loan.

- Action effect (*Build house*, *Space*)

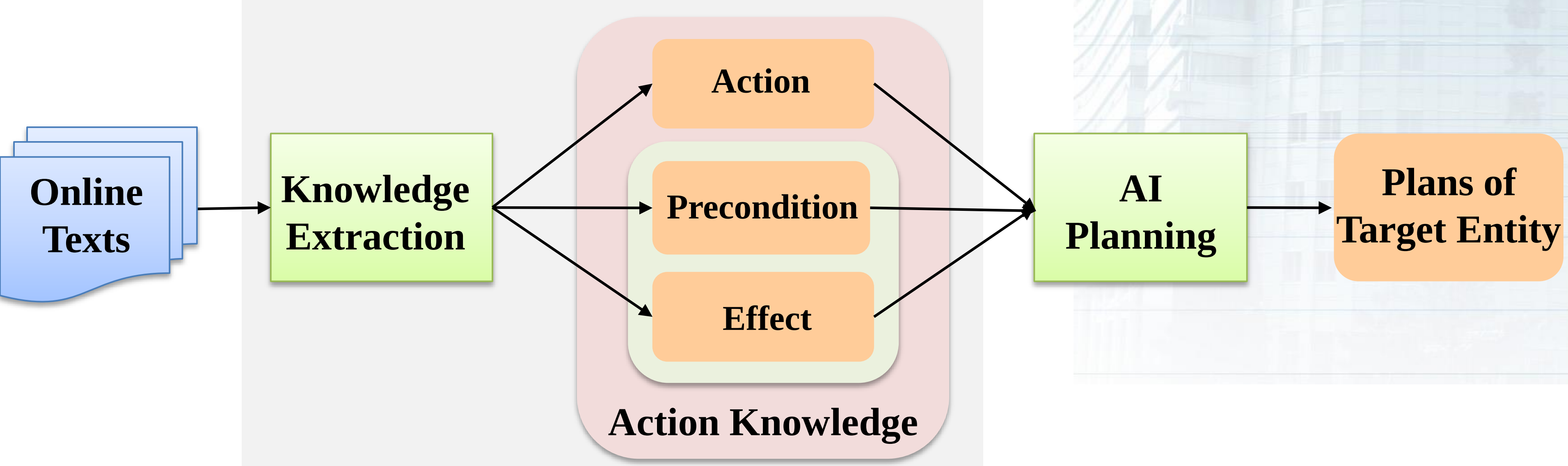
- Action precondition (*Make bomb*, *Fertilizer*)

- Temporal-relation (*Buy land* & *Get loan*, *Build house*)



Main Challenges of Knowledge Extraction

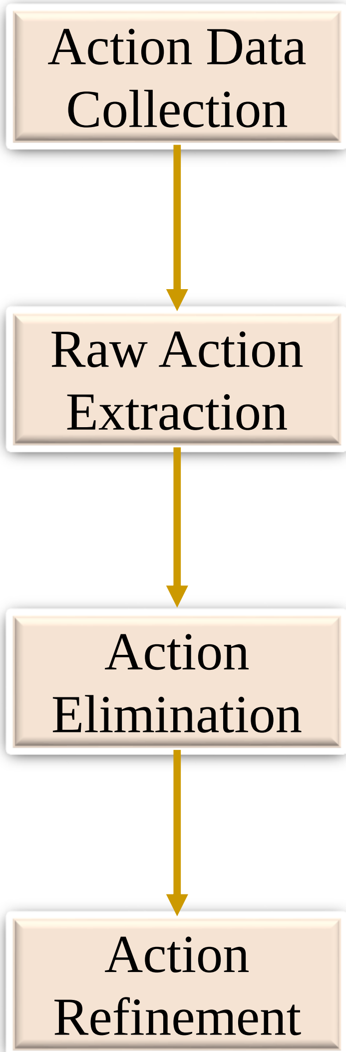
- Need to develop computational approaches to *identifying the associations* between organizations, actions and state affairs
- Correctly map the implications of action knowledge to the corresponding *linguistic manifest* in open source data



Related Research

- Extracting general causal relations between two clauses or two noun phrases
  - Khoo, Chan & Niu (*ACL'00*); Girju (*ACL'03*); Persing & Ng (*ACL'09*)
- Extracting action preconditions and effects via building SVM-based classifiers (Sil *et al*, *AAAI 2010 Fall Symposium*)
  - Actions are treated as *single verbs*, tested one frame in *FrameNet*
- Action knowledge extraction in simulated world (Xu & Laird, *AAAI 2011*)
- Recent renewed attention on learning action models from structured (Aineto *et al*, *AI Journal 2019*) and unstructured data (Asai & Fukunaga, *AAAI 2018*)

Main Steps of Action Extraction



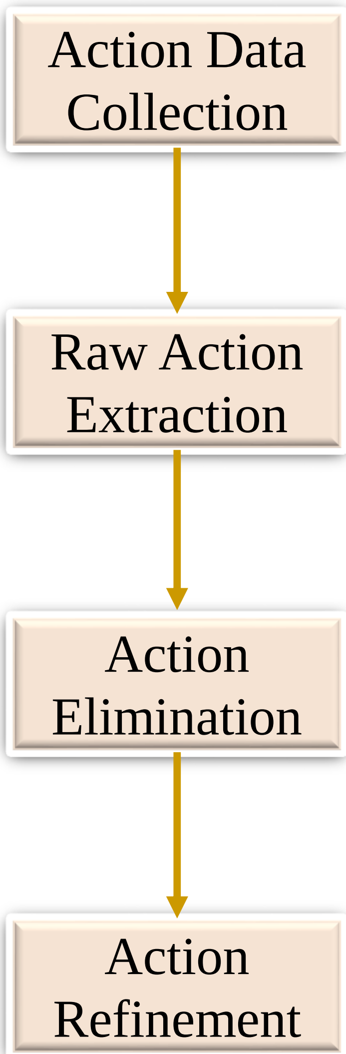
Collect relevant sentences from Web texts:
(referring to *organization structure T*, e.g. "*Al-Qaeda*")

Action format: *verb+object* (*physical action*)

Al-Qaeda leaders attend a rally in Gaza City. ⇨ ***attend rally***

Rule E1: <subject> (NNP(T)) </subject> & <predicate> (VB.*?) </predicate> & <object> (?!(NNP(T)$))(NN.*?) </object>

Main Steps of Action Extraction



Collect relevant sentences from Web texts:
(referring to *organization structure T*, e.g. "*Al-Qaeda*")

Action format: *verb* (*communicative action*)

Rule E2: <subject> (NNP(T)) </subject> & <predicate> (VB.*?) </predicate> & <object> (NNP(T)) </object>

Filter the extracted actions using WordNet synsets:

- "*communication, intercommunicate*"
- "*communicate, pass*"
- "*state, say, tell*"
- "*accept, content*"
- "*disapprove, reject*"
- "*intend, mean, think*"

Main Steps of Action Extraction

Action Data Collection

Collect relevant sentences from Web texts:
(referring to *organization structure T*, e.g. "*Al-Qaeda*")

Raw Action Extraction

Action format: *verb+object* *or* *verb*

Al-Qaeda leaders attend a rally in Gaza City. ⇨ ***attend rally***

Rule E1: <subject> (NNP(T)) </subject> & <predicate> (VB.*?) </predicate> & <object> (?!(NNP(T)$))(NN.*?) </object>

Action Elimination

Remove *stative verbs*:
(e.g., *have* and *be*)

- *have* capability
- *is* friend

Remove *irrelevant actions*:
(i.e. actions with *low* occurrence)

- *play role*
- *justify attack*

Action Refinement

Action *trimming*:

plan attacks → ***plan attack***
planned attack → ***plan attack***
planning attack → ***plan attack***

+

Action *combination*:
(referring to WordNet)

kidnap soldier → ***kidnap soldier***
abduct soldier → ***kidnap soldier***

Extracting Action Precondition & Effect

- Use *linguistic patterns* for action state extraction
- Connections between actions and effects are *causal*; Connections between actions and preconditions are *conditional*
- Able to acquire *rich* knowledge types and linguistic forms, e.g. *cause*, *reason*, *goal*, *condition*, *positive* and *negative* forms

前提识别

Patterns for Extracting Preconditions

Precondition	Patterns
Necessity/need	<action (verb-ing+object/verb-ing) set> *require* | *demand* | *need* <precondition set>
	<node-name> *need* <precondition set> *to* <action (verb+object/verb) set>
Permission/possibility	<precondition set> *allow* <node-name> *to* <action (verb+object/verb) set>
	<precondition set> *enable* | *create the possibility for* <node-name> *to* <action (verb+object/verb) set>
Means/tools	<node-name> *use* <precondition set> *to* <action (verb+object/verb) set>
	provide | *supply* | *offer* <precondition set> *for* <node-name> *to* <action (verb+object/verb) set>
	provide | *supply* | *offer* <node-name> *with* <precondition> *to* <action (verb+object/verb) set>
Negative patterns	<¬precondition set> *prevent* | *stop* <node-name> *from* <action (verb-ing+object/verb-ing) set>
	<¬precondition set> *disable* | *undermine* <node-name> *to* <action (verb+object/verb) set>
	lack of <precondition set> *prevent* | *stop* <node-name> *from* <action (verb-ing+object/verb-ing) set>
	the shortage of <precondition set> *disable* | *undermine* <action (verb-ing+object/verb-ing) set>
	cannot <action (verb+object/verb) set> *without* | *unless* <precondition set>

W. Mao, A. Ge and X. Li. From Causal Scenarios to Social Causality: An Attributional Approach. *IEEE Intelligent Systems*, 26(6):48-57, November/December, 2011.

Action Precondition Extraction: Necessity & Permission

- **Necessity/Need**

  < *action* (*verb-ing+object*) *set*> **require | demand | need** <*precondition set*>

  <*org-name*> **need** <*precondition set*> **to** <*action* (*verb+object*) *set*>

- **Permission/Possibility**

  <*precondition set*> **allow** <*org-name*> **to** <*action* (*verb+object*) *set*>

  <*precondition set*> **enable | create the possibility for** <*org-name*> **to** <*action* (*verb+object*) *set*>

Action Precondition Extraction: Means/Tools

- **Means/Tools**

<*org-name*> **use** <*precondition set*> **to** <*action* (*verb+object*) *set*>

provide | **supply** | **offer** <*precondition set*> **for** <*org-name*> **to** <*action* (*verb+object*) *set*>

provide | **supply** | **offer** <*org-name*> **with** <*precondition*> **to** <*action* (*verb+object*) *set*>

Action Precondition Extraction: Negative Patterns

- **Negative patterns**

  <¬*precondition set*> **prevent | stop** <*org-name*> **from** <*action* (*verb-ing+object*) *set*>

  <¬*precondition set*> **disable | undermine** <*org-name*> **to** <*action* (*verb+object*) *set*>

  lack of <*precondition set*> **prevent | stop** <*org-name*> **from** <*action* (*verb-ing+object*) *set*>

  the shortage of <*precondition set*> **disable | undermine** <*action* (*verb-ing+object*) *set*>

  cannot <*action* (*verb+object*) *set*> **without | unless** <*precondition set*>

Patterns for Extracting Action Effects

Effect	Patterns
Causation	<action (verb-ing+object/verb-ing) set> *bring about* | *lead to* | *result in* | *trigger* | *cause* | *produce* | *give rise to* <effect set>
	<effect set> *be caused* | *produced* | *triggered* | *brought about by* <action (verb-ing+object/verb-ing) set>
	<node-name> <action (verb+object/verb) set> *to cause* | *bring about* | *produce* | *trigger* <effect set>
	<node-name> <action (verb+object/verb) set>, *causing* | *producing* | *triggering* | *resulting in* | *leading to* <effect set>
	<node-name> <action (verb+object/verb) set>, *which* | *that bring about* | *lead to* | *result in* | *trigger* | *cause* | *produce* <effect set>
	<effect set> *caused* | *produced by* <action (verb-ing+object/verb-ing) set>
	What bring about | *lead to* | *result in* | *trigger* | *cause* | *produce* | *give rise to* <effect set> *be* <action (verb-ing+object/verb-ing) set>
Reason /goal	*the reason of* | *reason for* | *cause of* <action (verb-ing+object/verb-ing) set > *be* <effect set>
	<node-name> <action (verb+object/verb) set> *because of* | *on account of* | *due to* <effect set>
	<action (verb-ing+object/verb-ing) set> *be due to* <effect set>
	<node-name> <action (verb+object/verb) set> *for the purpose of* | *in an attempt to* | *in an effort to* | *in order to* | *so as to* | *in the cause of* <effect set>

W. Mao, A. Ge and X. Li. From Causal Scenarios to Social Causality: An Attributional Approach. *IEEE Intelligent Systems*, 26(6):48-57, November/December, 2011.

Action Effect Extraction: Cause

- **Causation**

<*action* (*verb-ing+object*) *set*> **bring about** | **lead to** | **result in** | **trigger** | **cause** | **produce** | **give rise to** <*effect set*>

<*effect set*> **be caused** | **produced** | **triggered** | **brought about by** <*action* (*verb-ing+object*) *set*>

<*org-name*> <*action* (*verb+object*) *set*>, **which | that bring about** | **lead to** | **result in** | **trigger | cause | produce** <*effect set*>

<*org-name*> <*action* (*verb+object*) *set*> **to cause** | **bring about** | **produce** | **trigger** <*effect set*>

<*org-name*> <*action (verb+object)* set>, **causing** | **producing** | **triggering** | **resulting in** | **leading to** <*effect set*>

<*effect set*> **caused** | **produced by** <*action* (*verb-ing+object*) *set*>

…

Action Effect Extraction: Reason

- **Reason/Goal**

the reason of | reason for | cause of <*action* (*verb-ing+ object*) *set* > **be** <*effect set*>

<*org-name*> <*action* (*verb+object*) *set*> **because of | on account of | due to** <*effect set*>

<*action* (*verb-ing+object*) *set*> **be due to** <*effect set*>

<*org-name*> <*action* (*verb+object*) *set*> **for the purpose of | in an attempt to | in an effort to | in order to | so as to | in the cause of** <*goal set*>

…

Action knowledge Extraction: Example

- Example: *Necessity/Need*

  Mr Evans said that *launching a coordinated attack on this scale would have required significant expertise*.

  Action: *launch attack*   Precondition: *expertise*

- Example: *Means/Tools*

  Documents obtained by The Washington Post show that al-Qaeda *used money from diamond deals to buy weapons including ground-to-air missiles*.

  Action: *buy weapon*   Precondition: *money*

Action knowledge Extraction: Example

- Example: *Negative Patterns*

  He said in a speech in Washington, adding that *the shortage of funds was undermining training combat skills*.

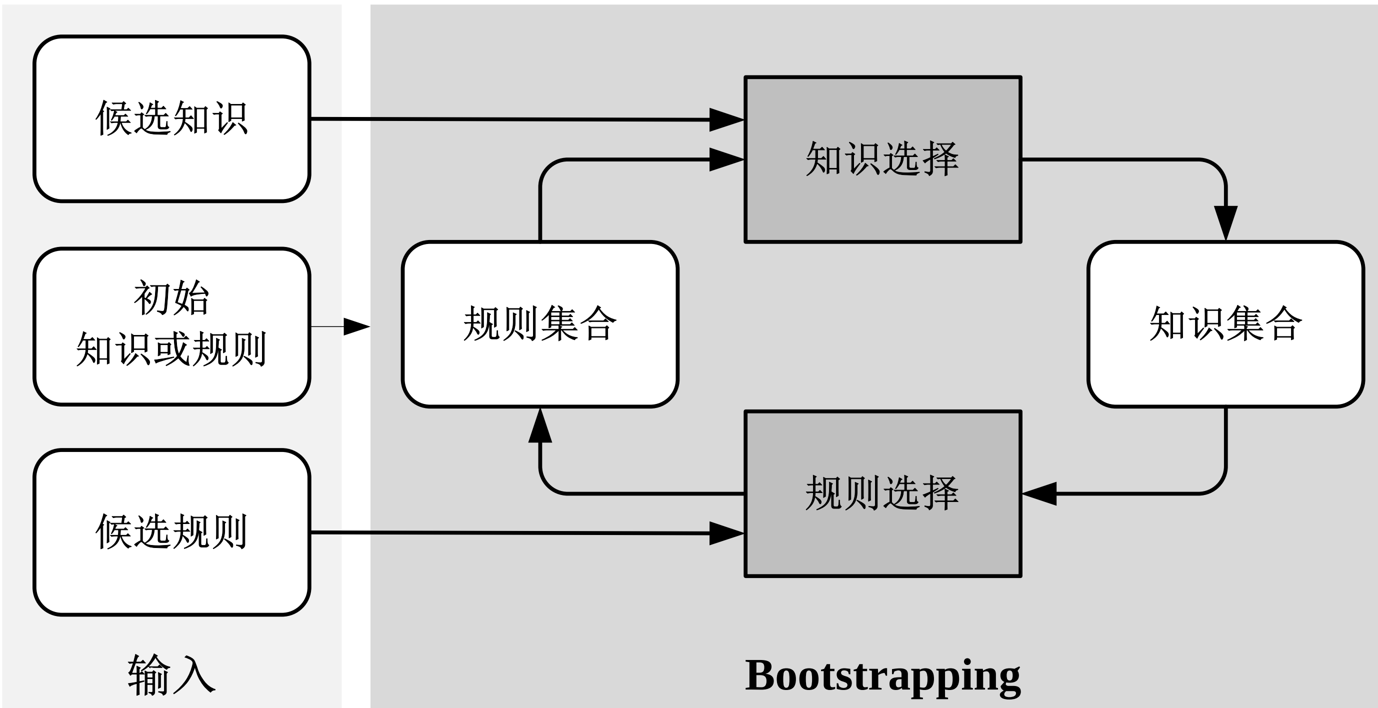
  Action: *train skill*   Precondition: *fund*

- Example: *Reason/Goal*

  An al-Qaeda operative *enters the country in an attempt to destroy the target*.

  Action: *enter country* Goal: *destroy target*

传统Bootstrapping的思想

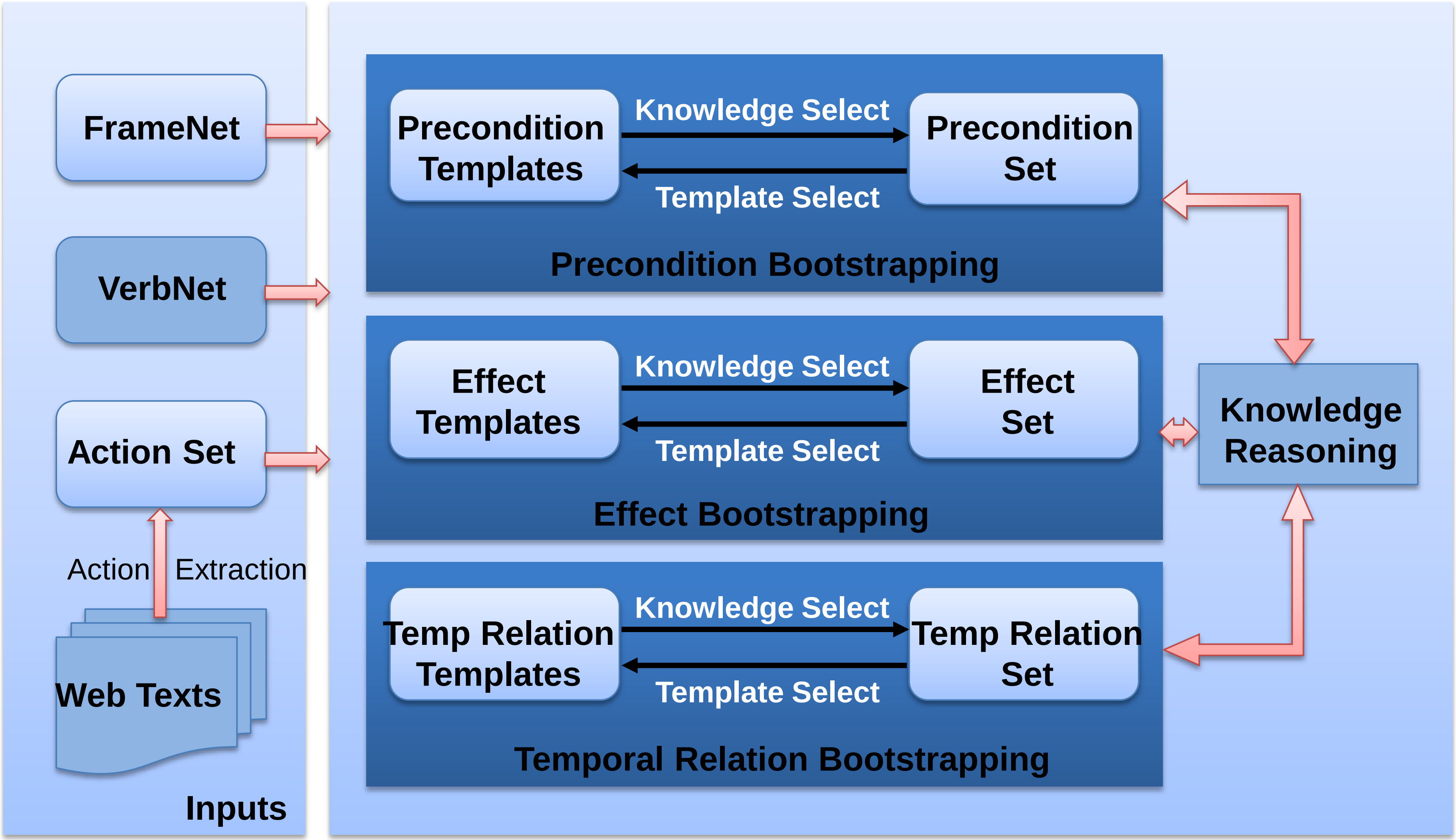


- 初始行为前提和结果抽取规则：FrameNet

Does Iran have the	infrastructure	necessary	to	produce bioweapons	?
	Required_entity	Core		Dependent	

Marcus	caused	the	first flurry	by	refusing meat	.
Actor	Core		Effect		Cause	

Bootstrapping-Based Approach



Knowledge Reasoning Technique

- Commonsense inference

Effect($a1$, s) $\wedge$ Precondition($a2$, s) $\Rightarrow$ Temp-relation($a1$, $a2$)

Temp-relation($a1$, $a2$) $\wedge$ Effect($a1$, s) $\Rightarrow$ Precondition($a2$, s)

Precondition($a2$, s) $\wedge$ Temp-relation($a1$, $a2$) $\Rightarrow$ Effect($a1$, s)

- Commonsense knowledge (referring to VerbNet)

Get Visa

have visa

effect

Buy Chemical

have chemical

has_possession(end(*E*), agent, theme)

exist(result(*E*), product)

Frame	NP + V + NP
Example	"Mohamed Atta gets his visa."
Syntax	Agent V Theme
Semantic	has_possession(start(E), ?Source, Theme) transfer(during(E), Theme) **has_possession(end(E), Agent, Theme)** cause(Agent, E)

Compute Reliability of Rule and Knowledge

- Compute reliability of a rule *r* or knowledge *k*:

using
- *SA*: Statistic Association（统计关联度）
- *SS*: Semantic Similarity （语义相似度）

$$R_i(r) = \frac{1}{\max R_i(r)}(1-\delta)SA_i(r) + \delta SS_i(r)$$

$$R_i(k) = \frac{1}{\max R_i(k)}(1-\delta)SA_i(k) + \delta SS_i(k)$$

δ is weight factor

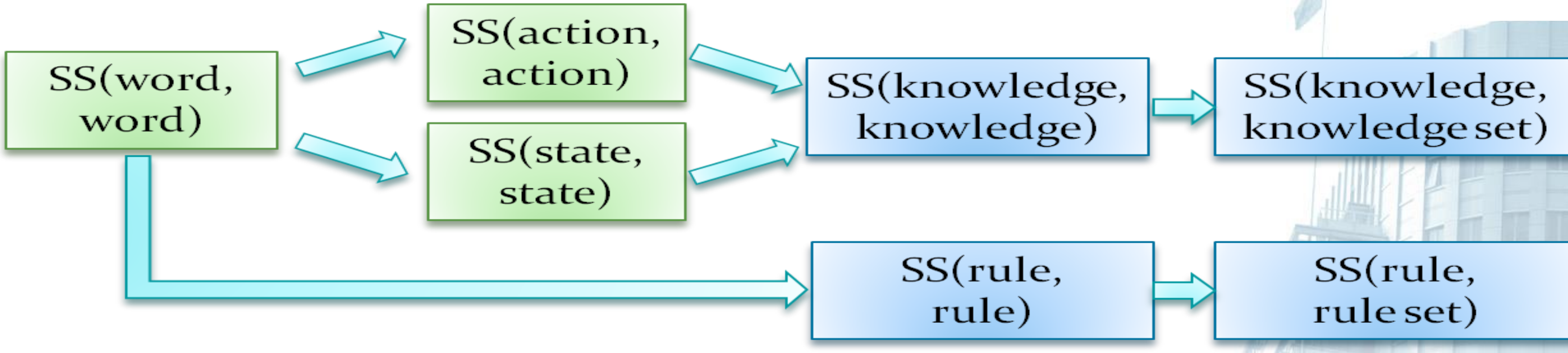
$\delta \in [0,1)$

- Compute *SA* values of *r* and *k*:

$$SA_i(r) = \frac{1}{\max SA_i(r)} \sum_{k_{last} \in K_{i-1}} PMI_+(k_{last}, r) \times R(k_{last})$$

$$SA_i(k) = \frac{1}{\max SA_i(k)} \sum_{r_{this} \in R_i} PMI_+(k, r_{this}) \times R(r_{this})$$

Compute Semantic Similarity (SS)



- Compute *SS* value between word w_1 and w_2:

$$SS(w_1, w_2) = \frac{1}{D(w_1, w_2) + 1}$$

- Compute *SS* value between knowledge $k(a_1,s_1)$ & $k(a_2,s_2)$:

$$SS(s_1, s_2) \times SS(a_1, a_2)$$

- Compute *SS* value between rule and rule set (or *knowledge*):

$$SS_i(r) = \frac{1}{\max SS_i(r)} \sum_{r_{last} \in R_{i-1}} SS(r_{last}, r) \times R(r_{last})$$

Experimental Study

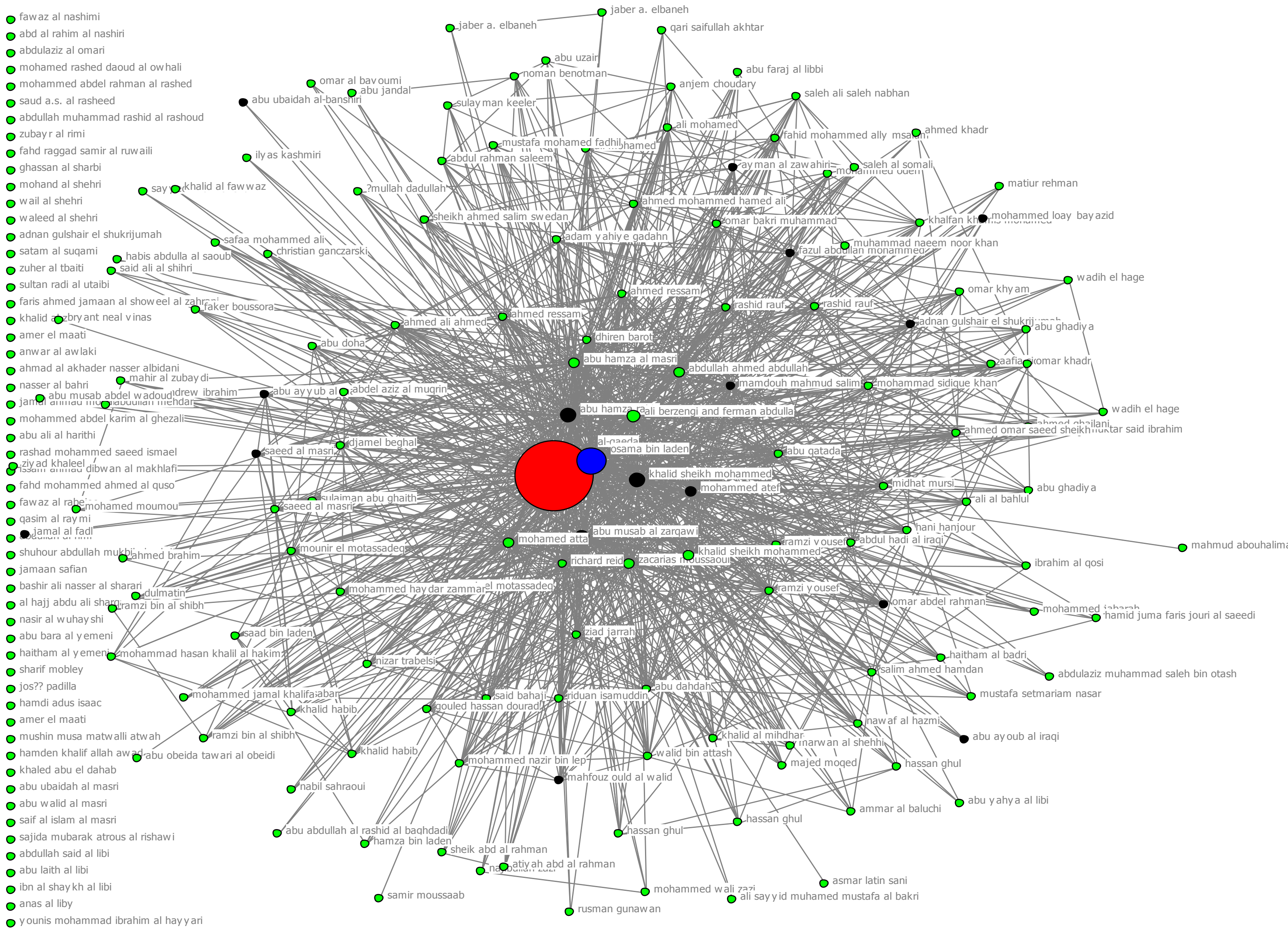
- Use online news about *Al-Qaeda* reported in *The Times*, *BBC*, *USA TODAY*, *The New York Times* and *The Guardian*, with totally *25,103* Web pages and *953,663* sentences

- Compute interconnections of the group members and specify a 3-layer organizational structure of the group

- Initial templates from FrameNet:

Precondition Templates: "necessary.a" "need.v" "use.v"

Effect Templates: "have.v" "obtain.v" "cause.v"

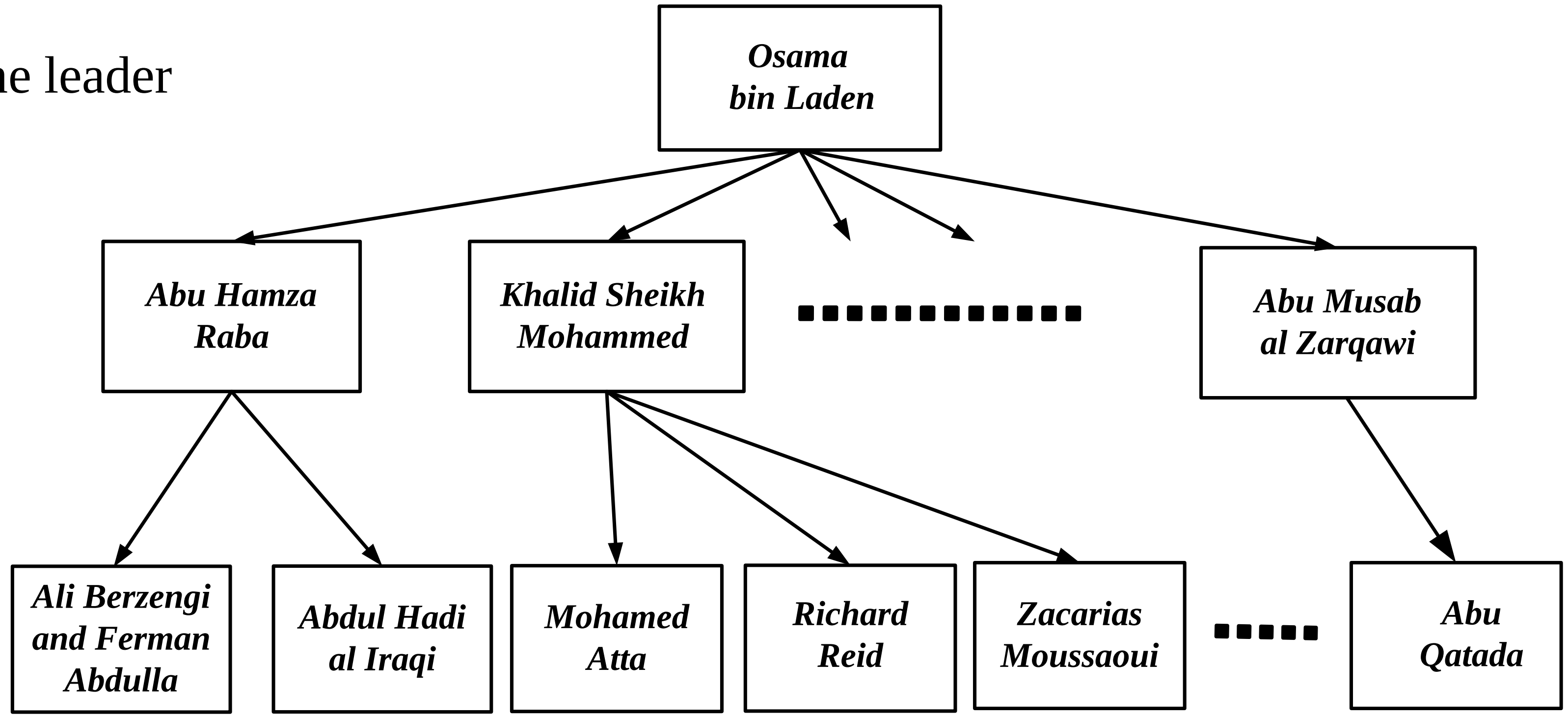

fawaz al nashimi
abd al rahim al nashiri
abdulaziz al omari
mohamed rashed daoud al owhali
mohammed abdel rahman al rashed
saud a.s. al rasheed
abdullah muhammad rashid al rashoud
zubayr al rimi
fahd raggad samir al ruwaili
ghassan al sharbi
mohand al shehri
wail al shehri
waleed al shehri
adnan gulshair el shukrijumah
satam al suqami
zuher al tbaiti
sultan radi al utaibi
faris ahmed jamaan al showeel al zahrani
amer el maati
anwar al awlaki
ahmad al akhader nasser albidani
nasser al bahri
mohammed abdel karim al ghezali
abu ali al harithi
rashad mohammed saeed ismael
fahd mohammed ahmed al quso
qasim al raymi
shuhour abdullah mukhbi
jamaan safian
bashir ali nasser al sharari
nasir al wuhayshi
abu bara al yemeni
haitham al yemeni
sharif mobley
hamdi adus isaac
amer el maati
mushin musa matwalli atwah
khaled abu el dahab
abu ubaidah al masri
abu walid al masri
saif al islam al masri
sajida mubarak atrous al rishawi
abdullah said al libi
abu laith al libi
ibn al shaykh al libi
anas al liby
younis mohammad ibrahim al hayyari
jaber a. elbaneh
jaber a. elbaneh
qari saifullah akhtar
abu uzair
noman benotman
omar al bayoumi
abu jandal
abu ubaidah al-banshiri
abu faraj al libbi
anjem choudary
saleh ali saleh nabhan
sulayman keeler
ali mohamed
ahmed khadr
mustafa mohamed fadhil
abdul rahman saleem
ilyas kashmiri
ayman al zawahiri
saleh al somali
matiur rehman
khalid al fawwaz
ahmed mohammed hamed ali
mohammed loay bayazid
sheikh ahmed salim swedan
omar bakri muhammad
adam yahiye gadahn
safaa mohammed ali
christian ganczarski
muhammad naeem noor khan
habis abdulla al saoub
said ali al shihri
wadih el hage
ahmed ressam
omar khyam
faker boussora
ahmed ressam
rashid rauf
rashid rauf
ahmed ali ahmed
abu ghadiya
abu doha
dhiren barot
abu hamza al masri
abdullah ahmed abdullah
omar khadr
mahir al zubaydi
mamdouh mahmud salim
mohammad sidique khan
abu musab abdel wadoud
abdel aziz al muqrin
ali berzengi and ferman abdulla
wadih el hage
djamel beghal
al-qaeda
osama bin laden
abu qatada
khalid sheikh mohammed
mohammed atef
midhat mursi
abu ghadiya
sulaiman abu ghaith
saeed al masri
ali al bahlul
mohamed moumou
jamal al fadl
hani hanjour
mohamed atta
abu musab al zarqawi
mahmud abouhalima
mounir el motassadeq
abdul hadi al iraqi
ahmed brahim
khalid sheikh mohammed
richard reid
zacarias moussaoui
ibrahim al qosi
dulmatin
mohammed haydar zammar
ramzi yousef
ramzi bin al shibh
omar abdel rahman
hamid juma faris jouri al saeedi
ziad jarrah
saad bin laden
mohammad hasan khalil al hakim
nizar trabelsi
haitham al badri
salim ahmed hamdan
abdulaziz muhammad saleh bin otash
abu dahdah
mohammed jamal khalifa
said bahaji
riduan isamuddin
mustafa setmariam nasar
khalid habib
gouled hassan dourad
nawaf al hazmi
ramzi bin al shibh
khalid al mihdhar
abu ayoub al iraqi
khalid habib
marwan al shehhi
abu obeida tawari al obeidi
walid bin attash
majed moqed
hassan ghul
mohammed nazir bin lep
mahfouz ould al walid
abu yahya al libi
nabil sahraoui
ammar al baluchi
hassan ghul
hassan ghul
abu abdullah al rashid al baghdadi
hamza bin laden
sheik abd al rahman
atiyah abd al rahman
asmar latin sani
samir moussaab
mohammed wali zazi
ali sayyid muhamed mustafa al bakri
rusman gunawan

Organizational Structure of the Group

1st layer: one leader

2nd layer:
17 cadres

3rd layer:
221 members

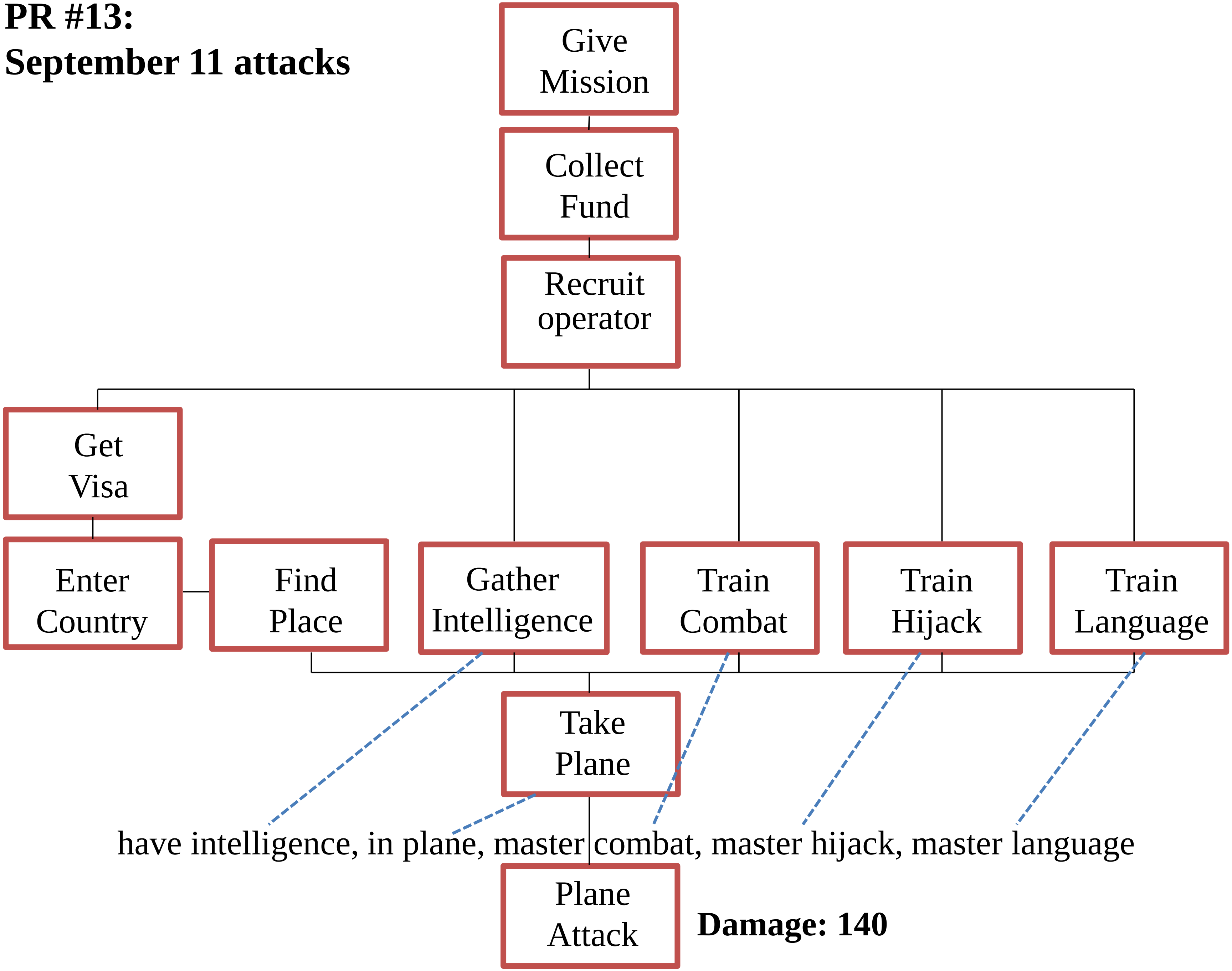


Experimental Results

Average Precision			Average Coverage		
Action	**Precondition**	**Effect**	**Action**	**Precondition**	**Effect**
0.978	**0.904**	**0.973**	**0.858**	**0.741**	**0.787**

Weight Factor	**Precision**		
	Precondition	Effect	Temporal Relation
δ=0 (no reasoning)	0.808	0.517	/
δ=0	0.825	0.533	0.805
δ=0.25	0.841	0.55	0.814
δ=0.5	0.858	0.558	0.830
δ=0.75	0.808	0.517	0.752

PR #13:
September 11 attacks



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End.