PurposeNet: A Knowledgebase Organized around Purpose

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What is PurposeNet

A structured knowledge based system that consists of

– A knowledge base (facts about the world) and

– An inference system that reasons over those facts and deduces new facts and also checks consistencies.
“The alarm clock goes off at 6:15 by my roommate's bed. I wake up, crawling down the stairs from my loft.

I put on my white Nike gym shorts and set out.

In an hour, I return, eager to jump in the shower”.

Queries

• What is an alarm clock?
• Did the author exercise?
• Why did the author put on white Nike gym shorts?
• Why the author wanted to take a shower?
Ans 1: An alarm clock is a clock that is designed to wake a person at a specific time.

Ans 2: Yes.

Ans 3: “Gym shorts are an article of clothing typically worn by people when exercising.”

The author intended to exercise, and therefore, wore it.

Ans 4: The author wanted to cool his body. A shower sprinkles water over the body. As a result, the body gets wet. A wet body feels cool when the evaporation of the moisture takes heat away from the skin. Therefore the author wanted to take a shower.
Expected Factual Knowledge

Assertion 1 - “An alarm clock is a clock that is designed to wake a person at a specific time.”

Assertion 2 - “Gym shorts are an article of clothing typically worn by people when exercising.”

Assertion 3 - “Shower is an apparatus used for bathing under a spray of water”.

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There is a need for factual knowledge
Proposal

• *creation and use of world knowledge*

• by engineering a KB consisting of a network of entities developed using a formal principle

• used in conjunction with a state-of-the-art inference engine

• thereby bridging the man-machine gap

• providing knowledge to NLP and reasoning systems.
Organization of Knowledge
Organizing Principle

• How does one organize knowledge?
• Principle: Purpose as the organizing principle
• Domain: Artifacts (Man made objects)
Indian Philosophical Tradition

Objects are described in terms of four major types of attributes

- **Dharm (Purpose):**
  - Property which is intrinsic (essential) to the objects in the category
  - Helps distinguish the category from other categories.
  
  Example, Dharm /Purpose of a car is to transport people from one place to another on land.

- **Svabhaav:**
  - Attributes which the object shares with objects of the same class
  
  Example, Car shares attributes with other machines, but does not share attributes with living beings.

- **Rup (Form):**
  - Attributes which can directly be perceived by our sensory organs.
  
  For example, rupa of car would be its shape, colour, weight, etc.

- **Gun (Quality):**
  - Properties that are not perceived directly but indirectly such as load carrying capacity, etc.
Example: Pen

- **Purpose/Dharm**: To transport human beings from one place to another place

- **Feature/Rupa**
  - Cylindrical shape
    - Purpose: In order to hold the pen comfortably
  - Pointed tip
    - Purpose: In order to put mark on the paper
## Dictionaries and Encyclopaedia

<table>
<thead>
<tr>
<th>Resources</th>
<th>Artifact</th>
<th>Defined as</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WordNet</strong></td>
<td>Fork</td>
<td>Cutlery used for <strong>serving and eating food</strong></td>
</tr>
<tr>
<td></td>
<td>Knife</td>
<td>Edge tool used as a <strong>cutting instrument</strong></td>
</tr>
<tr>
<td><strong>Wikipedia</strong></td>
<td>Chair</td>
<td>A raised surface, commonly <strong>for use by one person</strong></td>
</tr>
<tr>
<td></td>
<td>Wall</td>
<td>A vertical structure, usually solid, that <strong>defines and sometimes protects an area</strong></td>
</tr>
<tr>
<td><strong>Cambridge Dictionary</strong></td>
<td>Telephone</td>
<td>A device <strong>for speaking to someone in another place by means of electrical signals</strong></td>
</tr>
<tr>
<td></td>
<td>Rack</td>
<td>A frame, often with bars or hooks, <strong>for holding or hanging things</strong></td>
</tr>
</tbody>
</table>
Artifacts: Structure

• Structure: Parts put together in an organized way

• Related with the purpose
  – Parts have sub-purpose in turn
  – Each sub-purpose relates to the purpose

• Actions relate parts and purpose together
Architecture of PurposeNet
Architecture of PurposeNet

INSTANCE
NONCOMPOEXTRA
CORE COMPONENT
SUBTYPE

ARTIFACT

NAME | ALIAS | DESCRIPTION | PROPERTIES

FEATURES

DESCRIPTOR FEATURES

ACTION FEATURES

MAKE/BIRTH

PURPOSE

LIFE

DESTRUCTION
# Action Frame

**Artifact:** Car :: Purpose - Transport_Thing

<table>
<thead>
<tr>
<th>No</th>
<th>Action Frame Element</th>
<th>Value(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Precondition</td>
<td>Exists_Car_at_Source&lt;br&gt;Exists_Thing_Near_Car</td>
</tr>
<tr>
<td>2</td>
<td>Outcome</td>
<td>Result: Change_Position (Thing) &lt;br&gt;Side Effect: Change_Position (Car)&lt;br&gt;Change_Position (Driver) &lt;br&gt;Wear-and-tear: Worn_out(Engine)&lt;br&gt;Worn_out(Tyre)</td>
</tr>
<tr>
<td>3</td>
<td>Subactions</td>
<td>Load(Thing)&lt;br&gt;Drive(Car)&lt;br&gt;Unload(Thing)</td>
</tr>
<tr>
<td>4</td>
<td>Theta Roles</td>
<td>Theme – Thing&lt;br&gt;Source – Place&lt;br&gt;Destination – Place&lt;br&gt;Instrument – Car</td>
</tr>
</tbody>
</table>

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## Descriptor Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Definition</th>
<th>Value</th>
<th>Example: Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Produces different sensations on the eye due to Light</td>
<td>Red, Blue, Green, Cyan, Indigo, Pink, Orange, Black, White, Any</td>
<td>Any</td>
</tr>
<tr>
<td>Constitution</td>
<td>Material made of</td>
<td>Metal, rubber, wood, foam, plastic, glass</td>
<td>Metal</td>
</tr>
<tr>
<td>Shape</td>
<td>External appearance</td>
<td>Cubical, Oval, Triangular, Circular, Spherical, Aero, Any</td>
<td>Aerodynamic</td>
</tr>
<tr>
<td>Size</td>
<td>Amount of space occupied</td>
<td>Microscopic, very small, small, medium, large, any</td>
<td>Moderate_Size</td>
</tr>
<tr>
<td>State</td>
<td>Usual physical state</td>
<td>Solid, liquid, gas</td>
<td>Solid</td>
</tr>
</tbody>
</table>
... Relationships

CAR
... Relationships
... Relationships
... Relationships
... Relationships
... Relationships
... Relationships

- MUSIC_SYSTEM
  - AIR_CONDITIONER
    - SEAT
- NON-PURPOSE DRIVEN ACCESSORY
  - ACCESSORY
    - PURPOSE DRIVEN ACCESSORY
      - REAR-VIEW-MIRROR
        - GEAR
- SUBTYPE
  - AMBASSADOR
    - FIAT
    - LIMO
  - JEEP
- CAR
  - CORE COMPONENT
    - WHEEL
    - FUEL_TANK
      - FUEL
      - ROAD
  - NONCOMPOEXTRA
    - ENGINE
    - BRAKE
Building the knowledge base
Building the knowledge base

• Manual:
  – Labour intensive,
  – Time consuming,
  – Accurate

• Semi-Automatic:
  – Scalable,
  – Corpus dependent: web or static corpus
  – Requires manual checking

• Crowd-Sourcing:
  – Scalable,
  – Independent of data resource
  – Requires manual checking
Crowd-Sourcing
Detection and Extraction of Purpose

Experiments for detecting purpose data in text

<table>
<thead>
<tr>
<th>Sno</th>
<th>Method</th>
<th>Precision</th>
<th>Recall</th>
<th>F-Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Typed dependency</td>
<td>0.84</td>
<td>0.68</td>
<td>0.751</td>
</tr>
<tr>
<td>2</td>
<td>Simple Decision Tree</td>
<td>0.83</td>
<td>0.67</td>
<td>0.74</td>
</tr>
<tr>
<td>3</td>
<td>Decision Tree Forest</td>
<td>0.679</td>
<td>0.644</td>
<td>0.661</td>
</tr>
<tr>
<td>4</td>
<td>Bagging</td>
<td>0.755</td>
<td>0.619</td>
<td>0.68</td>
</tr>
<tr>
<td>5</td>
<td>Naïve Bayes</td>
<td>0.7</td>
<td>0.638</td>
<td>0.668</td>
</tr>
<tr>
<td>6</td>
<td>Bayes Net</td>
<td>0.699</td>
<td>0.639</td>
<td>0.668</td>
</tr>
<tr>
<td>7</td>
<td>RBF Neural Network</td>
<td>0.679</td>
<td>0.595</td>
<td>0.634</td>
</tr>
<tr>
<td>8</td>
<td>SVM</td>
<td>0.694</td>
<td>0.639</td>
<td>0.665</td>
</tr>
</tbody>
</table>
Detection and Extraction of Purpose

Experiments for extracting artifact, action pair from sentence containing purpose

<table>
<thead>
<tr>
<th>Method</th>
<th>Precision for extraction of (artifact, action) pair given purpose-containing sentences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface text patterns</td>
<td>88</td>
</tr>
<tr>
<td>Typed dependency parse</td>
<td>98.1</td>
</tr>
</tbody>
</table>
Application
Application: Domain Specific QA System for Hindi

For a given question in a specific domain, answer the question as precisely as possible.

The knowledgebase is deemed to be a conceptual representation of the domain.

The Ontology and the questions expected are in different languages (cross-lingual answer retrieval)
<table>
<thead>
<tr>
<th>Type of Questions</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>kab (Factoid single answer question)</td>
<td><em>Hyderabad se Secunderabad ki train kab jaegi?</em></td>
</tr>
<tr>
<td>kahan kahan (Factoid list answer question)</td>
<td><em>Hyderabad se Secunderabad ki train kahan kahan rukti hai?</em></td>
</tr>
<tr>
<td>Kaise (Reasoning question)</td>
<td><em>Ticket kaise khraidi jati hai?</em></td>
</tr>
<tr>
<td>kyun (Causal – Reasoning question)</td>
<td><em>Train chal kyun nahi rahi hai?</em></td>
</tr>
<tr>
<td>kya (Description/Boolean)</td>
<td><em>MMTS train hai kya?</em></td>
</tr>
</tbody>
</table>
Q. falaknuma se lingampally tak jane wali gadi bharatnagar par kab pahunchti hai?
Q. falaknuma se lingampally tak jane wali gaaDI bharatnagar par kab pahunchti hai?

identify the question word: kab
Q. falaknuma se lingampally tak jane wali gaaDI bharatnagar par kab pahunchti hai?

identify the question word: kitne baje

identified as a factoid question type
Q. falaknuma se lingampally tak jane wali gadi bharatnagar par kab pahunchti hai?

identify the question word: kitne baje

identified as a factoid question type

Falaknuma_se_lingampally_tak_ja_wali_gadi_bharatnagar_par_kab_pahunch_hai?
Q. falaknuma se lingampally tak jane wali gaaDI bharatnagar par kab pahunchti hai?

identify the question word: kitne baje

identified as a factoid question type

falaknuma se lingampally ja wali gadi bharatnagar par kitna baj pahunch hai?

some arguments assumed like the person is talking about the first train from now.
Q. falaknuma se lingampally tak jane wali gaaDI bharatnagar par kab pahunchti hai?

identify the question word: kitne baje

identified as a factoid question type

falaknuma se lingampally ja wali gadi bharatnagar par kitna baj pahunch hai?

some arguments assumed like the person is talking about the first train from now.

source - falaknuma (se);
at station - bharatnagar (par);
Q. falaknuma se lingampally tak jane wali gaaDI bharatnagar par kab pahunchti hai?

identify the question word: kitne baje

identified as a factoid question type

falaknuma se lingampally ja wali gadi bharatnagar par kitna baj pahunch hai?

some arguments assumed like the person is talking about the first train from now.

source - falaknuma (se);
destination - lingampally (jane wali);
at station - bharatnagar (par);

identify the sparql query which enquires the time and fill in these arguments to the sparql query
Q. falaknuma se lingampally tak jane wali gaaDI bharatnagar par kab pahunchti hai?

identify the question word: kitne baje

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source - falaknuma (se);
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6:30
Q. falaknuma se lingampally tak jane wali gaaDII bharatnagar par kitne baje pahunchti hai?
Identify the question word: kitne baje

Identified as a factoid question type

falaknuma se lingampally ja wali gadi bharatnagar par kitna baj pahunch hai?

Some arguments assumed like the person is talking about the first train from now.

Source - falaknuma (se);
Destination - lingampally (jane wali);
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Identify the sparql query which enquires the time and fill in these arguments to the sparql query

6:30

_ se _ tak ki _ gadi _ _ itne baje hai
falaknuma se lingampally jane wali gadi bharatnagar par kitne baje pahunchti hai?

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6:30

_ se_ tak ki_ gadi _ itne baje hai

falaknuma se lingampally tak ki gadi bharatnagar par itne inte baje pahunchti hai
Sparql Query

Q. falaknuma se lingampally jane wali gadi bharatnagar par kitne baje pahunchti hai?

```
SELECT ?deptime
WHERE {
    SELECT (MIN(?time) AS ?deptime)
    WHERE {
        :source(?trav, "Falaknuma")
        :dest(?trav, "Lingampally")
        :departureTime(?trav, ?time1)
        :byTrain(?trav, ?t)
    }
    GROUP BY ?t
}
```
Q. falaknuma se lingampally jane wali gadi bharatnagar par kitne baje pahunchti hai?

```
SELECT ?deptime
WHERE {
  SELECT (MIN(?time) AS ?deptime)
  WHERE {
    :source(?)trav, "Falaknuma")
    :dest(?)trav, "Lingampally")
    :departureTime(?)trav, ?time
    :byTrain(?)trav, ?t
  } GROUP BY ?t
}
```

7/4/2014
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  WHERE {
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7/4/2014
IASNLP 2014
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    :departureTime(?trav, ?time1)
    :byTrain(?trav, ?t)
  }
  GROUP BY ?t
}

5:45
6:15
6:30
6:45
Q. falaknuma se lingampally jane wali gadi bharatnagar par kitne baje pahunchti hai?

SELECT ?deptime
WHERE {
  SELECT (MIN(?time) AS ?deptime)
  WHERE {
    :source(?trav, "Falaknuma")
    :dest(?trav, "Lingampally")
    :departureTime(?trav, ?time1)
    :byTrain(?trav, ?t)
  }
  GROUP BY ?t
}

14567
12342
21345
36243

5:45
6:15
6:30
6:45
Q. falaknuma se lingampally jane wali gadi bharatnagar par kitne baje pahunchti hai?

```
SELECT ?deptime
WHERE {
  SELECT (MIN(?time) AS ?deptime)
  WHERE {
    :source(?trav, "Falaknuma")
    :dest(?trav, "Lingampally")
    :departureTime(?trav, ?time1)
    :byTrain(?trav, ?t)
  }
  GROUP BY ?t
}
```
Q. ticket kaise kharidi jaati hai?
Q. ticket kaise kharidi jaati hai?

identify the question word: kaise
Q. ticket kaise kharidi jaati hai?

identify the question word: kaise

identified as a reasoning question type
Q. ticket kaise kharidi jaati hai?

identify the question word: kaise

identified as a reasoning question type

v:kharid k2:ticket
Build a graph around the main action

- **Buy MMTS Ticket**
  - Outcome: have Ticket
  - Subaction:
    - **Pay Money**
      - Precondition: have Money
      - Outcome: paid Money
    - **Receive Ticket**
      - Precondition: paid Money
      - Outcome: have Ticket
Convert the graph to DAG

- Buy MMTS Ticket
- have Ticket
- Pay Money
- Receive Ticket
- have Money
- paid Money
- have Money
Topologically sort the DAG

1. have Money
2. paid Money
3. Pay Money
4. Receive Ticket
5. have Ticket
6. Buy MMTS Ticket
Q. ticket kaise kharidi jaati hai?

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v:kharid k2:ticket

BuyMMTSTicket

Paise dein, Ticket lein, Ticket kharidein
## Application

### Experiment and Result

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Total Questions</th>
<th>Questions Answered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factoid single-answer questions</td>
<td>38</td>
<td>32</td>
</tr>
<tr>
<td>Factoid list-answer questions</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Reasoning Type questions</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Description Type questions</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Boolean Type questions</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Input: Random questions from users
Analysis

Of the 11 unanswered questions

– frames of 5 question were were not formed. eg.
  • lingampally se falaknuma ki agli gaadi mein kya ladies coach hai?
– 3 question could not be linguistically parsed. eg.
  • lingampally se falaknuma kaun kaun si train kitne kitne baaje jaati hai?
– information for 3 questions was not present In the ontology. eg.
  • lingampally se falaknuma ki agli train kitni late hai?
Summary

• PurposeNet is a knowledgebase of artifacts that present
  – Properties of artifacts,
  – Their relationship with other artifacts and
  – Actions in which they participate
• Purpose is the organizing principle
• Experimental results in domain-specific question answering using PurposeNet produces promising results.
Acknowledgement

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