Toward Plan Recognition in Discourse Using Large-Scale Lexical Resources

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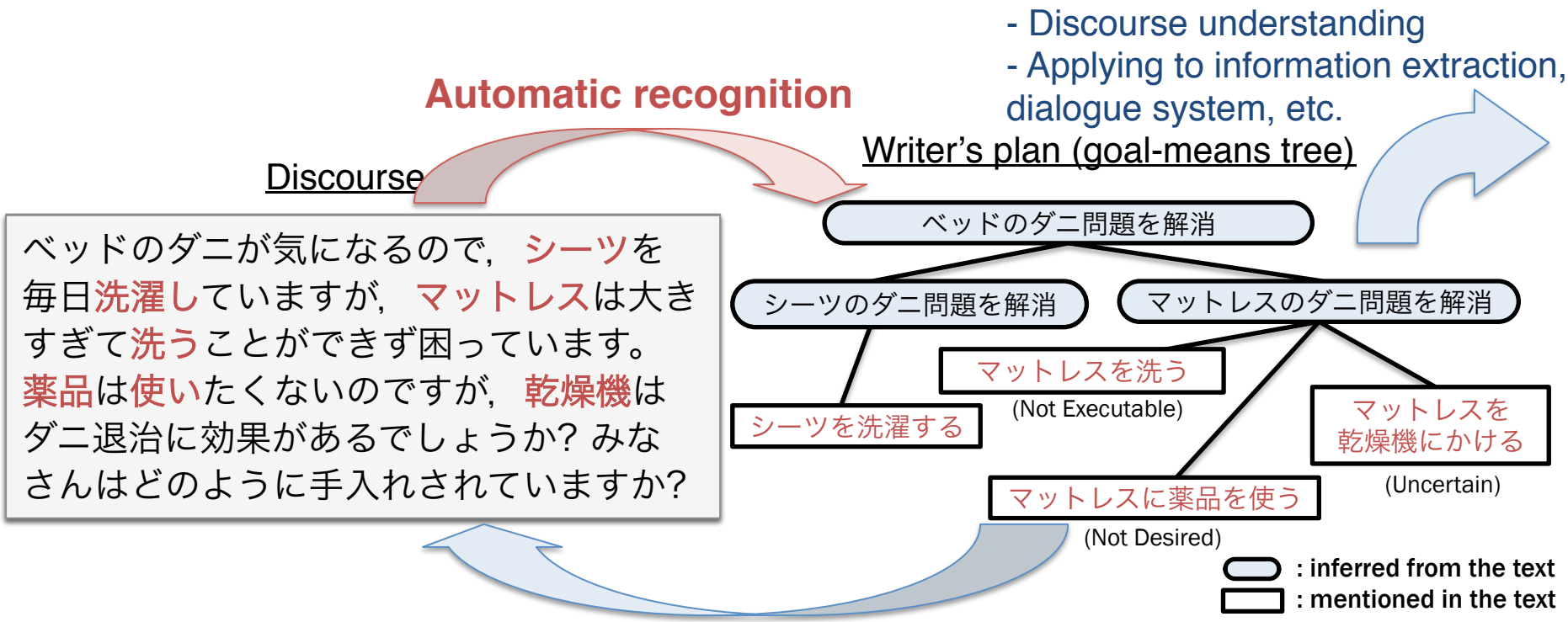
Research Goal

- Recognizing an agent's belief and intention to achieve a goal (*plan*) in discourse



Research Background

Ready for practical discourse processing!

1970 1980 1990 2000 **2011**

Work on discourse processing:

- Script (Schank 77)
- Plot Unit (Lehnert 81)
- Rhetorical Structure Theory (Mann&Thompson 87)
- Memory Organization Packets (Schank 82)
- Intentional structure (Grosz&Sidner 86)
- Script Applier Mechanism (Schank 75)
- **Plan recognition** (Allen&Perrault 80; Carberry 90; Charniak&Goldman 91, 94; etc.)
- Plan Applier Mechanism (Wilensky 78)

- **Plan recognition using large-scale world knowledge** (Not explored)
- Plot unit recognition (Goyal+ 10)

The scale of knowledge base (KB):

Hand-coded for each task.

- FrameNet (Baker+ 98)
- WordNet (Fellbaum 98)
- ALAGIN (www.alagin.jp)
- OpenCyc (opencyc.org)
- Automatic script acquisition (Gordon 10; Regneri+ 10; Chambers & Jurafsky 09, 10; etc.)

KB was insufficient for robust discourse processing...

Issues of Large-Scale Plan Recognition

- **Issue 1:** The sufficiency of knowledge bases
  - Are existing large-scale knowledge bases enough to perform plan inference in an open-domain?

Main focus

- **Issue 2:** Inference mechanism
  - How should the inference system utilize large-scale knowledge bases?

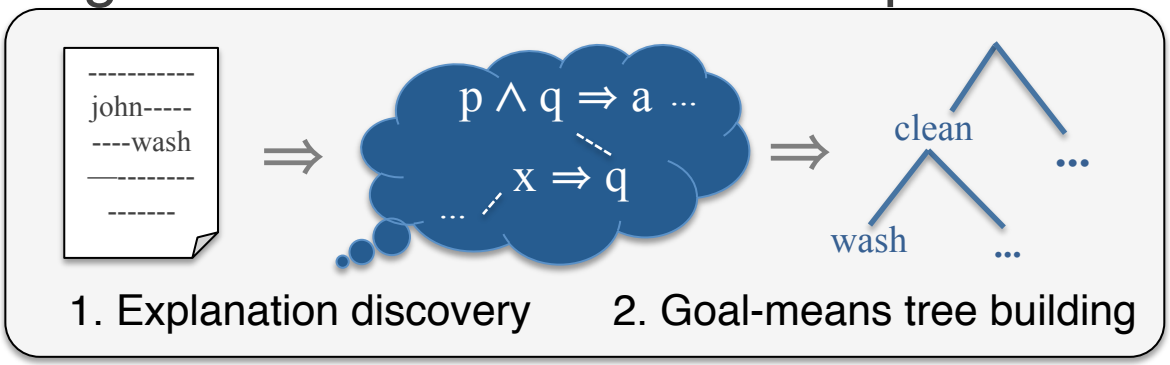
    → An existing framework++ as our first step

Overview of This Talk

- ☑ Introduction
  - Goal, motivation, key issues
- ☐ The plan inference model
  - Abductive inference
- ☐ Knowledge base
  - Translation of the existing lexical resources
  - Meta-knowledge
- ☐ Experiments
  - Verification of the sufficiency of knowledge bases

The Plan Inference Model

- Overview
  1. Find *the reasonable explanation (説明)* to a situation described in a discourse
  2. Build a goal-means tree from the explanation

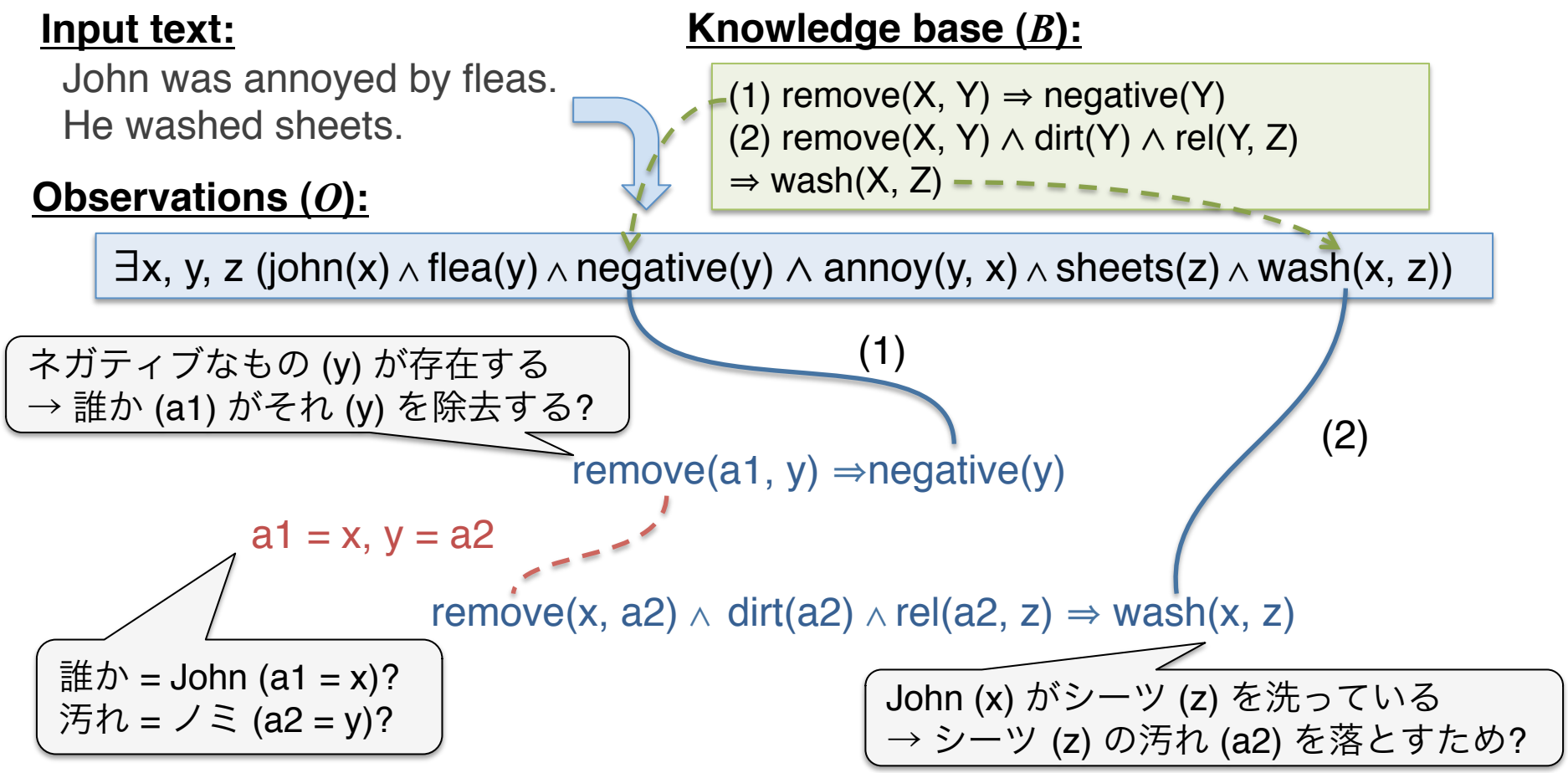


- Motivation
  - Inferring agents' intention is subsumed by explaining a situation described in a discourse
  - Number of previous work (Ng&Mooney 92; etc.) have formulated plan recognition as explanation discovery

Step 1/2: Finding the Explanation

- Abductive inference (仮説推論) is a suitable framework:
  - Given a knowledge base B and observations O
  - Find a minimal hypothesis H (*explanation*) such that $H \wedge B \models O, H \wedge B \not\models \bot$
- What is “minimal”?
  - Simplicity, cost-based (Hobbs+ 93; etc.), probabilistic (Charniak&Goldman 91), ...
  - *Simplicity* is adopted in this talk

Step 1/2: Find H s.t. $H \wedge B \models O, H \wedge B \not\models \bot$



Step 1/2: Find H s.t. $H \wedge B \models O, H \wedge B \not\models \bot$

Input text:

John was annoyed by fleas.
He washed sheets.

Knowledge base (B):

(1) remove(X, Y) ⇒ negative(Y)
(2) remove(X, Y) ∧ dirt(Y) ∧ rel(Y, Z) ⇒ wash(X, Z)

Observations (O):

∃x, y, z (john(x) ∧ flea(y) ∧ negative(y) ∧ annoy(y, x) ∧ sheets(z) ∧ wash(x, z))

(1)

(2)

ネガティブなもの (y) が存在する
→ 誰か (a1) がそれ (y) を除去する?

remove(a1, y) ⇒negative(y)

a1 = x, y = a2

誰か = John (a1 = x)?
汚れ = ノミ (a2 = y)?

remove(x, a2) ∧ dirt(a2) ∧ rel(a2, z) ⇒ wash(x, z)

John (x) がシーツ (z) を洗っている
→ シーツ (z) の汚れ (a2) を落とすため?

仮説：ジョンがシーツの
ノミを落としている

Hypothesis (H):

john(x) ∧ flea(y) ∧ remove(x, y) ∧ annoy(y, x) ∧
sheets(z) ∧ dirt(y) ∧ rel(y, z)

Step 1/2: Find H s.t. $H \wedge B \models O, H \wedge B \not\models \bot$

Input text:

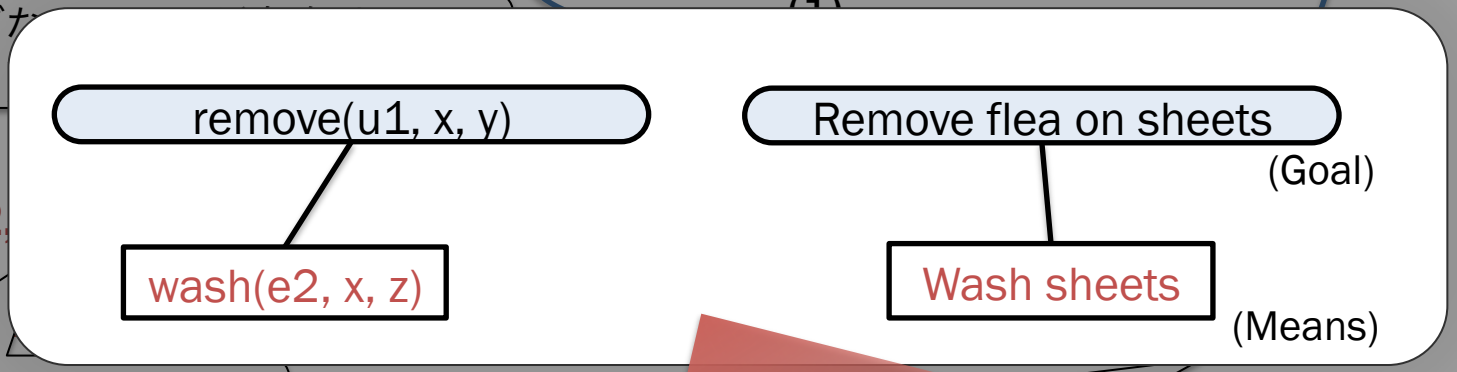
John was annoyed by fleas.
He washed sheets.

Knowledge base (B):

(1) remove(**E**, X, Y) ⇒ negative(Y)
(2) remove(**E1**, X, Y) ∧ dirt(Y) ∧ rel(Y, Z) ∧ **goal_means(E1, E2)** ⇒ wash(**E2**, X, Z)

Observations (O):

∃x, y, z (john(x) ∧ flea(y) ∧ negative(y) ∧ annoy(**e1**, y, x) ∧ sheets(z) ∧ wash(**e2**, x, z))



ネガティブな
→ 誰か (a1

u1 = u2

remo

誰か = John (a1 = x)?
汚れ = ノミ (a2 = y)?

仮説：ジョンがシーツのノミを落としている

John (x) がシーツ (z) を洗っている
→ シーツ (z) の汚れ (a2) を落とすため?

Step 2/2: Tree Construction

Hypothesis (H):

john(x) ∧ flea(y) ∧ remove(**u1**, x, y) ∧ annoy(**e1**, y, x) ∧ sheets(z) ∧ dirt(y) ∧ rel(y, z) ∧ **goal_means(u1, e2)**

Overview of Our Knowledge Base

1. Convert existing lexical resources into axioms

2. Manually encode general inference rules of human beings (called *meta-knowledge*)

Axioms from Existing Lexical Resources

Synonym (1,419,948 axioms)

- Japanese WordNet 1.1 (Bond+ 08)
- A database of relations between events (Matsuyoshi+ 08)
- ex) $discover(x) \Rightarrow find(x)$
  $clean(e1, x, y) \Rightarrow wash(e1, x, y)$

Hypernym-hyponym (1,871,984)

- Japanese WordNet 1.1 (Bond+ 08)
- A database of relations between events (Matsuyoshi+ 08)
- ex) $human(x) \Rightarrow mammal(x)$
  $mammal(x) \Rightarrow human(x)$

Words of similar context (4,998,620)

- A database of words in similar context (Kazama+ 10)
- ex) $pillow(y) \Rightarrow futon(x)$

Relations between events (12,033)

- A database of relations between events (Matsuyoshi+ 08)
- ex) $dirt(z) \wedge rel(z,y) \wedge remove(e2,x,y) \wedge goal\_means(e2,e1) \Rightarrow wash(e1,x,y)$

Sentiment polarity information (33,755)

- Japanese sentiment polarity lexicon (Higashiyama+ 08; Kobayashi+ 05)
- A database of trouble expressions (Saeger+ 08)
- ex) $negative(x) \Rightarrow flea(x)$

Meta-knowledge (23 axioms)

The variety of linguistic expressions

- ○○する(*E1*) ∧ *goal_means(E1, E2)*
  ⇒ ○○機を使う(*E2*)
  ex) 掃除機を使う

- *X* を使う(*E*) ⇒ *X* で *Y* する(*E*)
  ex) 掃除機で対応する

State interaction of an object

- *X* が positive な状態である
  ⇒ *rel(X, Y)* ∧ *negative(Y)* ∧
  Y を取り除く

- *X* が *Y* にある ⇒ *rel(X, Z)* ∧
  Z が *Y* にある

Direct expression of plan

- *goal_means(X, Y)*
  ⇒ *X* するために *Y* する

- *goal_means(X, Y)* ⇒ *goal_means(X, Z)* ∧
  Z したくないので *Y* する
  ex) 歩いて行きたくないので電車で行く

Associations between entities or events

- *Y* は動詞の項である ⇒ *Y* は名詞である

- *rel(X, Y)* ⇒ *X* は名詞である

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Experiments

- Verify the sufficiency of knowledge base
  - Manually judged whether an inference path from an observed action to its goal could be bridged by the background knowledge
- Extracted the fairly open-domain
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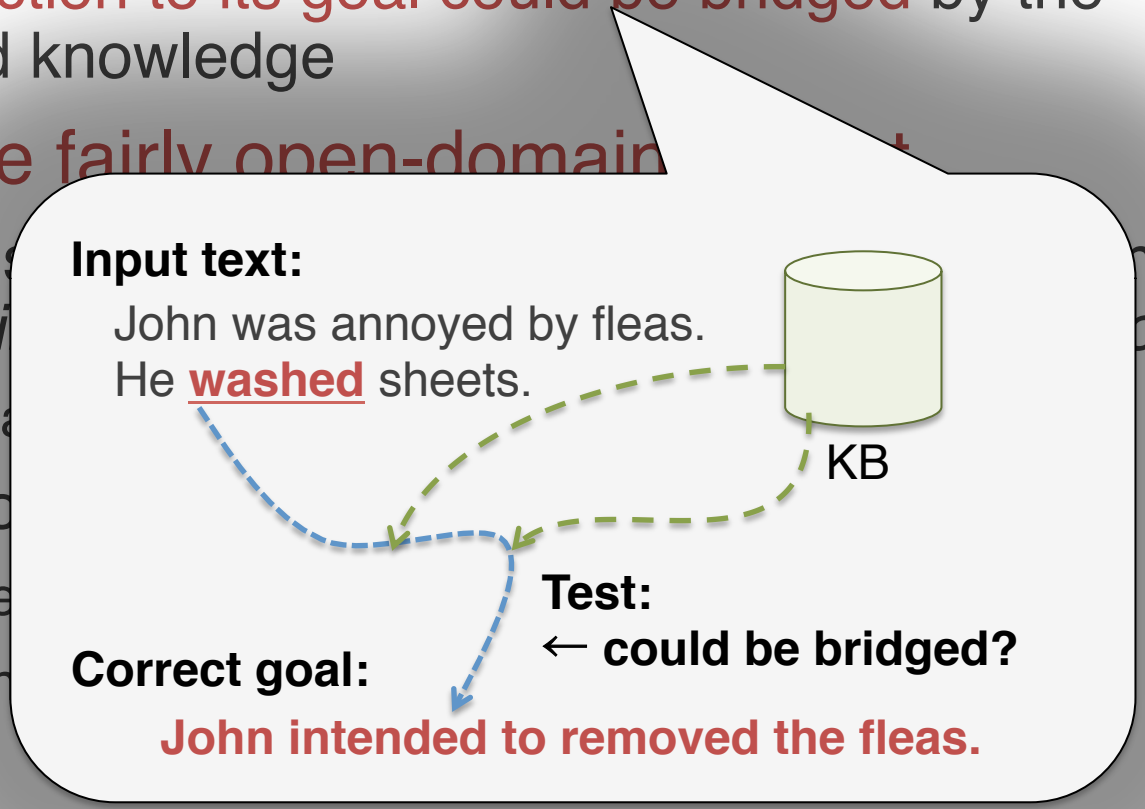


Results 1/3

☺ An inference path was generated for the actions of 77.4% (48/62)

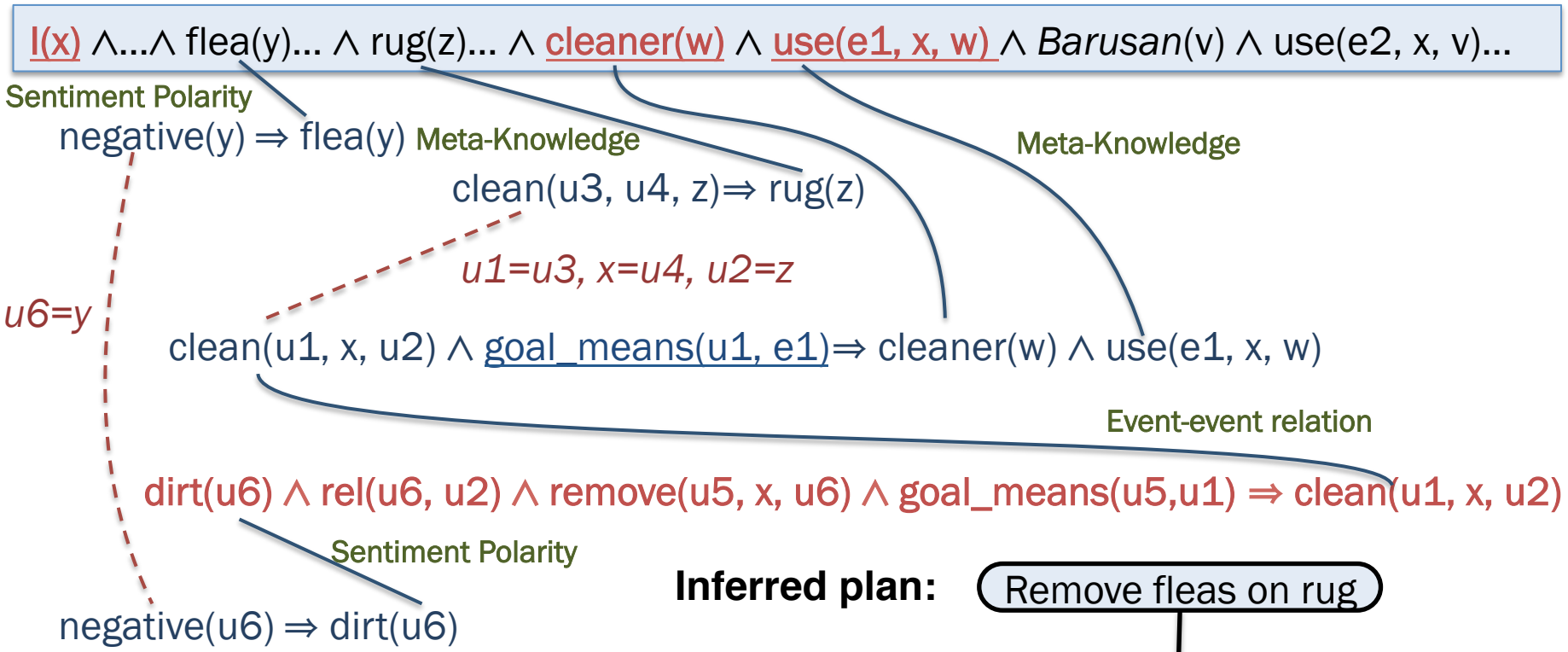
- Meta-knowledge was necessary to infer a plan for the positive instances of 56.3% (27/48)

Results 2/3

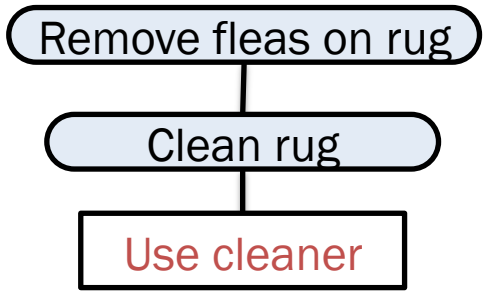
Input:

娘と私がノミに噛まれました。リビングにはラグがあります。
2, 3日に一度掃除機をかけていますが，不十分でしょうか。毎日...

Explanation:



Inferred plan:



Correct goal:

ラグのノミを取り除こうとしている

Results 3/3

☹ The explanations to the actions of 22.6% (14/62) were failed to generate

- Due to a lack of world knowledge about NEs
- Example

> 娘と私がノミに噛まれました。リビングにはラグがあり，2, 3日に一度掃除機をかけていますが，不十分でしょうか。毎日掃除機をかければ，ノミはいなくなりますか? 健康のことを考えると，できればバルサンは使いたくありません。

  - カビキラーを使う，ファブリーズをする，パイプフィニッシュを使う，カビ取りハイターを使う，バルサンを焚く

- World knowledge about *telic role* is crucial to recognize an intention
  - ex) バルサン: a substance used for killing insects

Findings from Our Experiments

1. The knowledge bases are moderately sufficient for exploring how to utilize them

2. Meta-knowledge plays an important role even if we have large-scale knowledge base

Recent Progress

- Developing the fast inference engine for Hobbs+ (93)'s weighted abduction
  - Automatically finds a reasonable explanation (in a limited setting) based on the cost of explanation
  - Solves a problem that can not be solved by state-of-the-art engine (Mulkar-Mehta 07) in practical time

- Now we have an environment to try lots of interesting ideas!

Summary

- Discussed the sufficiency of knowledge bases in open-domain plan recognition
  - Findings:
    - *Existing knowledge bases are moderately sufficient for exploring how to use them*
    - *Meta-knowledge plays an important role even if we have large-scale world knowledge*
- Topics to be addressed in the next step
  - A wider range of meta-knowledge
  - The efficient algorithm of abductive inference
    - Preliminary addressed in recent work
  - The mechanism to select the reasonable explanation