Textual Entailment
&
It's Application in QA

Partha Pakray

My Education Career

- Bachelor of Engineering, Computer Science & Engineering, Jalpaiguri Govt. Engineering College, 2000-2004, **INDIA**

- Master of Engineering, Computer Science & Engineering, Jadavpur University, 2005-2007, **INDIA**

  Maters Thesis: "***MULTILINGUAL RESTRICTED DOMAIN QA SYSTEM WITH DIALOGUE MANAGEMENT (BENGALI AND TELUGU AS A CASE STUDY)***"

- PhD(Engineering), Computer Science & Engineering Dept., Jadavpur University, 2009-2013, **INDIA**

  Supervisors: Prof Sivaji Bandyopadhyay and Prof Alexander Gelbukh

  Doctoral Thesis: "***Answer Validation through Textual Entailment***"

My Work Career

- **Research Intern**, Semantics & Parsem Group, ***Xerox Research Center Europe*** (XRCE), Grenoble, **FRANCE.** [May- Oct, 2012]

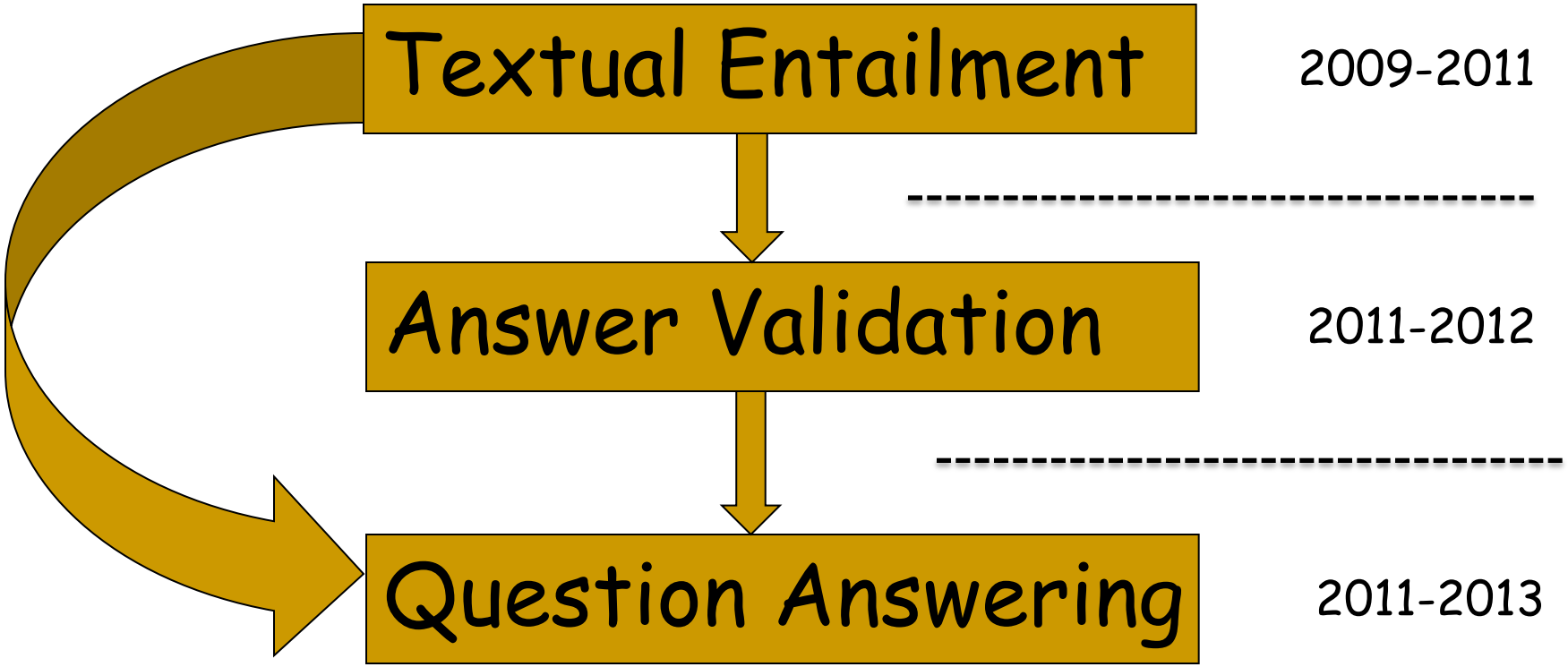
- Worked as a **Senior Research Engineer** at ***Jadavpur University*** in Indian Languages Search Engine project "*Cross Lingual Information Access*" sponsored by Govt. of India, **INDIA**. [2008-2012]

- Worked as a **Research Engineer** in ***National Polytechnic Institute (IPN), Mexico*** in Project "*Answer Validation through Textual Entailment*" as a Bilateral Programme between Govt. of India and Conacyt, Mexico and worked in IPN, **MEXICO**. [Nov-Dec, 2011 and June-July, 2013]. (Under Prof Alexander Gelbukh)

- **Post Doctoral Fellow**, Computer and Information system, ***Norwegian University of Science and Technology***, (ERCIM Marie-curie Fellowship ABCDE Programme August, 2013 - July, 2014). **NORWAY**.
- Now, I am here as a Post Doctoral Researcher.

Research Interests

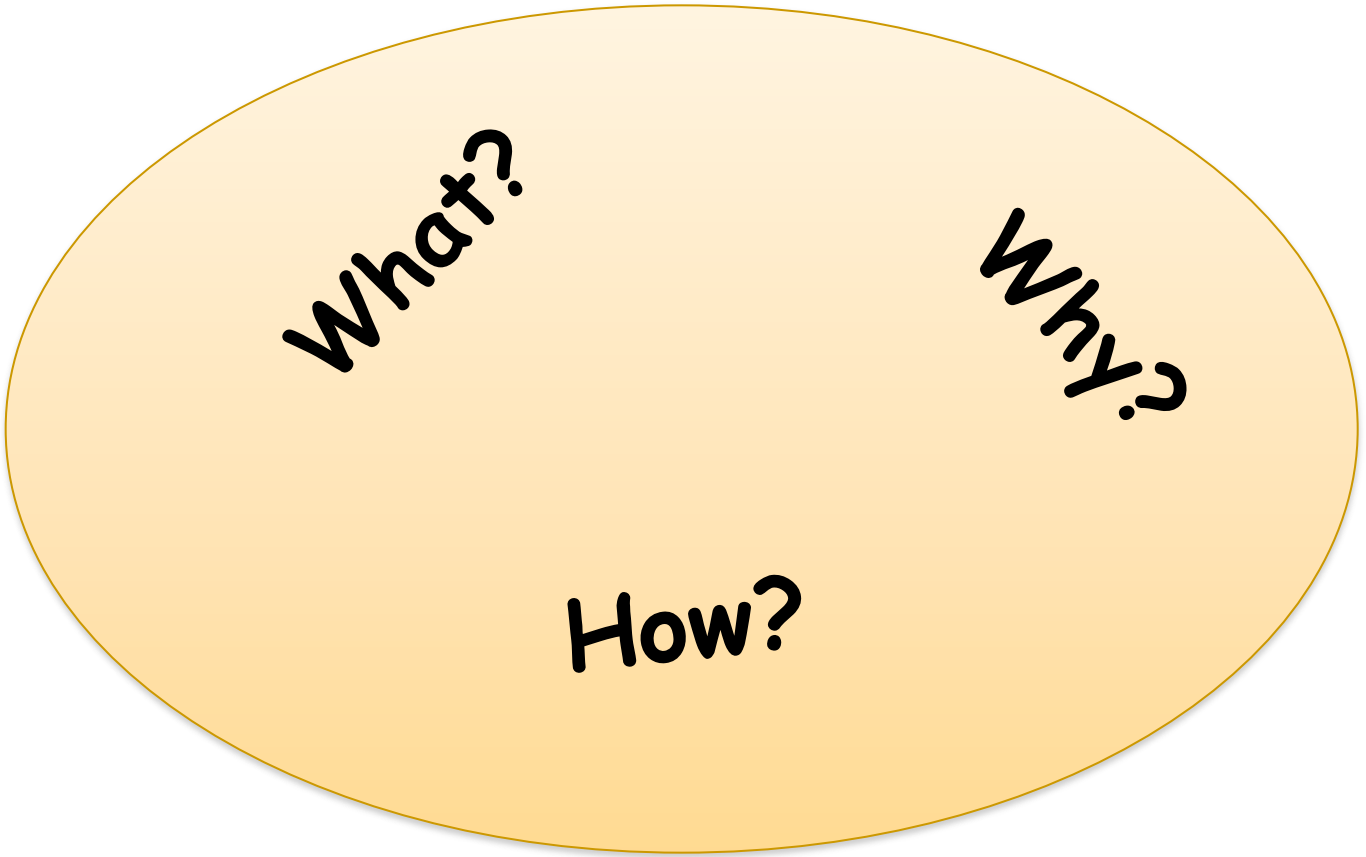
- Textual Entailment
- Question Answering
- Answer Validation
- Case Based Reasoning
- Transliteration (e.g. Indian Languages)
- Information Retrieval
- Causal Sentence Identification


Textual Entailment
2009-2011
Answer Validation
2011-2012
Question Answering
2011-2013

Outline

- Textual Entailment
- Lexical Entailment
- Syntactic Entailment
- Semantic Entailment
- Entailment Classification
- Application: Answer Validation
- Application: Question Answering

Textual Entailment


What?
Why?
How?

Textual Entailment

Recognizing Textual Entailment (RTE) is one of the recent challenges of Natural Language Processing (NLP).

Textual Entailment: directional relationship between two texts, denoted by the entailing "Text" (T) and the entailed "Hypothesis" (H).

T entails H if the meaning of H can be inferred from the meaning of T.

For Entailment cases: H is simply a paraphrase of all or part of T.

Examples

Positive Entailment (Entailment Class: "**True**")
Text: iTunes software has seen strong sales in Europe.
Hypothesis: Strong sales for iTunes in Europe.

Negative Entailment (Entailment Class: "**False**")
Text: After the deal closes, Teva will earn about $7 billion a year, the company said.
Hypothesis: Teva earns $7.5 billion a year.

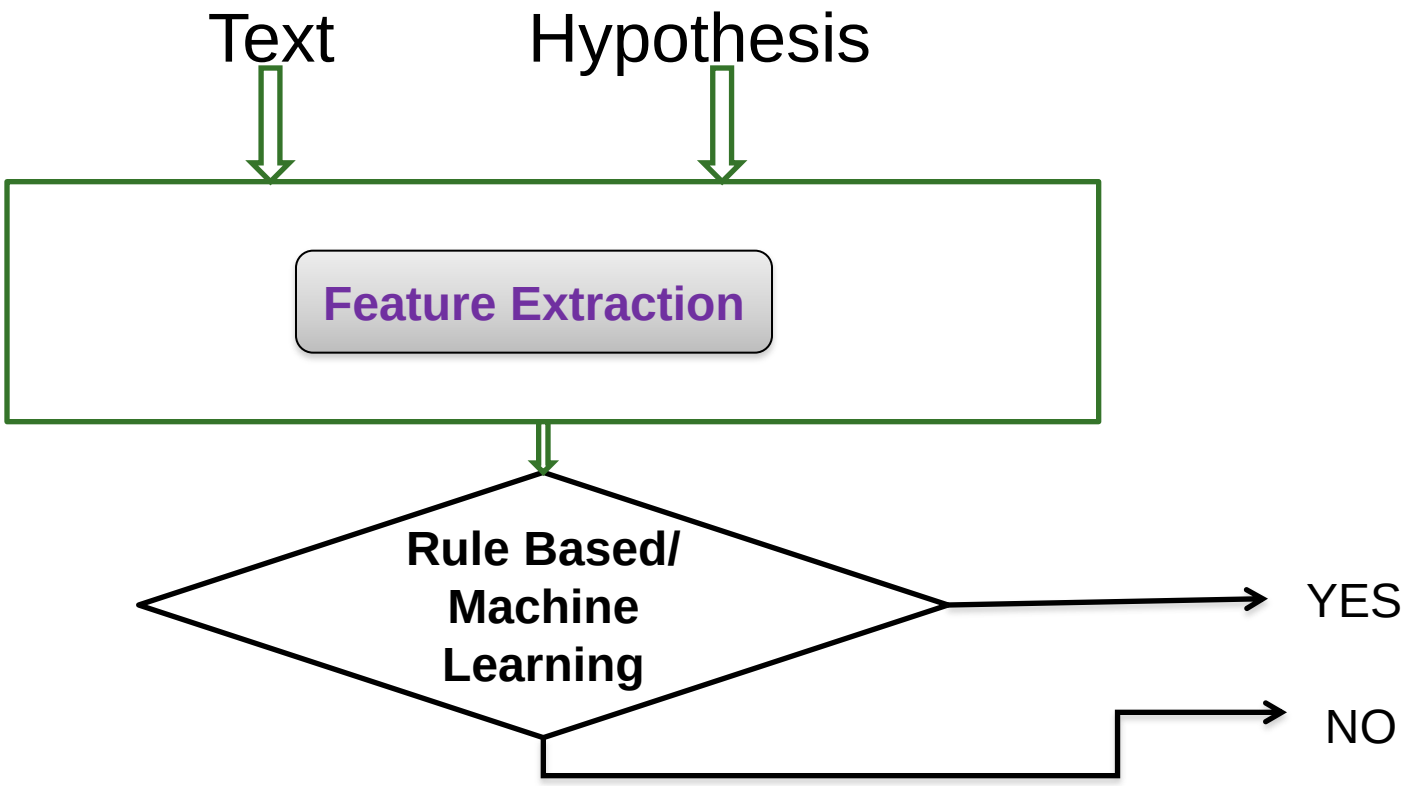
Application of Textual Entailment

- **Question Answering (QA)**
- **Paraphrases (PP)**
- **Summarization (SUM)**
- **Machine Translation (MT)**

Approaches

- Lexical Entailment
- Syntactic Entailment
- Semantic Entailment

System Architecture



Example

Lexical: *Smith bought a book.* ⇨ *Smith purchased a book.*

Syntactic: *Ram was singing and dancing.* ⇨ *Ram was dancing.*

Semantic: *Eric married Mary.* ⇨ *Mary married Eric.*

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Lexical Entailment

$$\text{Weight} = \frac{\text{Number of common [\#] between text and hypothesis}}{\text{Number of [\#] in hypothesis}}$$

1. Unigram Matching
2. Unigram with WordNet Matching
3. Bigram Matching
4. Stemmed Unigram Matching
5. Named Entity Matching
6. Lexical Distance Measure

Unigram Matching

Text (T)	Hypothesis (H)
A whale that became stranded in the River Thames has died after a massive rescue attempt to save its life. The 18ft (5m) northern bottle-nosed whale was first spotted in the river on Friday and rescuers began an attempt to save it on Saturday morning. But the whale died at about 1900 GMT on Saturday as rescuers transported it on a barge towards deeper water in the Thames Estuary.	A whale died in the River Thames.

Common Unigrams	whale, died, River, Thames

Unigram with WordNet Matching

Text (T)	Hypothesis (H)
Smith bought a book.	Smith purchased a book.

Common Unigrams	Smith, book
WordNet Matching	bought=purchase

WordNet: Synonym Dictionary for English.

Lexical Distance Matching

- **Vector Space Measures**: Euclidean distance, Block distance, Minkowsky distance, Cosine similarity
- **Set-based Similarities:** Dice, Jaccard, Overlap
- **Edit Distance Measures**: Levenshtein distance, Smith-Waterman distance, Jaro distance

Lexical distance measurement libraries: Soft Cardinality, SimMetrics, SimPack and SecondString.

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Lexical textual entailment = Lexical level

Syntactic textual entailment = Syntactic level e.g. structural paraphrasing between two texts.

For example:

1. **active - passive changes** between two texts.
2. **Auxiliary Reduction**: Example, “Ahmedinejad was attacked by the US” => “the US attacked Ahmedinejad”
3. **Copula Reduction**: Example, “Microsoft Corp. is a partner of Intel Corp.” => “Microsoft Corp., a partner of Intel Corp.”

Syntactic Textual Entailment

Input: Pairs of dependency relations of text snippets (text and hypothesis)

Output: “YES” if the text entails the hypothesis and “NO” otherwise.

Parser generally used: Stanford Dependency Parser and C&C Combinatory Categorical Grammar (CCG) Parser.

Output of Stanford Dependency Parser

Sentence	Nigeria seizes 80 tonnes of drugs
Output	[**nsubj** (seizes, Nigeria), **num** (tonnes, 80), **dobj** (seizes, tonnes), **prep_of** (tonnes, drugs)]

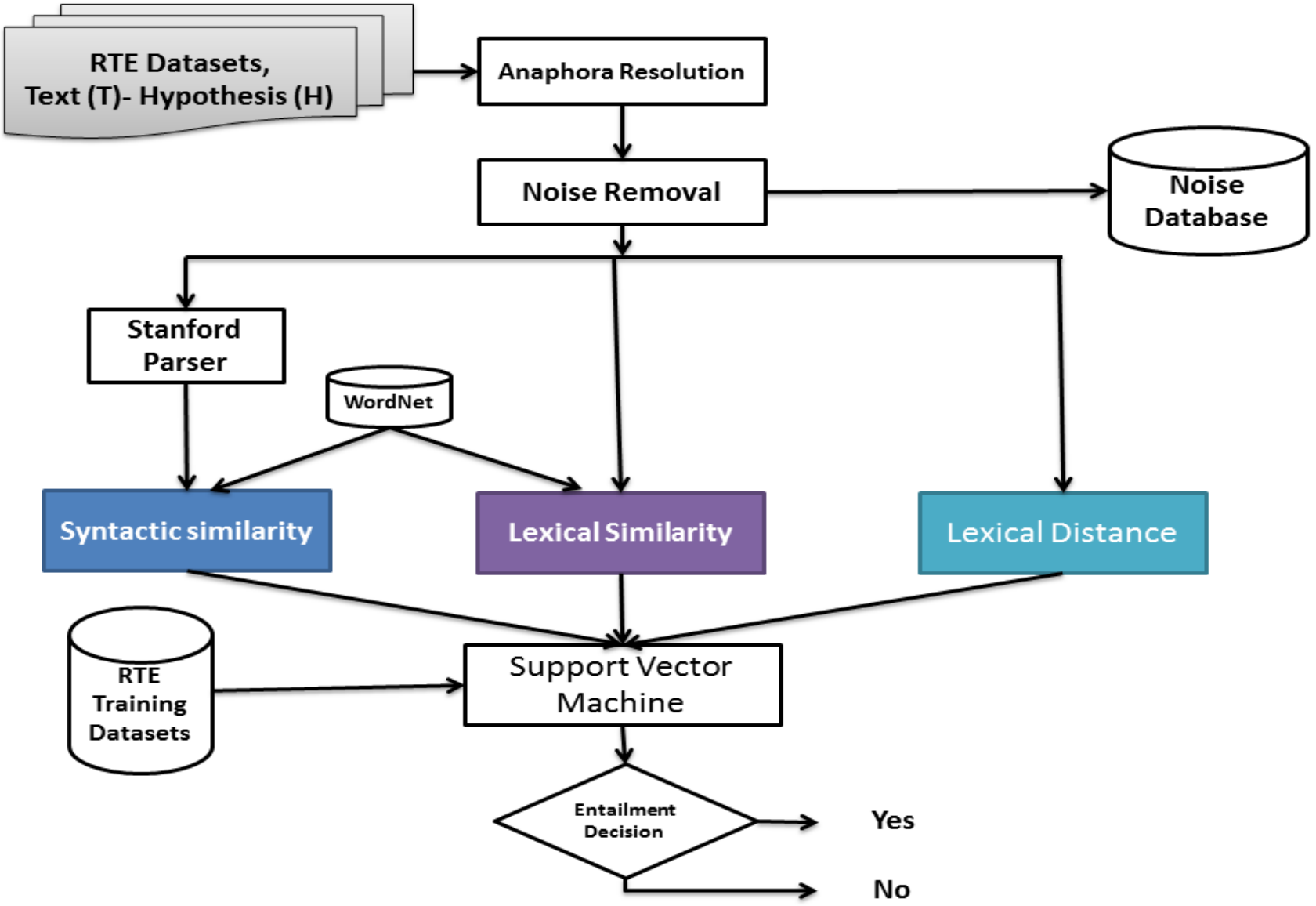
Example

Text	Hypothesis
One species of ambiguity tries to baffle by interweaving repetition.	**One species tries to baffle.**
num species One nsubj tries species prep_of species ambiguity aux baffle to xcomp tries baffle prepc_by baffle interweaving dobj interweaving repetition	num species One nsubj tries species aux baffle to xcomp tries baffle

Comparison of Dependency Relations

i. Comparison of Subject-Subject
ii. Comparison of WordNet Based Subject-Verb
iii. Comparison of Object-Verb
iv. Comparison of WordNet Based Object-Verb
v. Comparison of Cross Subject-Object
vi. Comparison of Number
vii. Comparison of Noun
viii. Comparison of Prepositional Phrase

System Architecture



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Semantic Textual Entailment

Universal Networking Language (UNL) Knowledge Representation in the form of semantic network with nodes.

Enconversion: Natural language sentences to UNL graphs.
Deconversion: UNL graphs to natural language sentence.

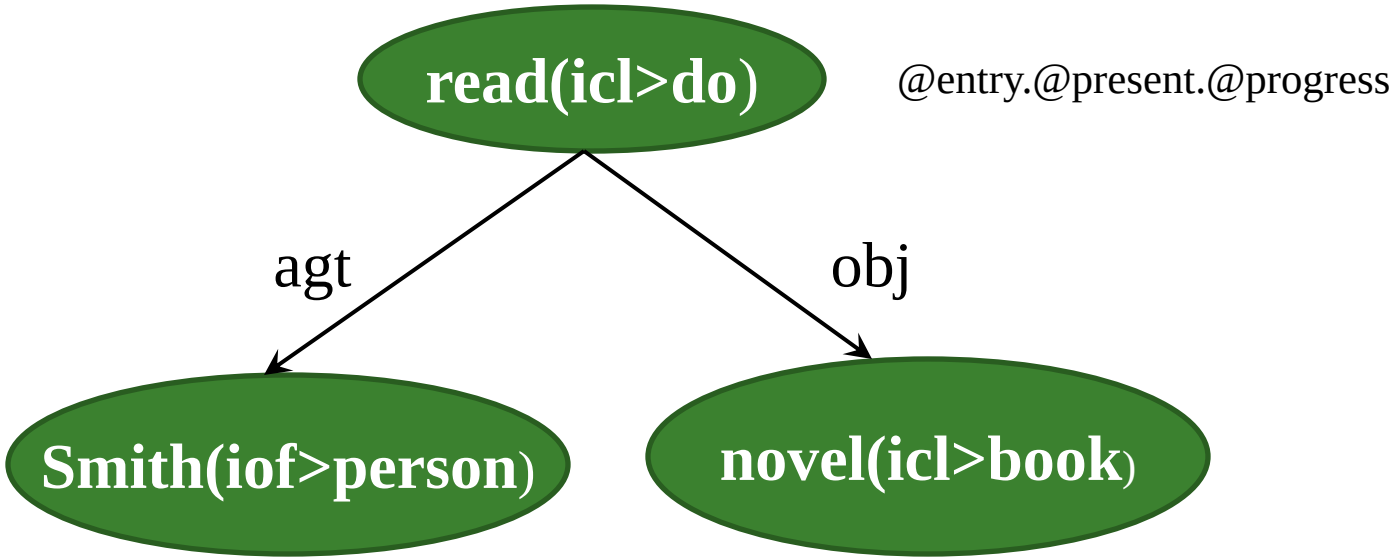
UNL format:

[Relation Name] [Relation Scope ID] {[UW1][UW1 Scope id], [UW2][UW2 Scope id]}

UNL Features : Relations, Concept words (Universal Words) and Attributes.

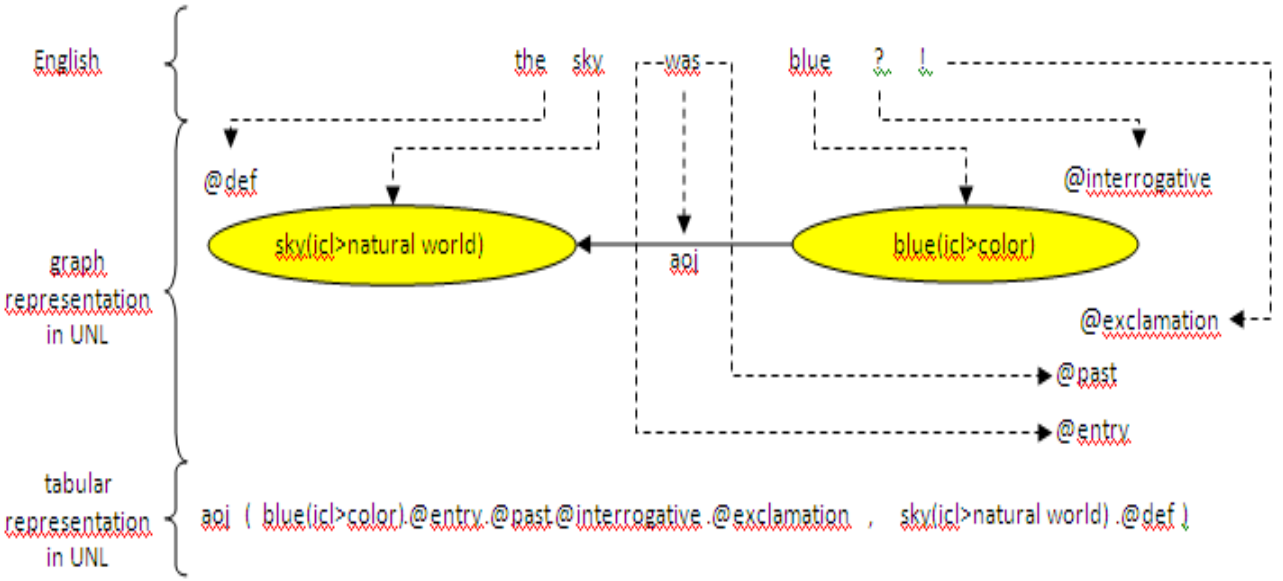
UNL Expression

- Smith is reading a novel.
- UNL Hypergraph



UNL Expression
[UNL]
agt(read(icl>do) @entry.@present.@progress, Smith(iof>person))
obj(read(icl>do) @entry.@present.@progress, novel(icl>book))
[/UNL]

UNL Example

Sentence	The sky was blue?
Semantic Representation of UNL	

EnConverter Module

[S:00]
{org:en}
Pfizer is accused of murdering 11 children {/org}
{unl}

obj(accuse(icl>do,equ>charge,cob>abstract_thing,agt>person,obj>person).@entry.@present,pfizer.@topic)

qua:01(child(icl>juvenile>thing).@pl,11)

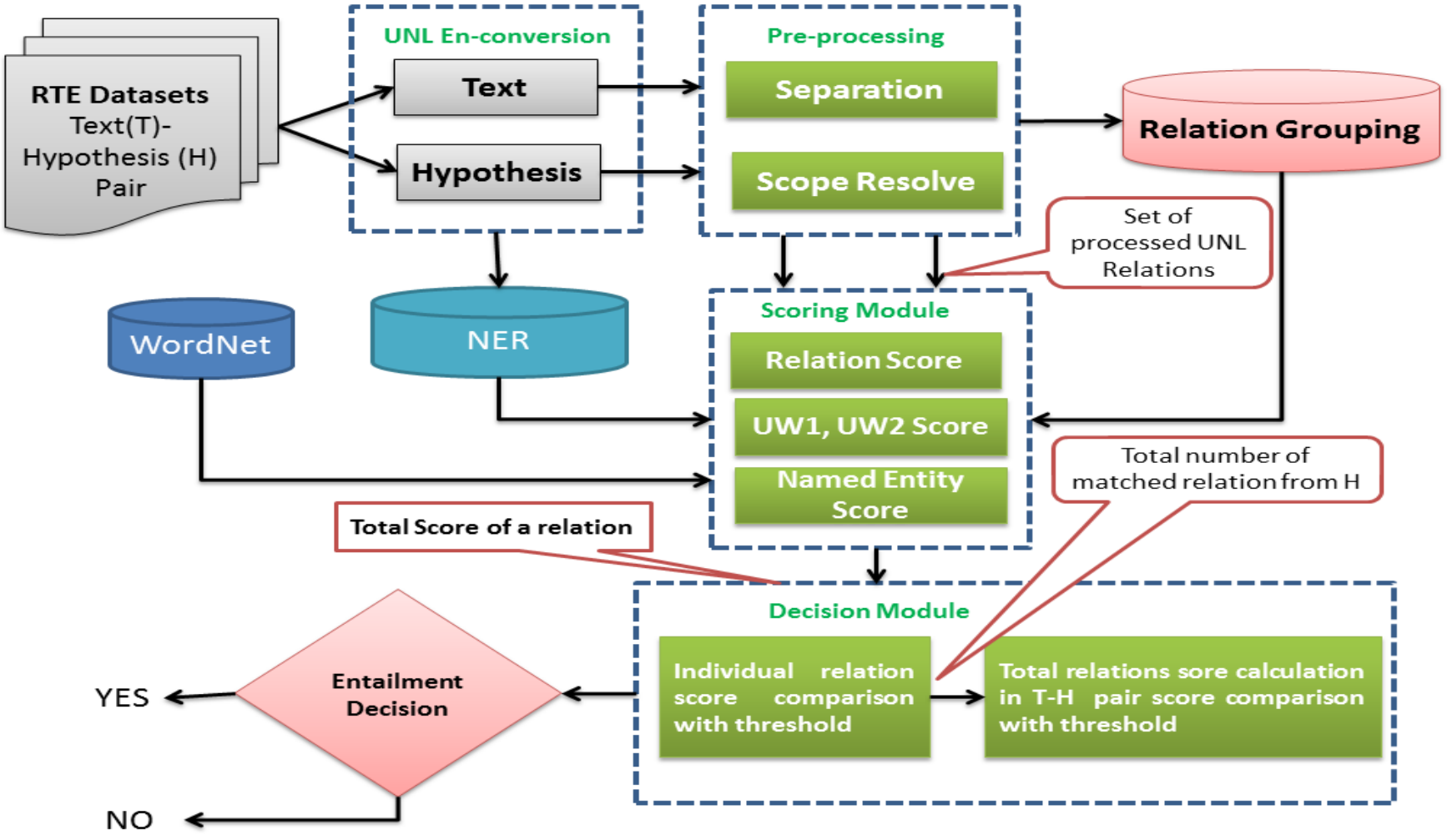
obj:01(murder(icl>kill>do,agt>thing,obj>living_thing).@entry,child(icl>juvenile>thing).@pl)

cob(accuse(icl>do,equ>charge,cob>abstract_thing,agt>person,obj>person).@entry.@present,:01)

{/unl}

[/S]

System Architecture



Pre-processing Module

Separation Module: Extraction individual UWs from T and H.

[Relation Name] [Relation Scope ID]
{[UW1][UW1 Scope id], [UW2][UW2 Scope id]}

Relation Grouping Module: [46 Relations in UNL]

Group Name	Relations
Agent	agt, cag, aoj, cao, ptn
Object	obj, cob, opl, ben
Place	plc, plf, plt
Instrument	ins, met
State	src, gol, via
Time	tim, tmf, tmt, dur
Manner	man, bas
Logical	and, or
Concept	equ, icl,iof
Cause	con, pur, rsn
Sequence	coo, seq, cnt, mod, nam, per, pof, pos, qua

Scoring Module

The rules are

i. Relation grouping rule
ii. UW Rule
iii. Name Entity Rule

Dataset used for Experiments

Recognizing Textual Entailment (RTE) competitions

i. RTE-1 in 2005
ii. RTE-2 in 2006
iii. RTE-3 in 2007
iv. RTE-4 in 2008
v. RTE-5 in 2009
vi. RTE-6 in 2010
vii. RTE-7 in 2011

Experiment Results

RTE DATA	F-SCORE (%)
RTE-1 Development Set	0.61
RTE-1 Test Set	0.63
RTE-2 Development Set	0.56
RTE-2 Test Set	0.61
RTE-3 Development Set	0.59
RTE-3 Test Set	0.68
RTE-4 Test Set	0.69
RTE-5 Development Set	0.58
RTE-5 Test Set	0.65

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Entailment Class

Before:

Yes / No

Now :

Entailment Class	Termed As	Definition
Forward Entailment	F	t1 entails t2 AND t2 does not entail t1
Reverse Entailment	R	t2 entails t1 AND t1 does not entail t2
Bidirectional Entailment	B	t1 entails t2 AND t2 entails t1
Contradiction	C	t1 and t2 contradict or cannot be true at the same time

Before:

- **Monolingual**: Text and Hypothesis is in Same language., i.e. English

Now:

- **Multilingual / Cross-lingual**: Text is in one Language i.e. in Spanish and Hypothesis is in another language i.e. English

Example

Entailment Class: **Bidirectional**

Text (t1): Mozart nació en la ciudad de Salzburgo.

[Google Trns: Mozart was born in Salzburg.]

Text (t2): Mozart was born in Salzburg.

Entailment Class: **Forward**

Text (t1): Mozart nació el 27 de enero de 1756 en Salzburgo.

[Google Trns: Mozart was born on January 27, 1756 in Salzburg.]

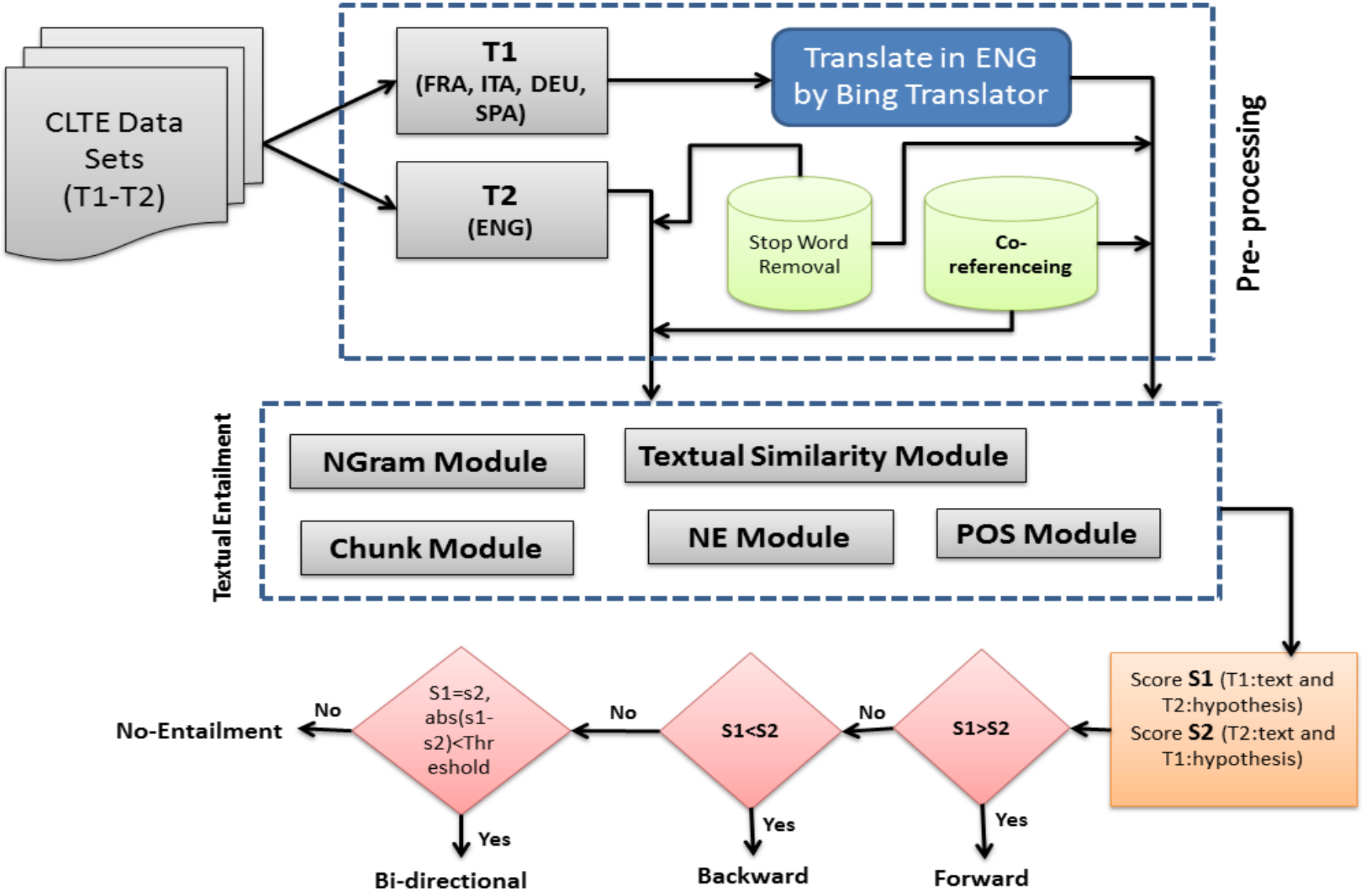
Text (t2): Mozart was born in 1756 in the city of Salzburg.

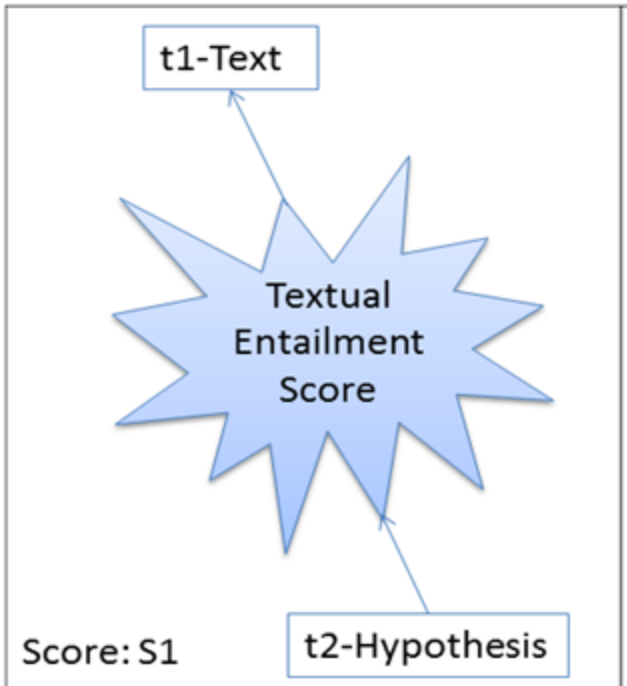
Entailment Class: **Backward**

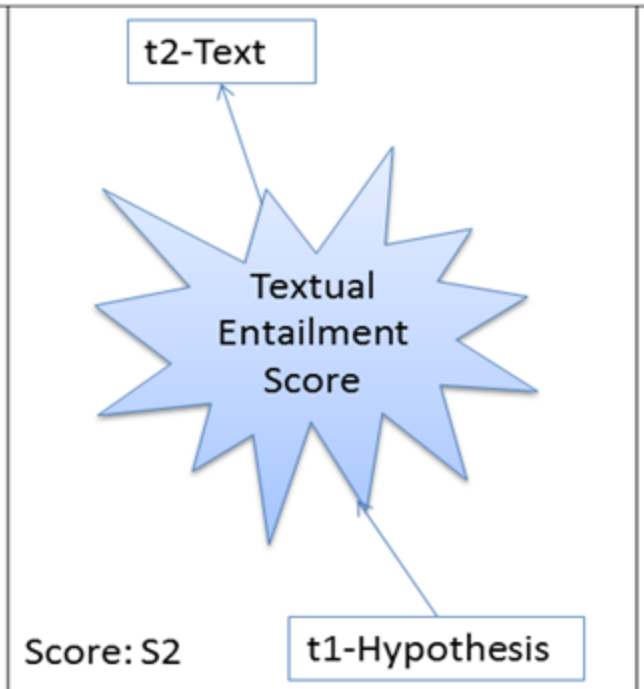
Text (t1): Mozart nació en la ciudad de Salzburgo.

[Google Trns: Mozart was born in Salzburg.]

Text (t2): Mozart was born on 27th January 1756 in Salzburg.


CLTE Data Sets (T1-T2)
T1 (FRA, ITA, DEU, SPA)
T2 (ENG)
Translate in ENG by Bing Translator
Stop Word Removal
Co-referenceing
Pre- processing
Textual Entailment
NGram Module
Textual Similarity Module
Chunk Module
NE Module
POS Module
Score S1 (T1:text and T2:hypothesis)
Score S2 (T2:text and T1:hypothesis)
S1>S2
S1<S2
S1=s2, abs(s1-s2)<Threshold
No
Yes
Forward
Backward
Bi-directional
No-Entailment





ENTAILMENT CLASS

Score (S1)	Score (S2)	
71.341211	62.14211	FORWARD
54.662555	58.65433	BACKWARD
73.382333	73.63452	BIDIRECTIONAL
53.424452	12.56666	CONTRADICTION

Dataset@Evaluation Track

- NTCIR-9 Recognizing Inference in TExt (RITE) Tasks in 2011 and 2012
- Cross-lingual Textual Entailment for Content Synchronization in SemEval-2012 and SemEval-2013

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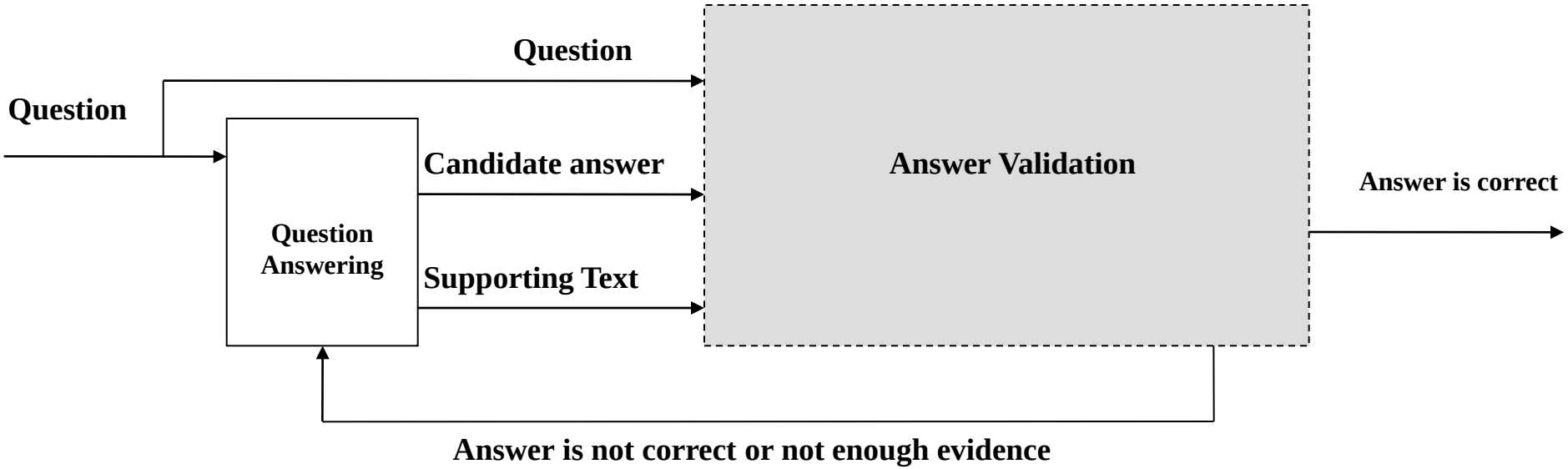
Application: Answer Validation

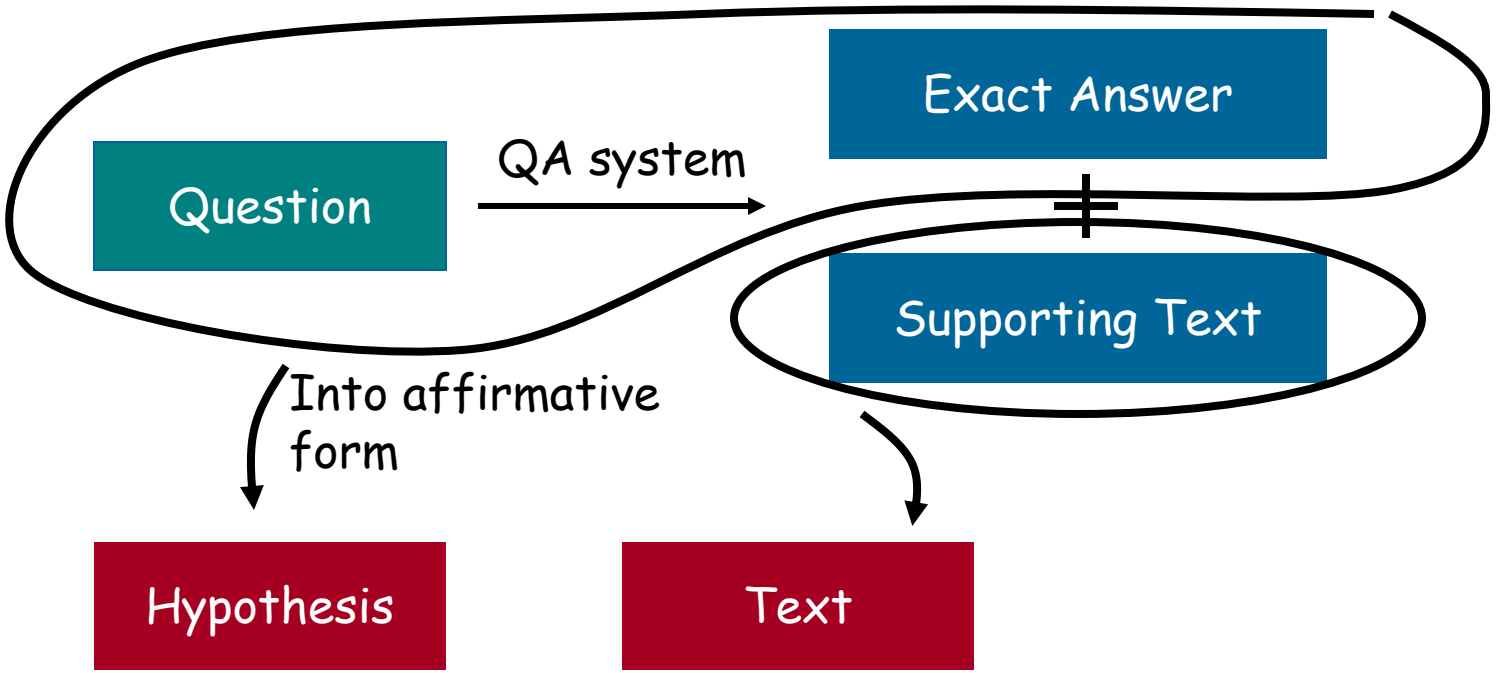
Question Answering

Find the answer to a question in a large collection of documents

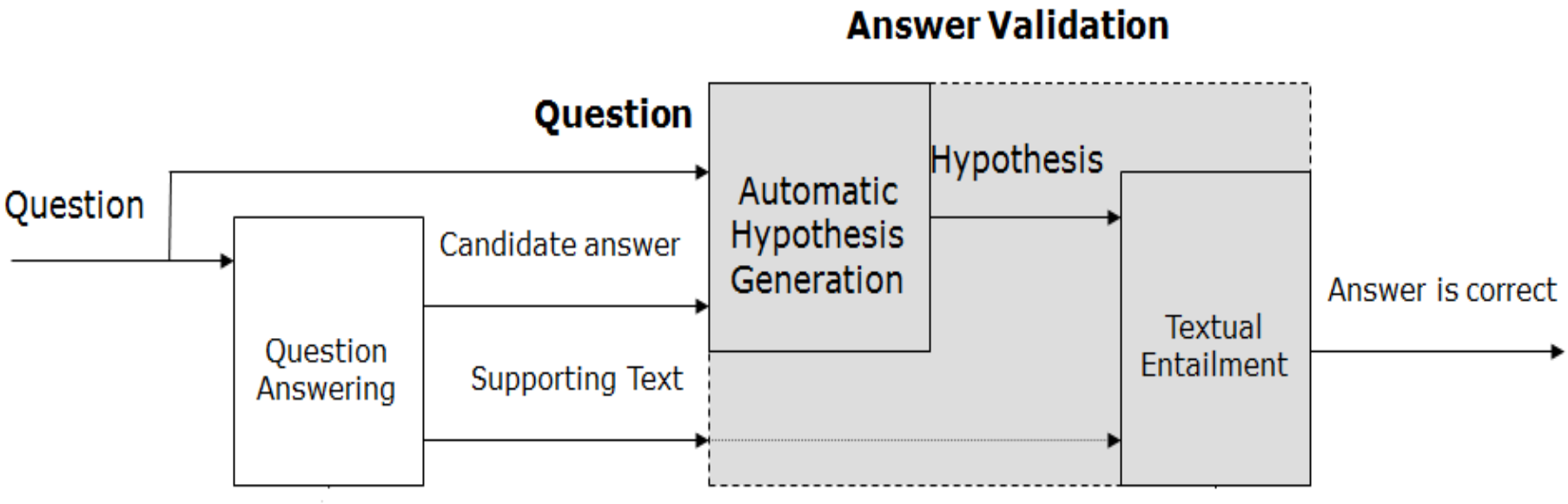
Answer Validation

Validate the correctness of real systems answers





If the text entails the hypothesis, then the answer is expected to be correct.


Answer Validation
Question
Question
Question Answering
Candidate answer
Supporting Text
Automatic Hypothesis Generation
Hypothesis
Textual Entailment
Answer is correct

Answer Validation System

- Input: <Question, Candidate Answer, Supporting Text>
- Output: "**Boolean Value**" indicating if the Answer is correct for the Question according to the Supporting Text or not.

Question	**In what date was the first tennis championship at Wimbledon?**
Supporting Text (i.e., T)	The first championships at Wimbledon, in London were played in 1877.
Answer	1877
Expected Answer (i.e., H)	The first tennis championship at Wimbledon was in 1877.

<q id="0061" lang="EN">
<q_str>***Where was Joseph Fourier born?***</q_str>

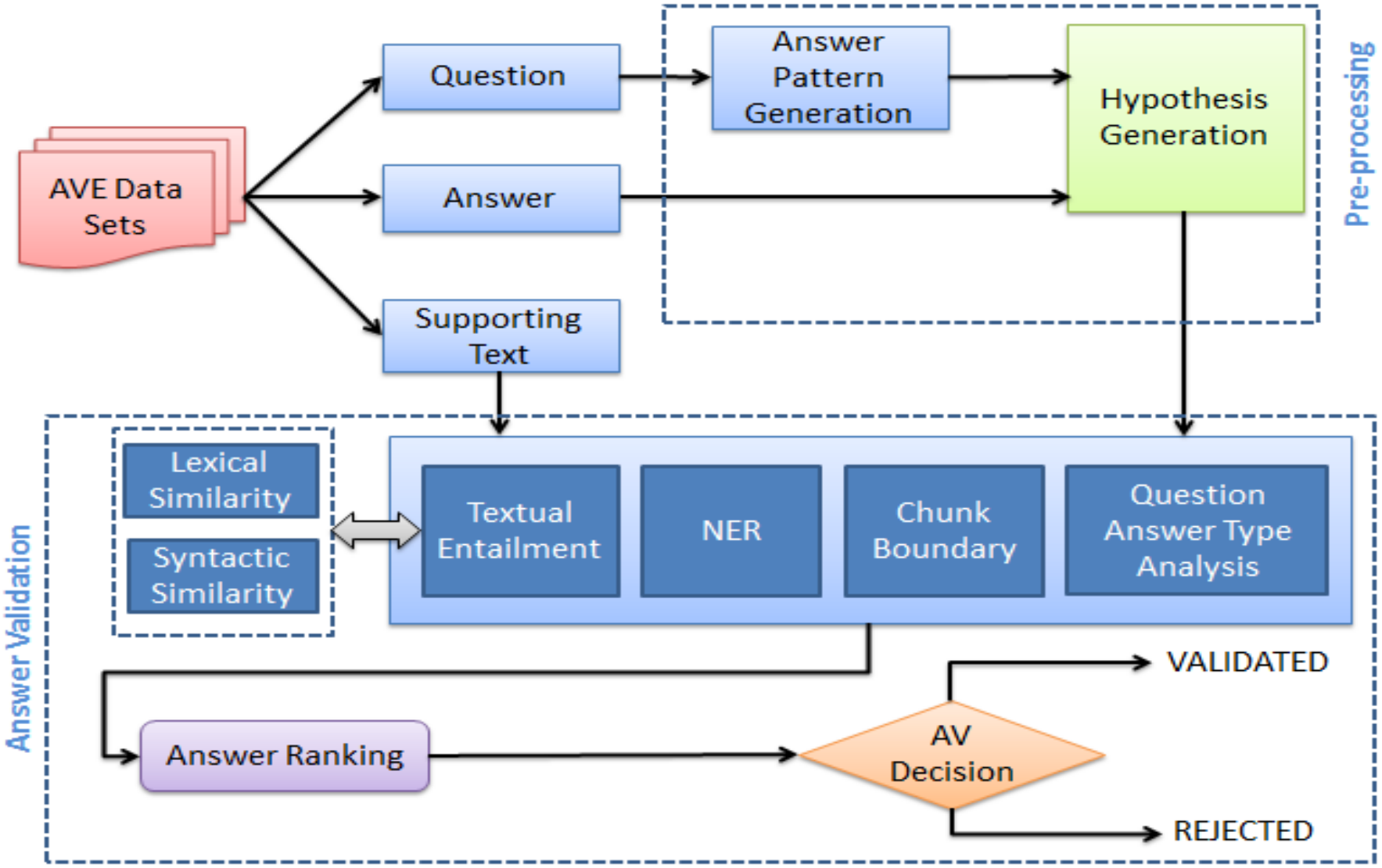
<a_str>***Paris***</a_str>
<t_str doc="Joseph Fourier">*Joseph Fourier Joseph Fourier Joseph Fourier Jean Baptiste Joseph Fourier Born March 21, 1768 Auxerre, Yonne, France Died May 16, 1830 Paris, France Residence France Nationality French Field Mathematician, physicist, and historian Institution École Normale École Polytechnique Alma Mater École Normale Doctoral Advisor Joseph Lagrange Doctoral Students Gustav Dirichlet Giovanni Plana Known for Fourier transform Religion Roman Catholic Jean Baptiste Joseph Fourier (March 21, 1768 - May 16, 1830) was a French mathematician and physicist who is best known for initiating the investigation of Fourier series and their application to problems of heat flow.*</t_str>

<a_str>**France**</a_str>
<t_str doc="Joseph Fourier">Life Fourier was born at Auxerre in the Yonne département of France, the son of a tailor.</t_str>

<a_str>***Grenoble***</a_str>
<t_str doc="Joseph Fourier University">*Joseph Fourier University Joseph Fourier University Université Joseph Fourier (Joseph Fourier University) is a French university situated in the city of Grenoble and focused on the fields of sciences, technologies and health.*</t_str>

<a_str>***Auxerre***</a_str>
<t_str doc="Auxerre.html">*Auxerre.*</t_str>

System Architecture



Answer Pattern generation

Convert

Question $\Longrightarrow$ Assertive sentence (e.g. Expected Hypothesis)

Question: "How" Type

How many players are there in "Singles" tennis?

How <many/much> NP1 VP NP2?

</Answer> NP1 VP NP2?

</Answer> players are there in "Singles" tennis.

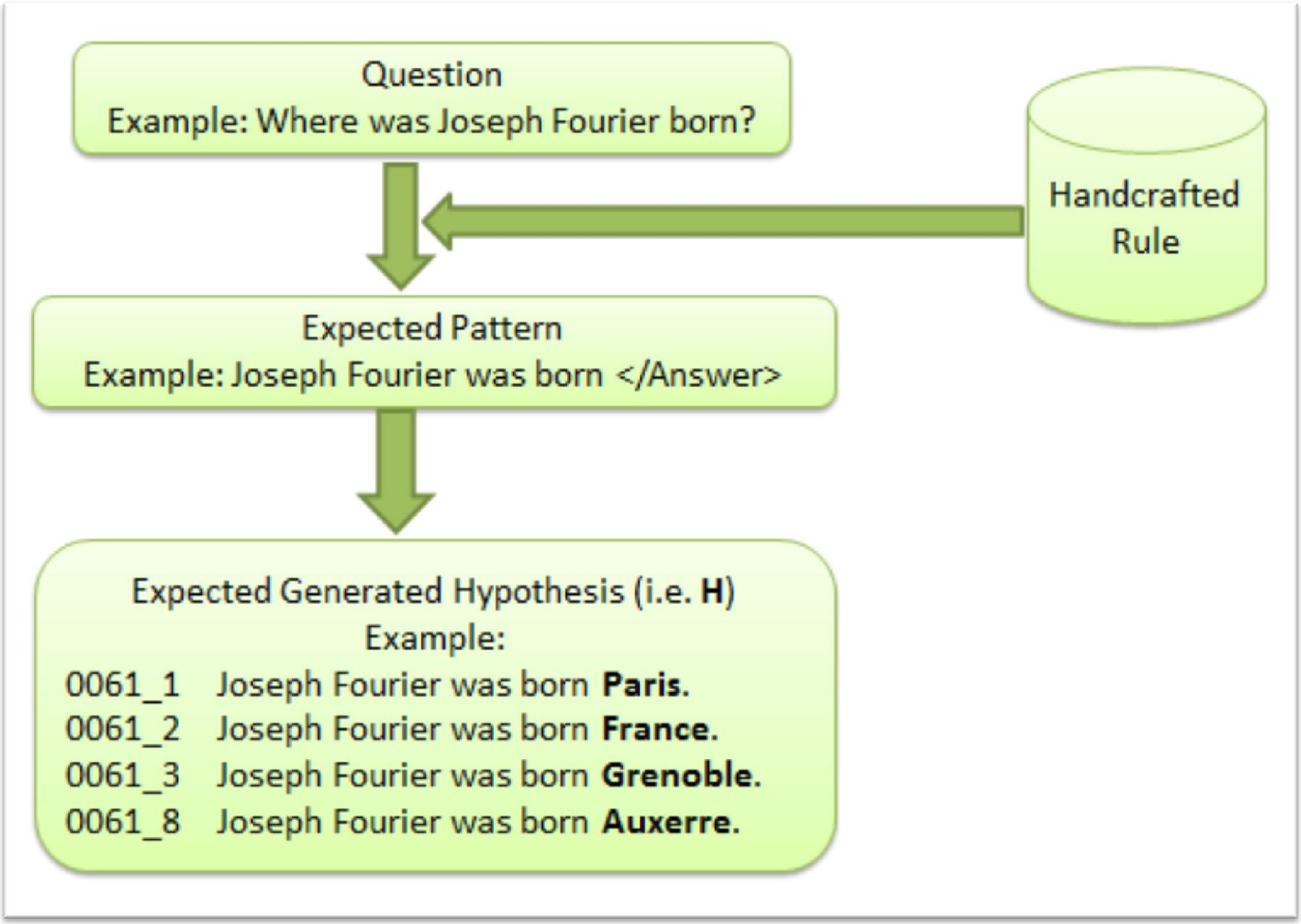
Question: "Which" Type

Which is the best city in India?

Which <be-verb> NP?

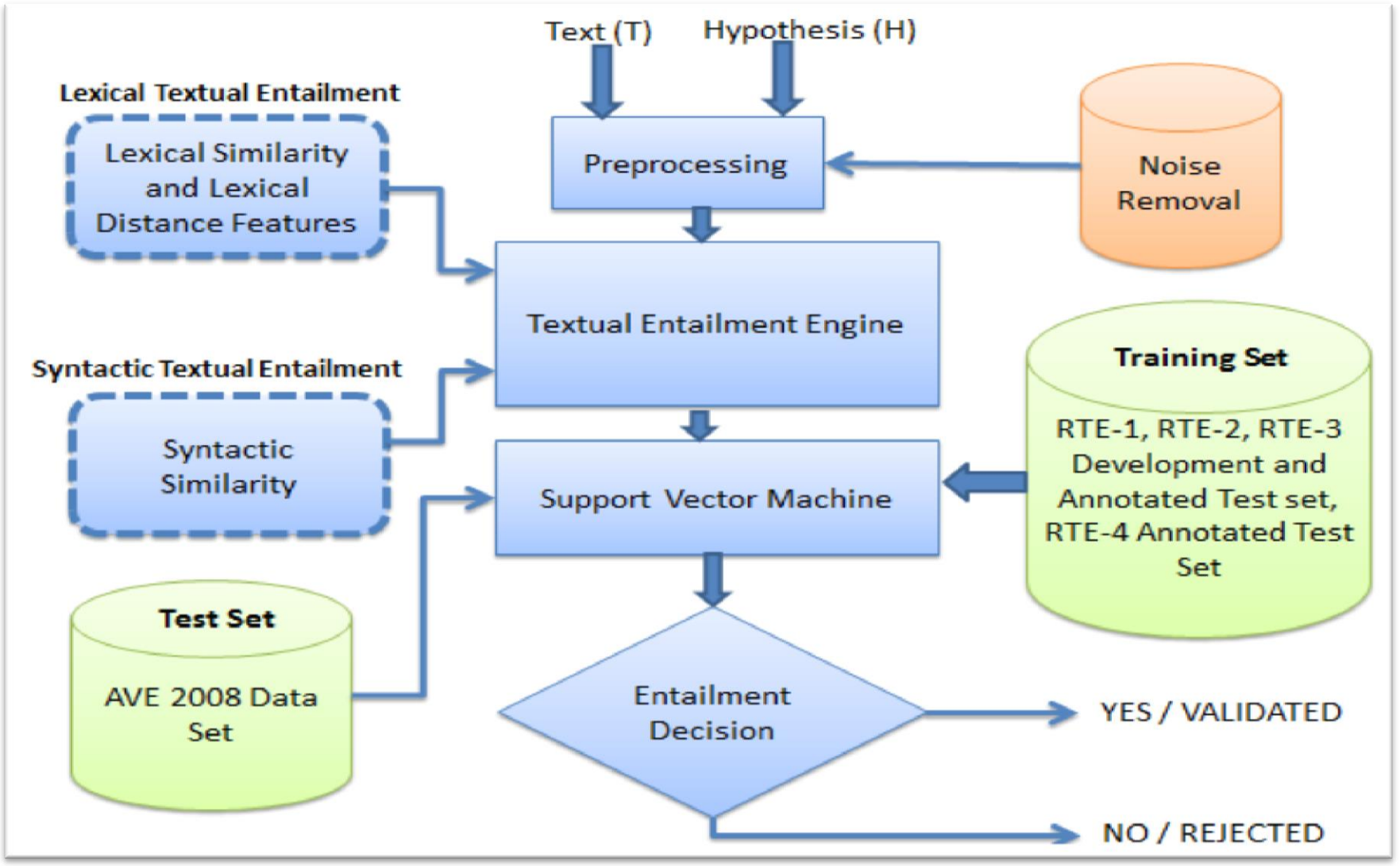
NP <be-verb> **</Answer>**

The best city in India is **</Answer>**


Question
Example: Where was Joseph Fourier born?
Handcrafted Rule
Expected Pattern
Example: Joseph Fourier was born </Answer>
Expected Generated Hypothesis (i.e. H)
Example:
0061_1 Joseph Fourier was born Paris.
0061_2 Joseph Fourier was born France.
0061_3 Joseph Fourier was born Grenoble.
0061_8 Joseph Fourier was born Auxerre.

Pair 1	**Text (T)**	Joseph Fourier Joseph Fourier Joseph Fourier Jean Baptiste Joseph Fourier Born March 21, 1768 Auxerre, Yonne, France Died May 16, 1830 Paris, France Residence France Nationality French Field Mathematician, physicist, and historian Institution École Normale École Polytechnique Alma Mater École Normale Doctoral Advisor Joseph Lagrange Doctoral Students Gustav Dirichlet Giovanni Plana Known for Fourier transform Religion Roman Catholic Jean Baptiste Joseph Fourier (March 21, 1768 - May 16, 1830) was a French mathematician and physicist who is best known for initiating the investigation of Fourier series and their application to problems of heat flow.
	Hypothesis (H)	Joseph Fourier was born Paris.
Pair 2	**Text (T)**	Life Fourier was born at Auxerre in the Yonne département of France, the son of a tailor.
	Hypothesis (H)	Joseph Fourier was born France.
Pair 3	**Text (T)**	Joseph Fourier University Joseph Fourier University Université Joseph Fourier (Joseph Fourier University) is a French university situated in the city of Grenoble and focused on the fields of sciences, technologies and health
	Hypothesis (H)	Joseph Fourier was born Grenoble.
Pair 4	**Text (T)**	Auxerre
	Hypothesis (H)	Joseph Fourier was born Auxerre.

System Architecture



Features

- **Lexical similarity features**: WordNet based Unigram match, Bigram match, Longest Common Subsequence match, Skip-gram and stemming.

- **Lexical distance features: Vector Space Measures** (Euclidean distance, Manhattan distance, Minkowsky distance, Cosine similarity, Matching coefficient), **Set-based Similarities** (Dice, Jaccard, Overlap, Cosine, Harmonic), **Soft-Cardinality**, **Q-Grams Distance**, **Edit Distance Measures** (Levenshtein distance, Smith-Waterman Distance, Jaro).

- **Syntactic features**: Subject-subject comparison, WordNet Based Subject-Verb Comparison, Subject-Subject Comparison, Object-Verb Comparison, WordNet Based Object-Verb Comparison, Cross Subject-Object Comparison, Number Comparison, Noun Comparison, Prepositional Phrase Comparison, Determiner Comparison and Other relation Comparison.

- **Semantic Features from UNL**

Machine Learning

Tool generally used: LIBSVM (Chang and Lin, 2001)

Training Data sets: RTE-1 development and test set, RTE-2 development and annotated test set, RTE-3 development and annotated test set and RTE-4 annotated test set. 3967 text-hypothesis pairs have been used.

Test Data sets: AVE 2008 data set.

Output: Entailment score with entailment decisions (i.e., "YES" or "VALIDATED" / "NO" or "REJECTED").

Question Answer Type Module

Factoid Question Type	Expected Answer
Who	PERSON
When	DATE / TIME
Where	LOCATION
What	OBJECT
How	MEASURE

Question	Where was the Volkswagen Polo Playa built?		
Target Answer	LOCATION		
Pair ID	Answer	NER	Target Answer
0108_1	South Africa	Location	VALIDATED
0108_2	Successor	X	REJECTED
0108_3	Pointer	X	REJECTED
0108_9	Tom Ennis	Person	REJECTED
0108_11	Ibiza	X	REJECTED
0108_12	Playa	X	REJECTED
0108_13	Europe	Location	VALIDATED

Dataset

- CLEF 2008

Answer Validation Exercise track

Evaluation Result

	AVE Development Data Set	AVE Test Data Set
“VALIDATED” in the Development Set (Gold Standard)	21	79
“VALIDATED” the proposed my AV system output	32	75
“VALIDATED” match	18	54
Precision	0.56	0.72
Recall	0.85	0.68
F-score	0.68	0.69

Application: Question Answering

Participated Evaluation Track

- ResPubliQA @ CLEF 2010
- QA4MRE @ CLEF 2011
- QA4MRE @ CLEF 2012
- QA4MRE @ CLEF 2013

QA4MRE: Question Answering System

- A Hybrid system based on
  - A system based on Information Retrieval and Answer Validation
  - QA based Machine Reading system

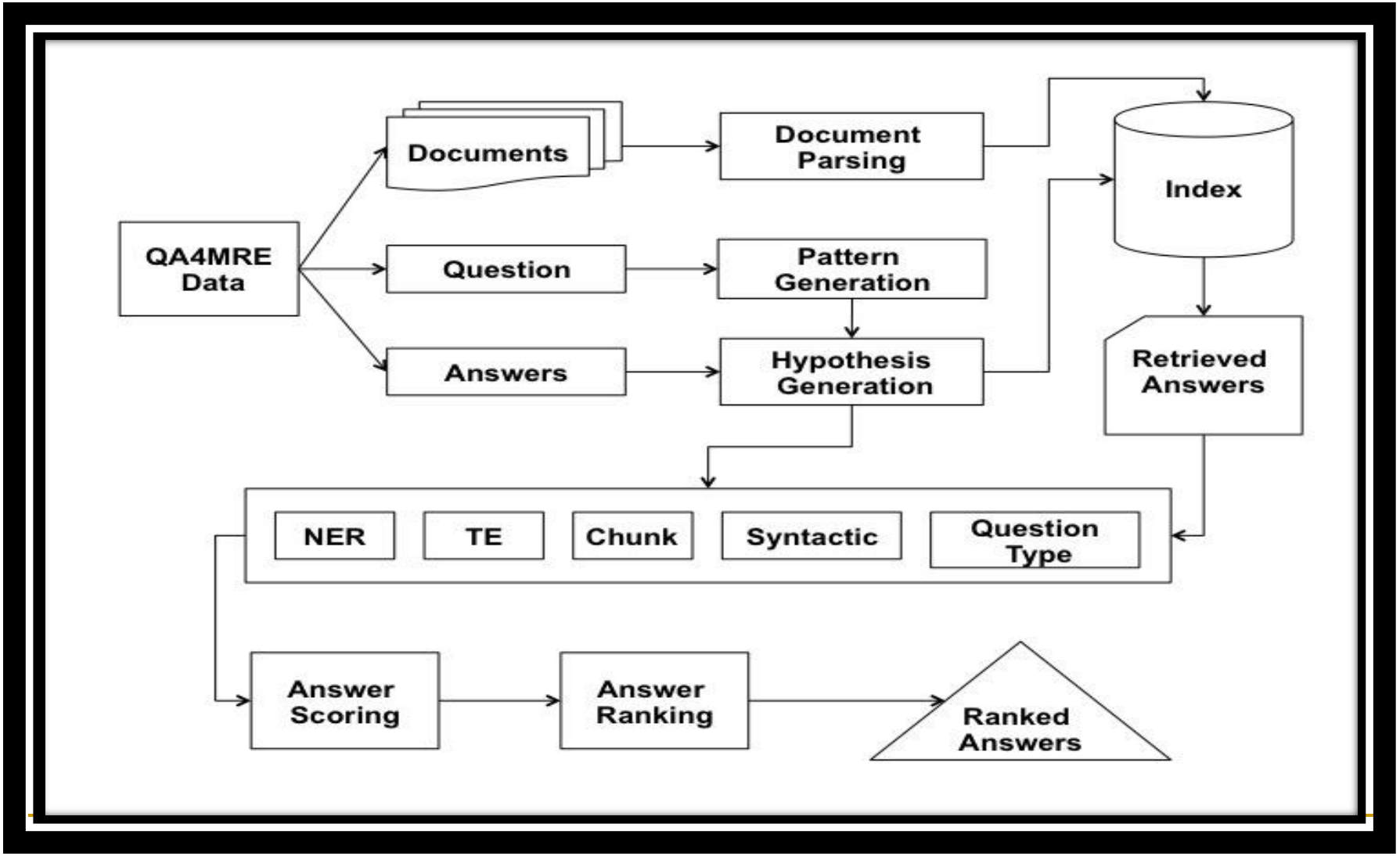
- Goal:

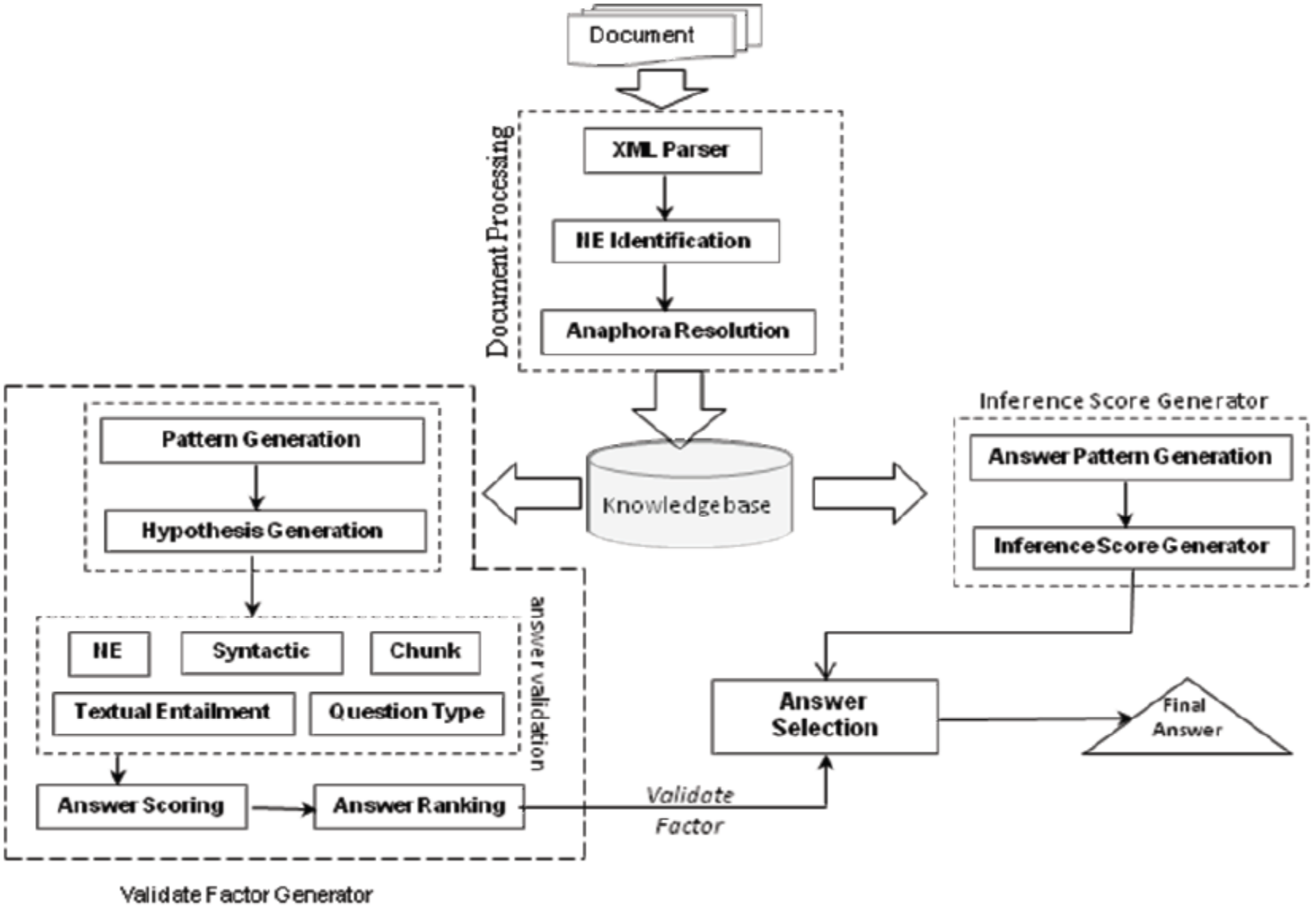
  An Answer Validation System (AV) based on Textual Entailment and Question Answering.

Method

- **Hypothesis Generation**: Combine the question and the answer into Hypothesis (H) and each retrieved sentence from passage is considered as the Text (T) to identify the entailment relation and give each pair as an entailment score.
- The **important features** in the AV system are Lexical Textual Entailment, Named Entity Recognition, Question-Answer type analysis, Chunk boundary module and Syntactic similarity module.
- The proposed AV system is **rule based**.
- Textual Entailment module

Basic Model: QA4MRE




Document
Document Processing
XML Parser
NE Identification
Anaphora Resolution
Knowledgebase
Inference Score Generator
Answer Pattern Generation
Inference Score Generator
Pattern Generation
Hypothesis Generation
NE
Syntactic
Chunk
Textual Entailment
Question Type
answer validation
Answer Scoring
Answer Ranking
Validate Factor
Answer Selection
Final Answer
Validate Factor Generator

Module

- Document Processing Module
  - XML parser
  - Anaphora Resolution
- Validate Factor Generator
  - Answer Pattern Generation
  - Answer Validation
- Answering Module
  - Scoring Assignment
  - Answer Selection

Track Name	C@1	Technique	Position
ResPubliQA @ CLEF 2010	0.50	IR, NGram	7th out of 9
QA4MRE @CLEF 2011	0.57	IR, Answer Validation, Textual Entailment	1st out of 25
QA4MRE @ CLEF 2012	0.53	IR, Answer Validation, Textual Entailment, Anaphora Resolution	1st out of 21
QA4MRE @ CLEF 2013	0.59	IR, Answer Validation, Textual Entailment, Anaphora Resolution, World Knowledge	1st out of 19

Resources & Tools

- Parsers: Stanford Dependency, CCG Parser
- Named Entity: Stanford NER, LT-**TTT2**
- Stanford POS Tagger, Stanford Core NLP
- NLTK
- Text Similarity tool: SimMetrics, SimPack and SecondString, DISCO, SEMILAR, Soft Cardinality
- Wikipedia Knowledge
- Anaphora Resolution - GuiTAR, JavaRAP
- Machine Learning: Weka tools (e.g. SVM, J48, etc. algorithm)
- Universal Networking Language (UNL)

Publications

- **No. of Journal**: 6
- **No. of International Conference**: 34
- **No. of Book**: 1

www.parthapakray.com

Thank you