Language Technologies for Indian Languages

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Perspective

Resource Richness: *how many members of the world's language families have them?*

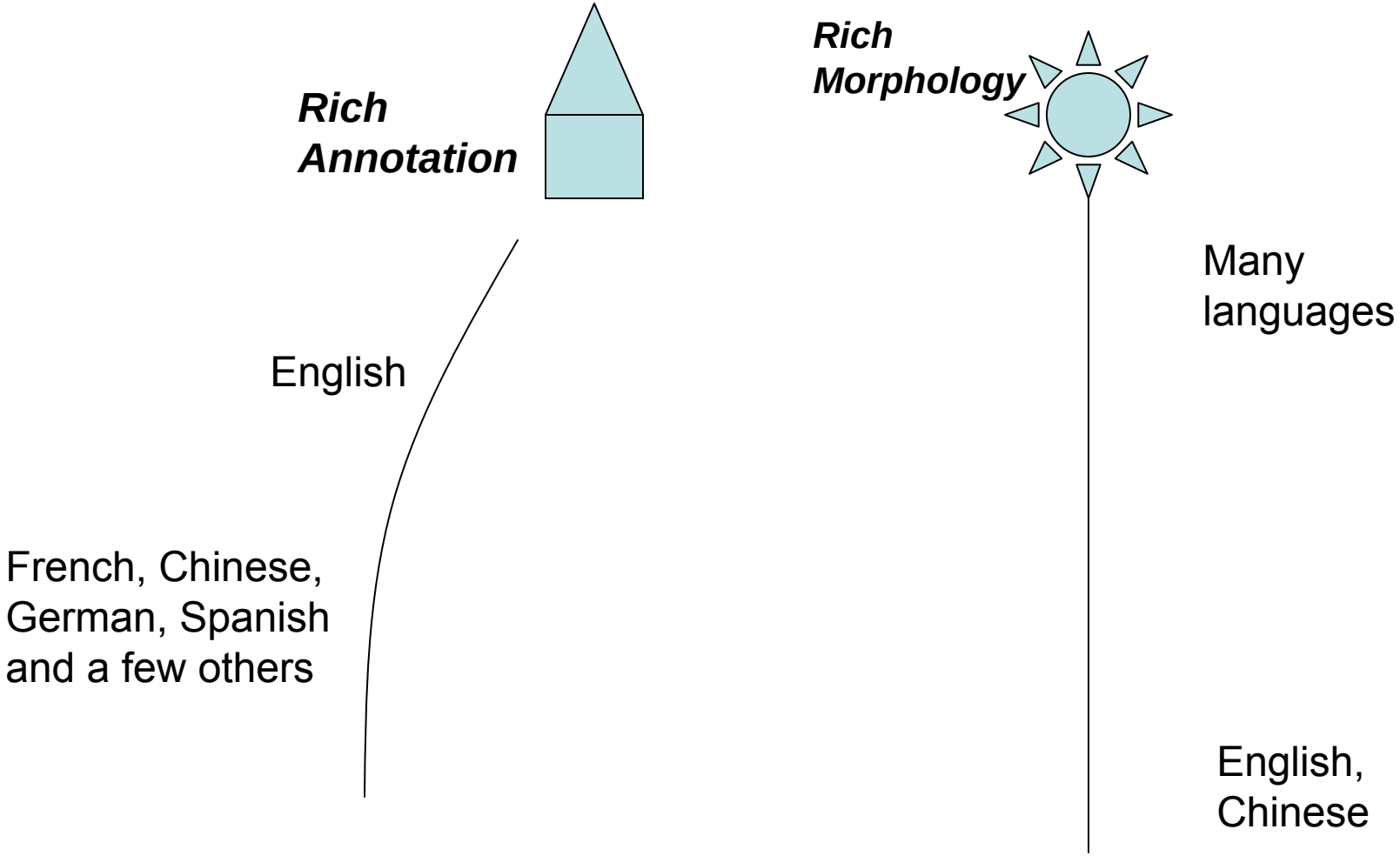
A list of language families

- Indo-European, Dravidian, and minor European languages
- Afro-Asiatic and Caucasian languages
- Nilo-Saharan, Kordofanian, and Khoisan languages
- Niger-Congo languages
- More Niger-Congo languages, including Bantu
- Uralic, and Altaic, and Miao-Yao, and Tai, and Austro-Asiatic, and other Asian languages
- Sino-Tibetan languages
- Austronesian languages
- North American Indian languages - Eskimo, Na-dené, Algic, Keres, Siouan, Caddoan, Iroquoian, Kiowa-Tanoan "Hokan", isolates
- Mesoamerican Indian languages - "Penutian", Uto-Aztecan, Oto-Manguean, Macro-Chibchan, Paezan Yanomaman
- South American Indian languages - "Andean", "Equatorial", Tupi-Cariban, Macro-Otomakoan, Guamo-Chapacuran, Macro-Arawakan, Bora-Witotoan, Macro-Waikurúan, Macro-Panoan, Macro-Ge, isolates
- Indo-Pacific languages
- Australian languages

Living Languages: *how many have richly annotated corpora?*
Ans: Less than 10

Continent	**No of languages**
Africa	2092
Americas	1002
Asia	2269
Europe	239
Pacific	1310
Total	*6912*

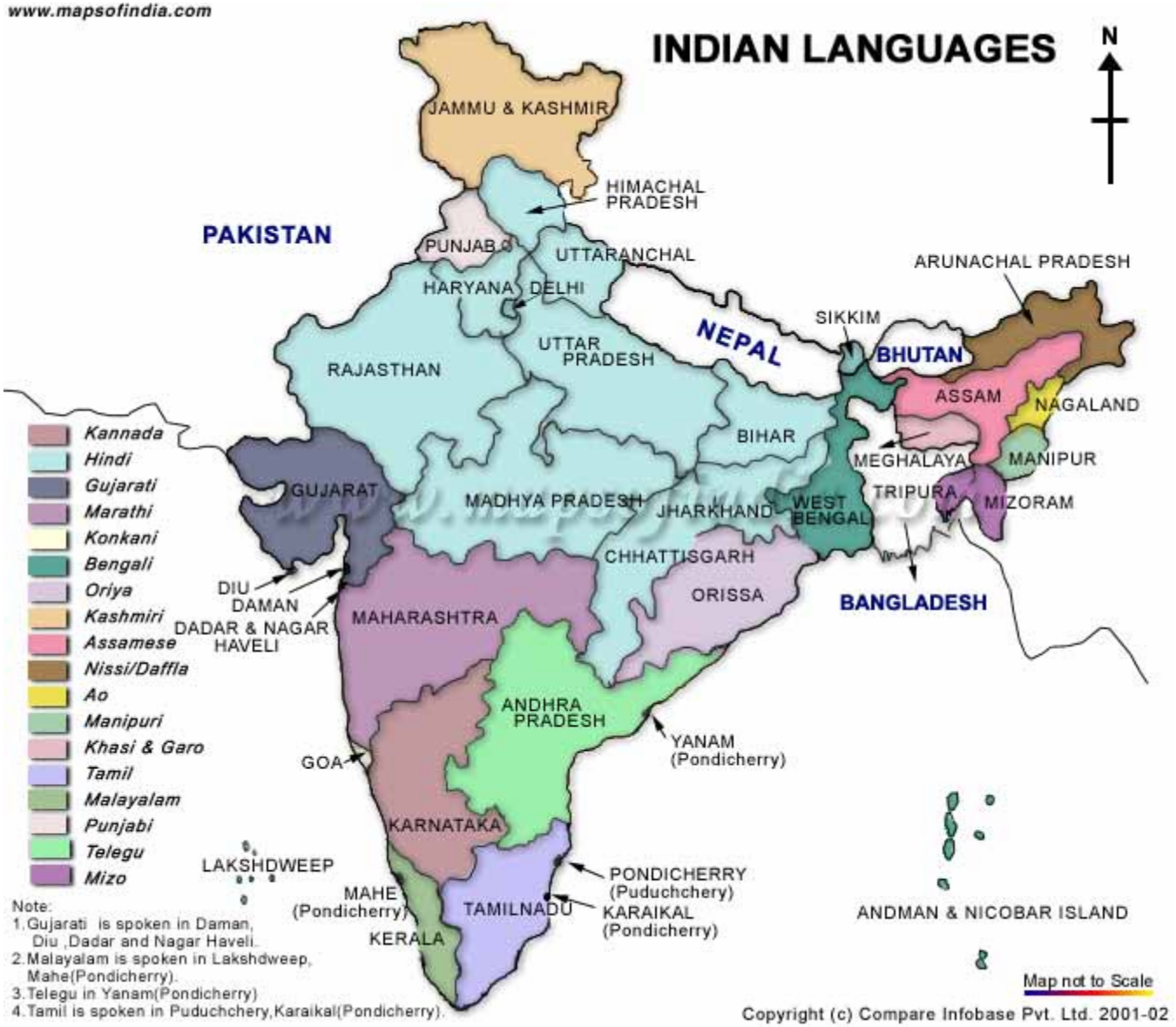
But Rich Language Properties like Morphology? Many languages have them



Roadmap

- Indian Linguistics and NLP Scenario
- NLP activities at IIT Bombay
- Tools and Resources developed at IIT Bombay for language processing
  - Shallow Parsing
  - Machine Translation
  - Wordnets

Indian Linguistic and NLP Scenario


www.mapsofindia.com
INDIAN LANGUAGES
N
JAMMU & KASHMIR
HIMACHAL PRADESH
PAKISTAN
PUNJAB
UTTARANCHAL
HARYANA
DELHI
ARUNACHAL PRADESH
SIKKIM
NEPAL
BHUTAN
UTTAR PRADESH
RAJASTHAN
ASSAM
NAGALAND
BIHAR
MEGHALAYA
MANIPUR
TRIPURA
MIZORAM
GUJARAT
MADHYA PRADESH
JHARKHAND
WEST BENGAL
CHHATTISGARH
ORISSA
BANGLADESH
DIU
DAMAN
DADAR & NAGAR HAVELI
MAHARASHTRA
ANDHRA PRADESH
YANAM (Pondicherry)
GOA
KARNATAKA
LAKSHDWEEP
PONDICHERRY (Puduchchery)
MAHE (Pondicherry)
TAMILNADU
KARAIKAL (Pondicherry)
KERALA
ANDMAN & NICOBAR ISLAND
Kannada
Hindi
Gujarati
Marathi
Konkani
Bengali
Oriya
Kashmiri
Assamese
Nissi/Daffla
Ao
Manipuri
Khasi & Garo
Tamil
Malayalam
Punjabi
Telegu
Mizo
Note:
1. Gujarati is spoken in Daman, Diu ,Dadar and Nagar Haveli.
2. Malayalam is spoken in Lakshdweep, Mahe(Pondicherry).
3. Telegu in Yanam(Pondicherry)
4. Tamil is spoken in Puduchchery,Karaikal(Pondicherry).
Map not to Scale
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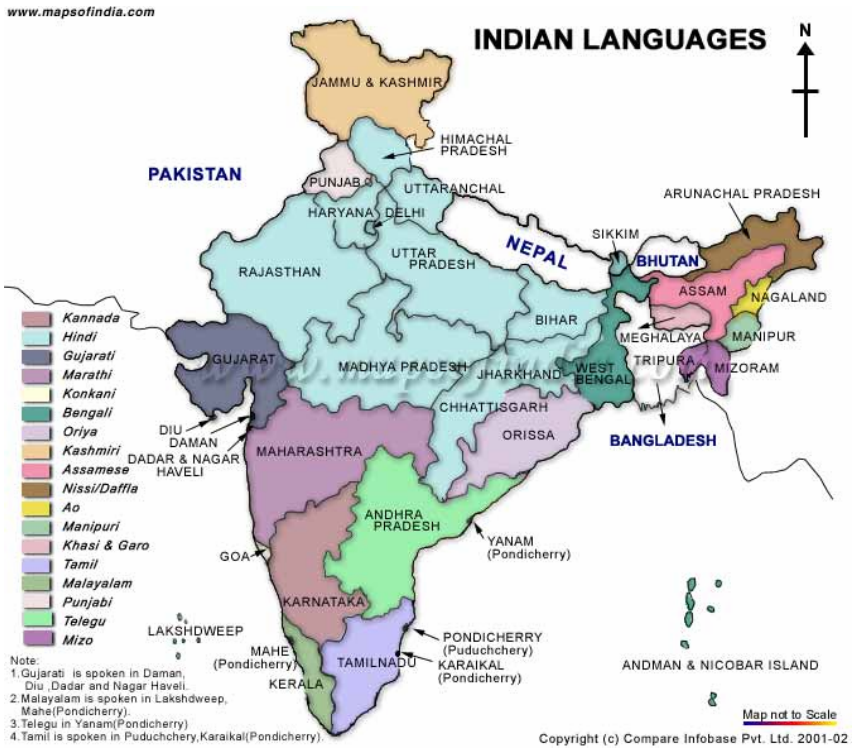
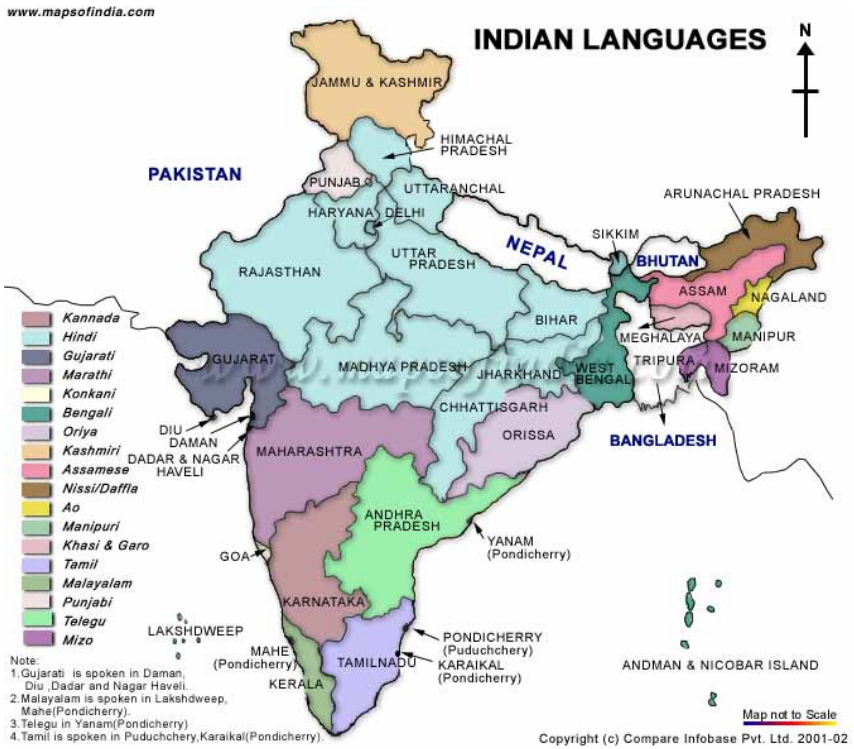
Great Linguistic Diversity

- Major streams
  - Indo European
  - Dravidian
  - Sino Tibetan
  - Austro-Asiatic
- Some languages are ranked within 20 in the world in terms of the populations speaking them
  - Hindi and Urdu: 5th (~500 milion)
  - Bangla: 7th
  - Marathi 14th



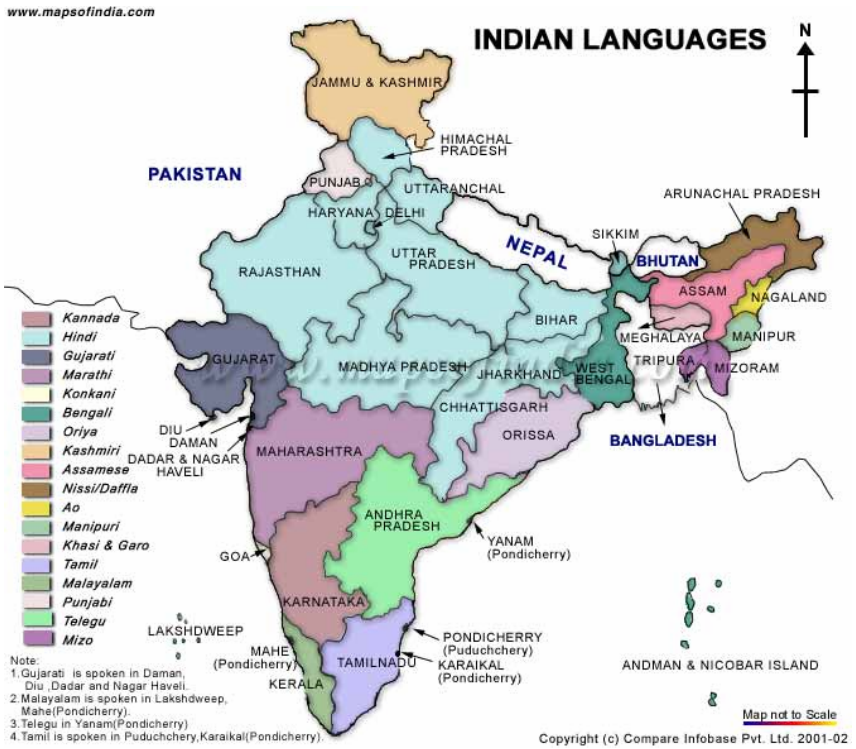
3 Language Formula

- Every state has to implement
  - *Hindi*
  - *The state language (Marathi, Gujarathi, Bengali etc.)*
  - *English*
- Big translation requirement, *e.g.*,during the financial year ends



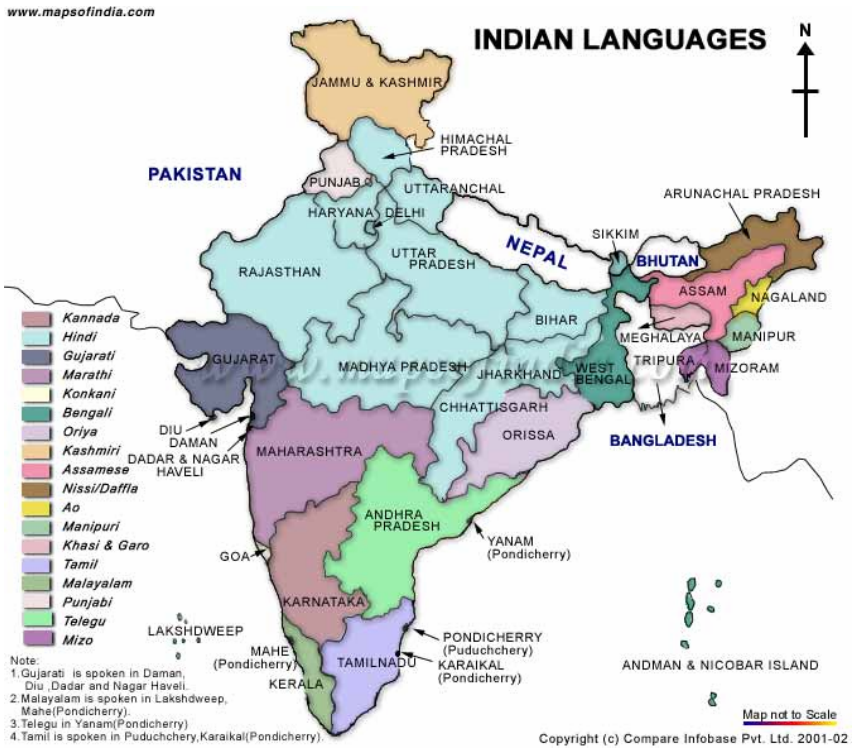
Major Language Processing Initiatives

- Mostly from the Government: *Ministry of IT, Ministry of Human Resource Development, Department of Sceince and Technology*
- Recently great drive from the industry: NLP efforts with Indian language in focus
  - *Google*
  - *Microsoft*
  - *IBM Research Lab*
  - *Yahoo*
  - *TCS*



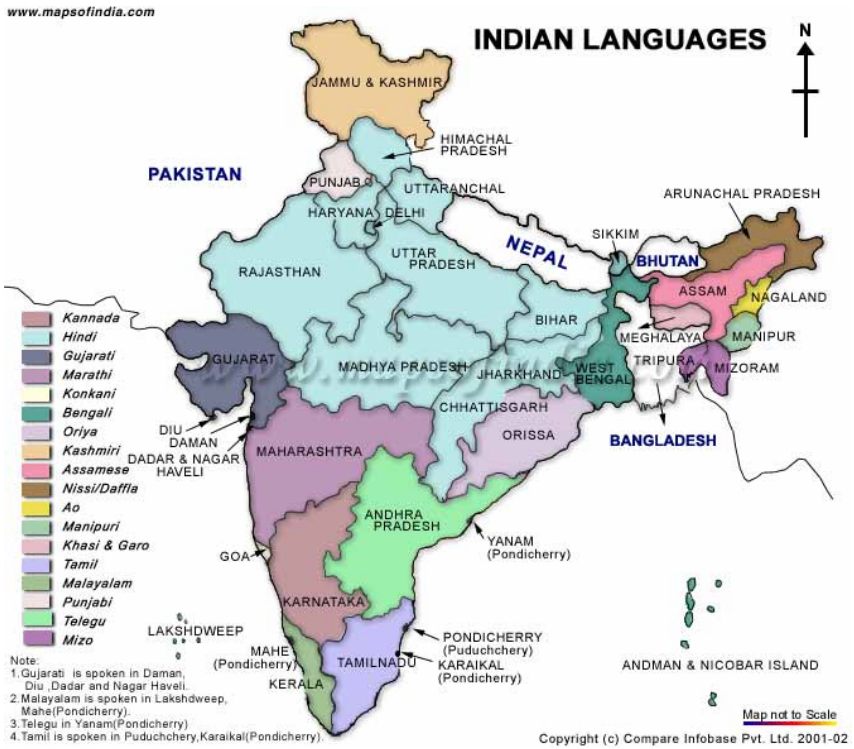
Technology Development in Indian Languages (TDIL)

- Started by the Ministry of IT in 2000
- 13 resource center across the country
- Responsibility for two languages: one major and one minor
- For example,
  - IIT Bombay: *Marathi* and *Konkani*
  - IIT Kanpur: *Hindi* and *Nepali*
  - ISI Kolkata: *Bangla* and *Santhaali*
  - Anna University: *Tamil*



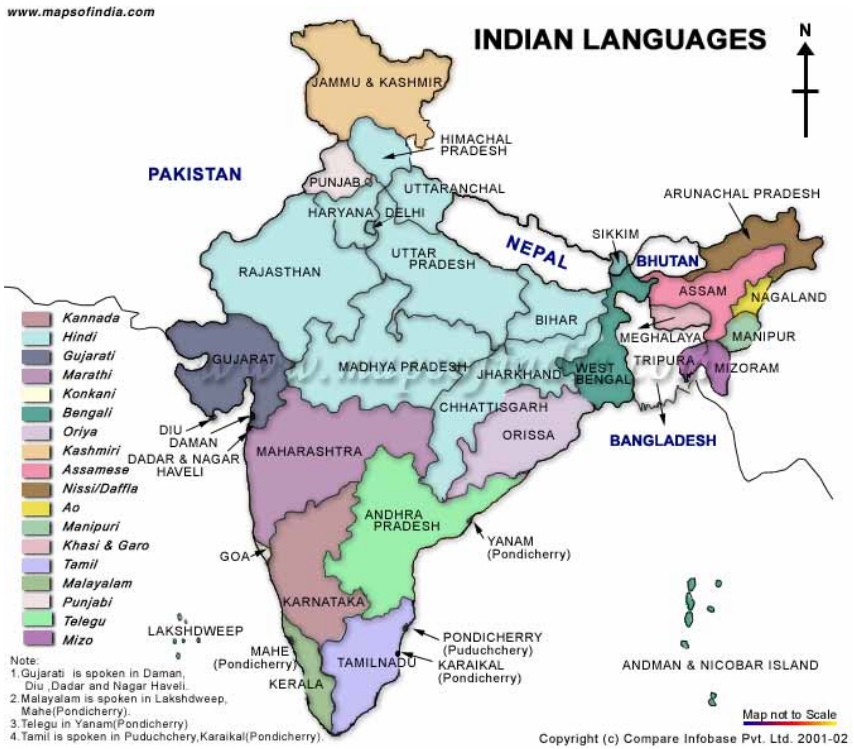
Achievements of TDIL

- Localization in most major languages, through the mediation of *Center for Development of Advanced Computing (CDAC)*
- *Office products, True type fonts*
- *Machine Translation Systems and Supports*
- *Lexical Resources*



Achievements in TDIL: *MT systems and Supports*

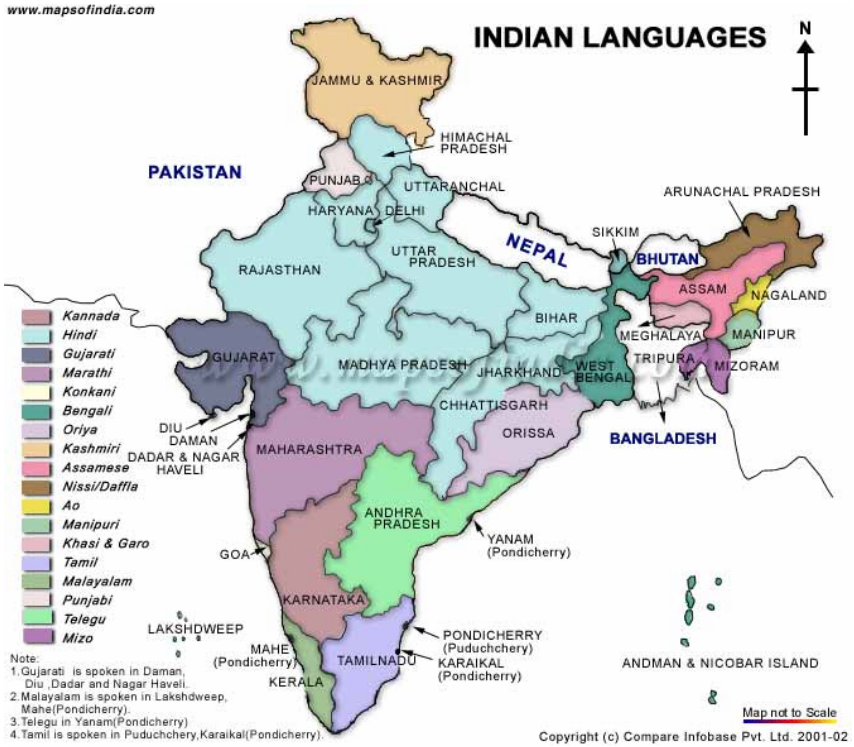
- Transfer based: *Anglabharati (IIT Kanpur), Shakti (IIIT Hyderabdad), Tamil-Hindi system (Anna University KBC, Chennal)*
- Interlingua based: *Universal Networking Language (UNL) based (IIT Bombay; part of an UN initiative with 15 other countries)*



Achievements in TDIL: *Lexical Resources*

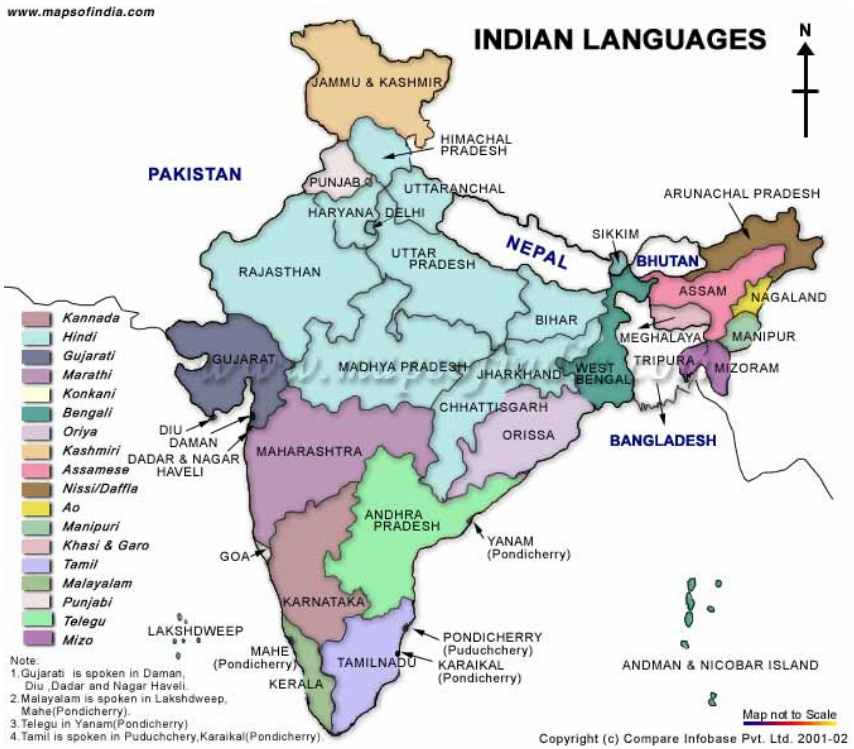
Wordnets: *Hindi and Marathi (IIT Bombay)*

- Ontologies: Tamil concept hierarchy (*Tanjavur University, AU-KBC)*
- Semantically rich lexicons: *IIT Kanpur, IIITH, IIT Bombay*
- Corpora: *Central Institute of Indian Languages (CIIL)*
- Web Content: *All 13 centers, Gujarathi content is exhaustive and of good quality*



Achievements in TDIL: *Shallow Processing*

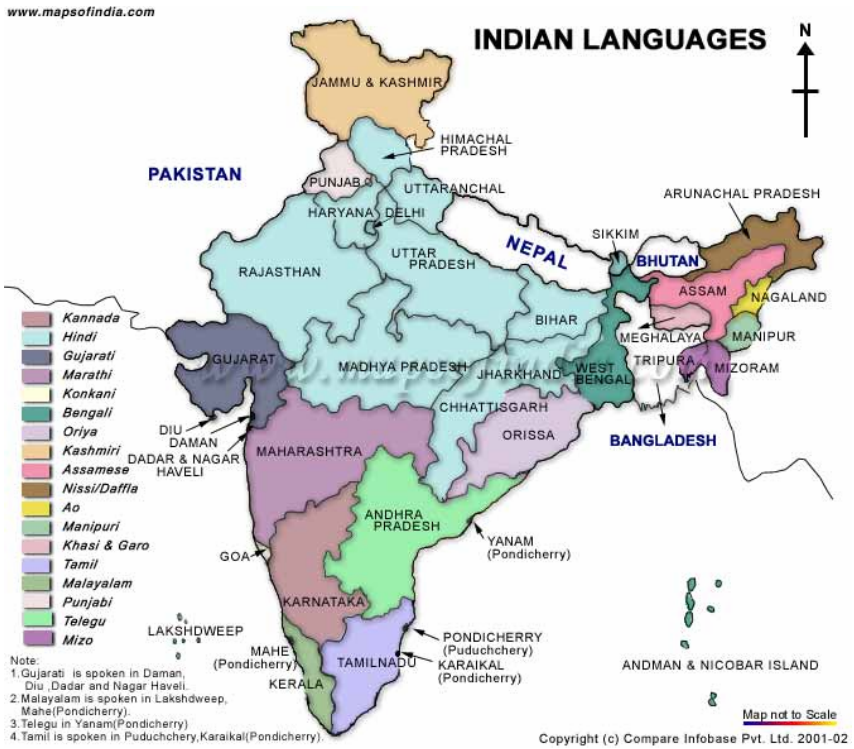
- Part of Speech Tagger: *Hindi (IIITH, IIT Bombay) and Marathi (IIT Bombay)*
- Chunker: *Hindi* (*IIITH, IIT Bombay), Marathi (IIT Bombay)*
- Parser: Nobody has started; but PoS tagger and chunker are the precursors



Achievements in TDIL: *Signal Level Processing*

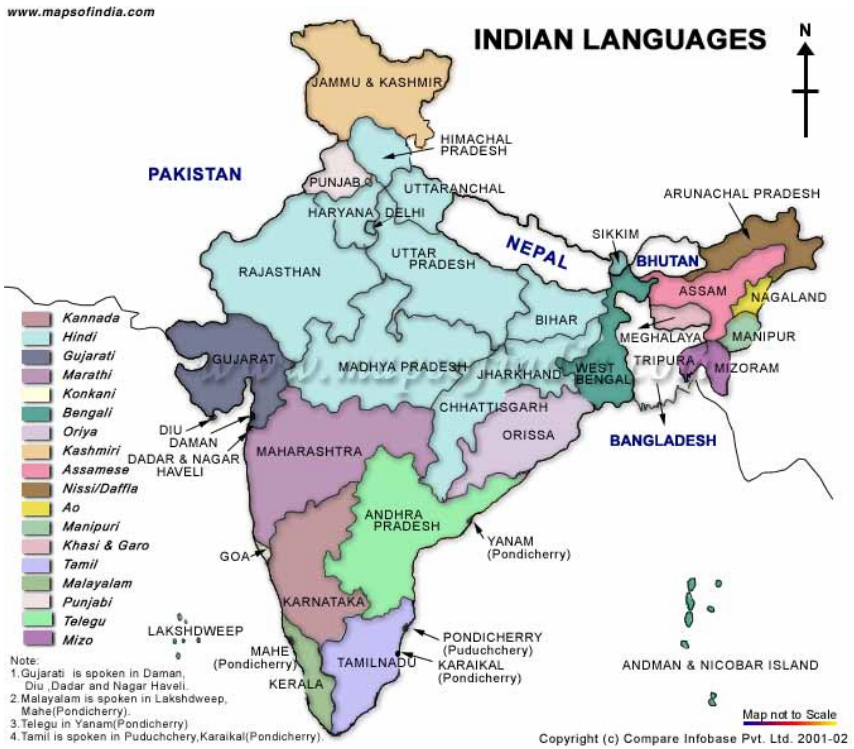
- Speech Processing: *CDAC Noida, Tata Institute of Fundamental Research, IIT Madras (Tamil speech processing engine deployed in Chennai Railway Station)*

- OCR: *ISI Kolkata (Bangla and Hindi; further developed and marketted by CDAC), University of Hyderabad (Telegu), Baroda University (Gujarathi)*



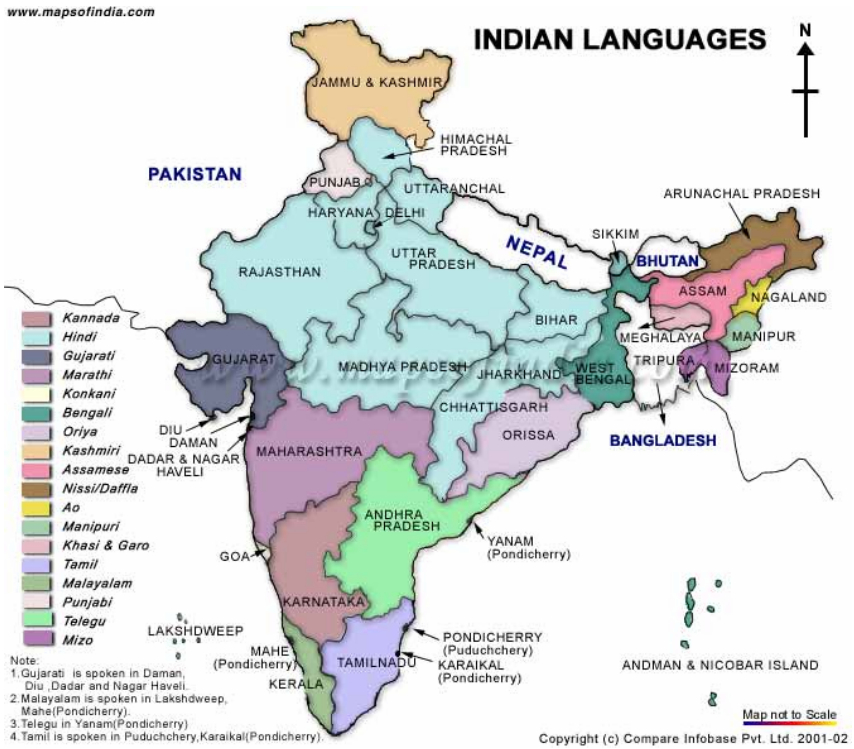
Recent Initiatives

- NLP Association of India: 2 years old: *recently efforts are on making tools and resources freely available on the websit of NLPAI*
- LDC-IL (like the *Linguistic Data Consortium* at *UPenn*)
  - Approved by the planning commission
- National Knowledge Commission: special drive on translation (human and machine)



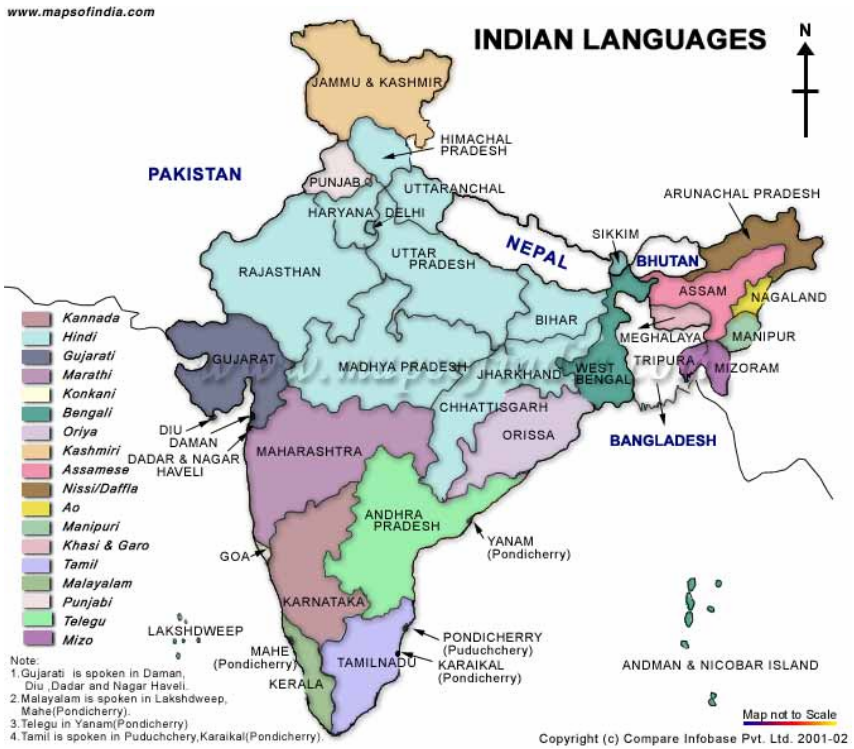
Recent Initiatives cntd

- India wide advertisement for CFP on *MT, CLIR, Speech and OCR*
- Consortia set up already for IL-IL MT, E-IL MT and CLIA
- SAALP: South Asian Association for Language Processing (formed with SAARC countries)



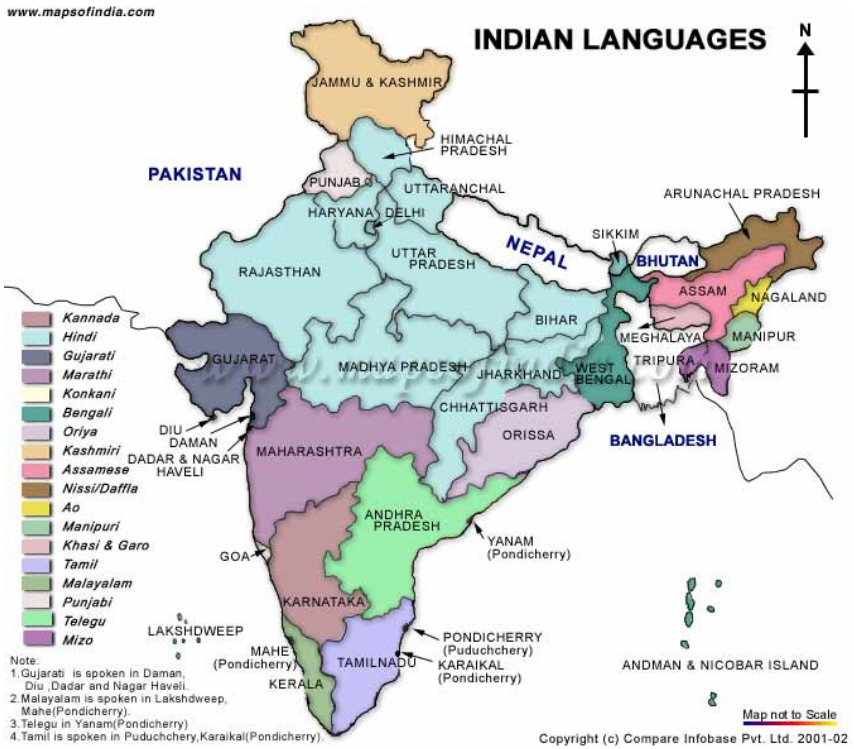
Industry Scenario: *English*

- How to use NLP to increase the search engine performance (*precision, recall, speed)*
- *Google, Rediff, Yahoo, IRL, Microsoft*: all have search engine, IR, IE R & D projects outsourced from USA and being carried out in India.



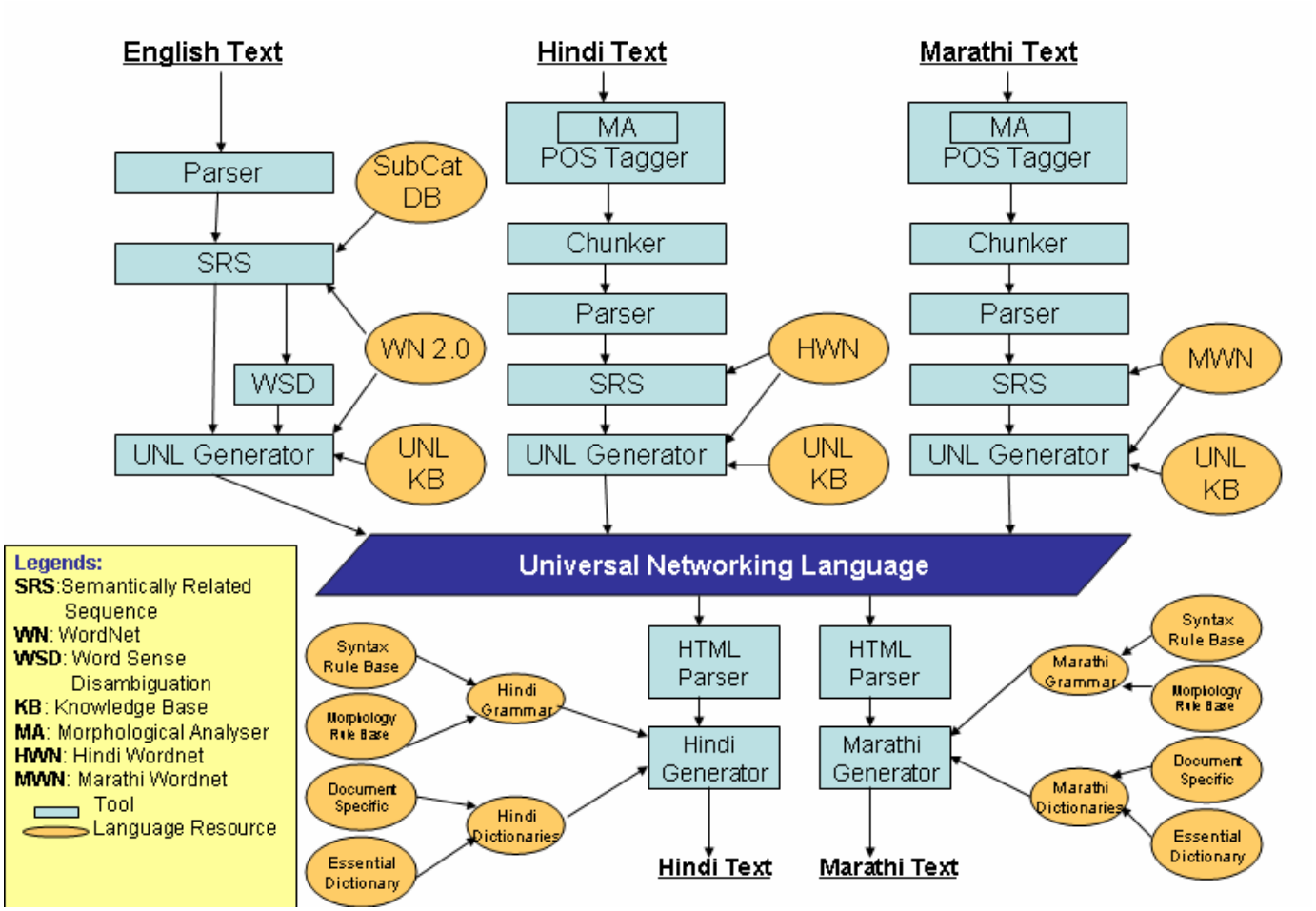
Industry Scenario: *Indian Language*

- **English-Hindi MT is regarded as critical**
- **IBM Research lab has massive English Hindi Parallel Corpora (news domain)**
  - **Statistical Machine Translation**
- **Microsoft India at Bangalore has opened a Multilingual Computing Division**
- ***Google* and *Yahoo India* is actively pursuing IL search engine**

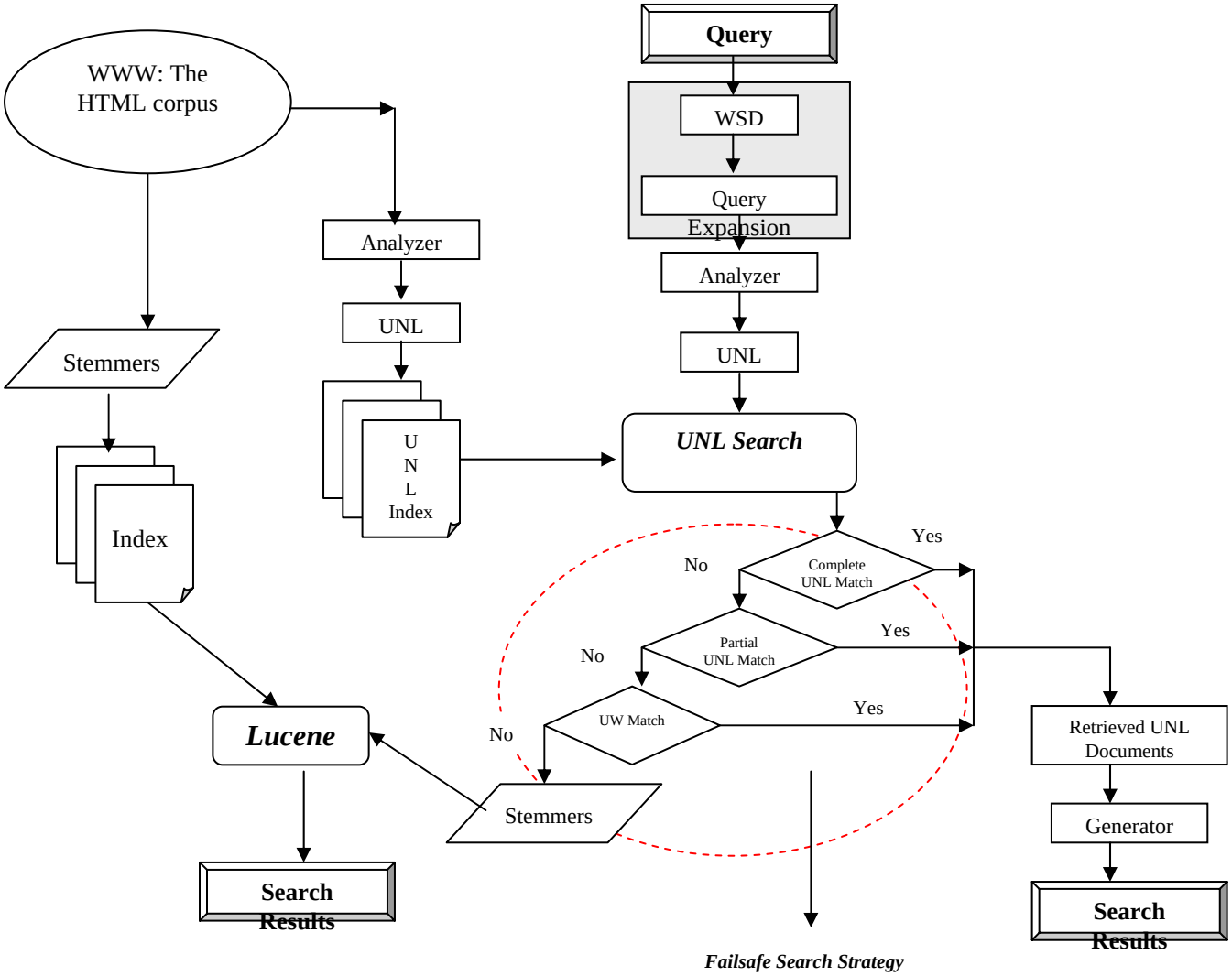


NLP at IIT Bombay

IIT Bombay's effort on MT and accessory systems



Cross Lingual IR



Centre for Indian Language Technlogy (CfILT)

The Center

- Part of Computer Science and Engineering Department, IIT Bombay
- Research in language processing
- Resource building
- Linguistics and computer science

Research Staff

- Language :13
- Computation : 03
- Associated Students : 06-07 each year
- Research Scholars : 05
- Associated faculty : 06

about 30 associated members at any point of time

Indian Language Lexical Resources and Tools

- Lexical Resources
  - –Verb Knowledge Base
  - –Hindi Wordnet
  - –Marathi Wordnet
- Tools
  - –Hindi POS Tagger
  - –Marathi POS Tagger
  - –Semantically Relatable Sequences: Intermediary to Semantics
  - –Hindi Generation
  - –Translation and Search in a QA-Forum

POS Tagging of Indian Languages

Introduction

- POS tagging is the process of identifying lexical category of a word in a sentence on the basis of its context

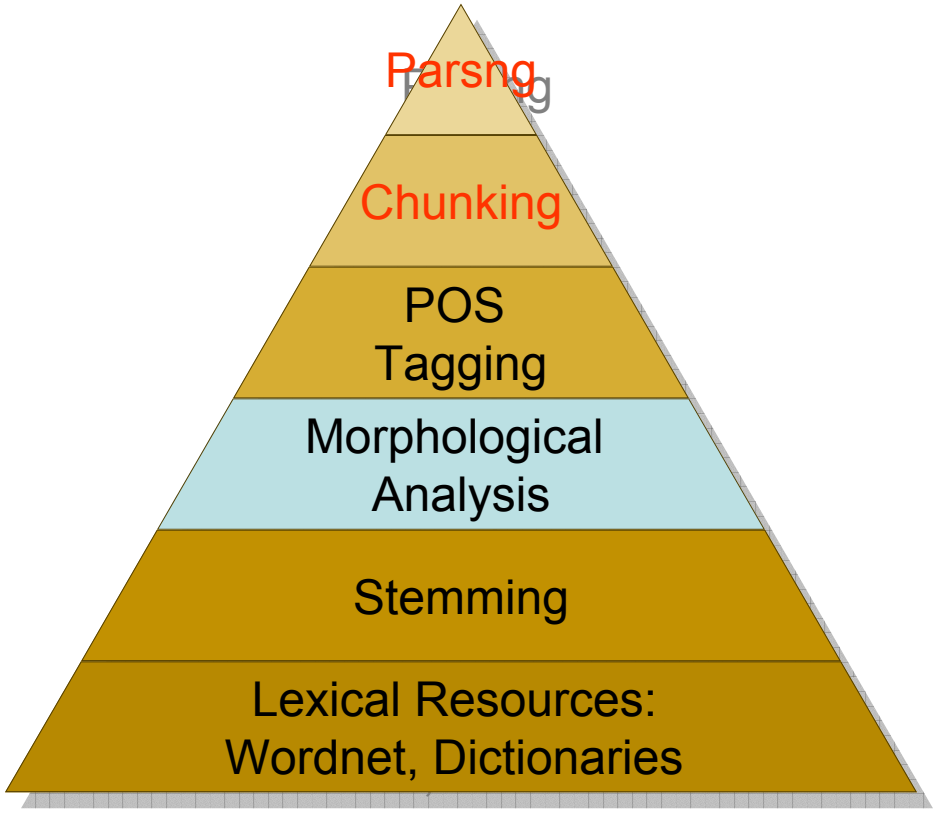
  Input: राम खेल रहा है (raam khel rahaa haai)

  raam play <verb string of continuity>

  Output: राम_NNP खेल_VM रहा_VAUX है_VAUX

- Wide applications
  - Machine translation, Information etc.

The Bigger Picture



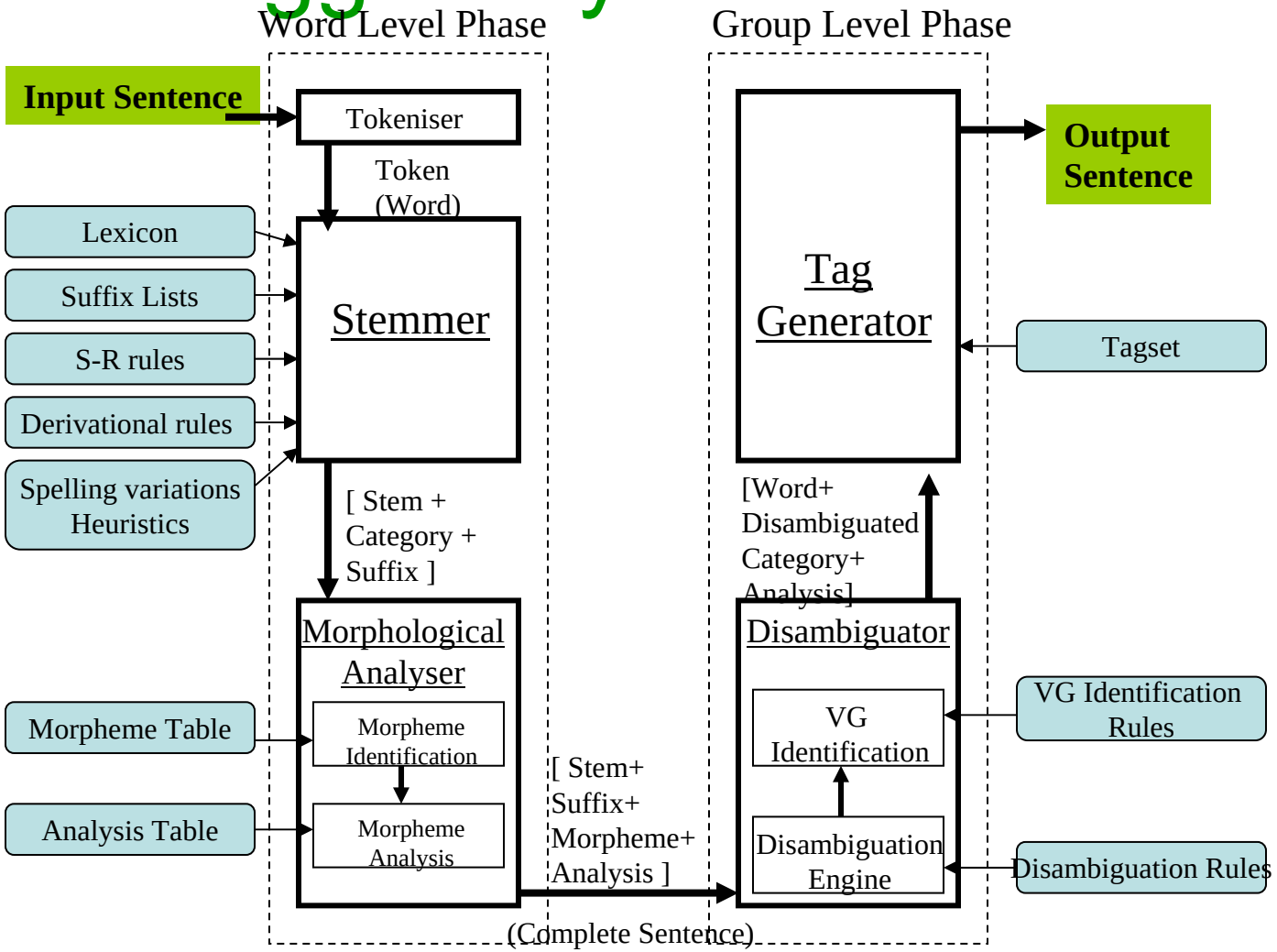
POS Tagging for Indian Languages
(Singh, Gupta, Sinha, Bhattacharyya, ACL 2006)

- Accurate POS taggers not available for Indian languages
- Indian languages are morphologically rich. Hence,
  - First step is to analyze the language
  - Tools for harnessing morphological information are needed
- Stochastic Methods cannot be used
  - Non-availability of tagged corpora

Challenges in POS Tagging for Indian Languages

- Large number of word forms making Stochastic techniques expensive and unreliable.
- Difficulty in identifying morpheme boundary as large number of morphemes are fused together
- Complexity due to -
  - Inter-POS ambiguity
  - Free word ordered structure
  - Complex morphology of Indian Languages

POS Tagger: System Architecture



Intermediate Tools

- Intermediate tools for initial processing
  - Stemmer
    - Identifies suffixes and stem
  - Morphological Analyser:
    - Analyses suffixes provided by stemmer
    - Provides category and grammatical feature information

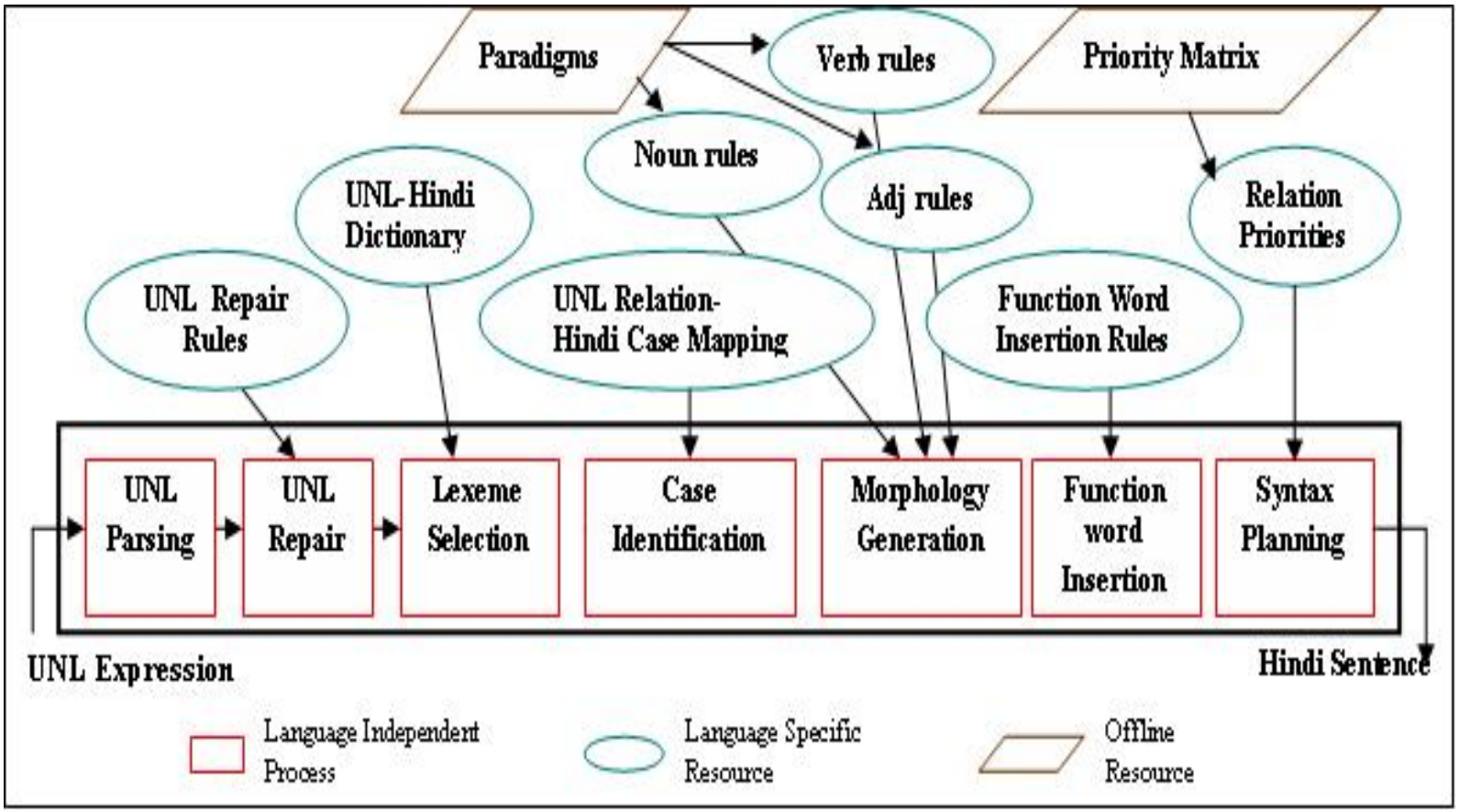
Results

- Results for Hindi :
  - Accuracy : 94.24
  - Trained on a corpus of 20,000 words
  - Corpus Domain : News
  - Source : http://www.bbc.co.uk/hindi/
- Results for Marathi :
  - Accuracy : 85.23
  - Trained on a corpus of 10,000 words
  - Corpus Domain : News
  - Source : http://www.e-sakal.com (newspaper)

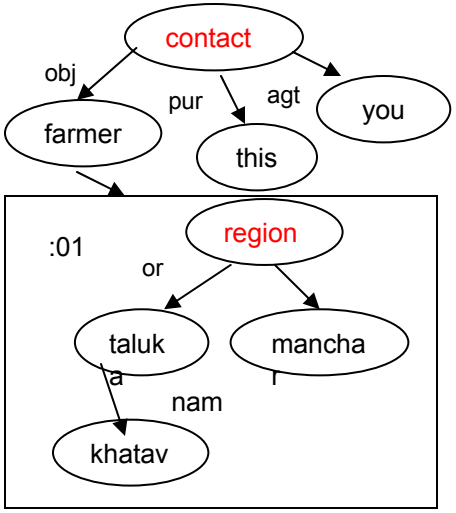
Application in MT: Hindi generation

Singh, Dalal, Vachani, Bhattacharyya and Damani, MT Summit 07

Schematic of the generation system



Example of output stages



Module	Output
Original English Sentence	For this, you contact the farmers of Manchar region or of Khatav taluka
UNL Expression	See Sentence 4 and Figure 1
Lexeme Selection	संपर्क क्रिसान् यह आप क्षेत्र् तालुक् मंचर खटाव contact farmer this you region taluka manchar khatav
Case Identification	संपर्क क्रिसान्* यह* आप क्षेत्र तालुक्* मंचर खटाव contact farmer* this* you region taluka* manchar khatav
Morphology Generation	संपर्क कीजिए क्रिसानों यह आप क्षेत्र contact .@imperative farmer.@pl this you region तालुके मंचर खटाव taluka manchar Khatav
Function Word Insertion	संपर्क कीजिए क्रिसानों को इसके लिए आप क्षेत्र _contact farmers this **for** you region या तालुके के मंचर खटाव **or** taluka **of** Manchar Khatav
Syntax Planning	इसके लिए आप मंचर क्षेत्र या खटाव This for you manchar region or khatav तालुके के क्रिसानों को संपर्क कीजिए | taluka of farmers contact

Evaluation

- 901 sentences from agricultural domain
- Actual questions and problem statements by farmers
- Translated into English
- Converted into UNL graphs (semi automatic)
- UNL-to-Hindi generation applied

Human evaluators: score the generated sentences

Fluency of the given translation is:

(4) Perfect: Good grammar

(3) Fair: Easy-to-understand but flawed grammar

(2)Acceptable: Broken - understandable with effort

(1) Nonsense: Incomprehensible

Adequacy: How much meaning of the reference sentence is conveyed in the translation:

(4) All: No loss of meaning

(3) Most: Most of the meaning is conveyed

(2) Some: Some of the meaning is conveyed

(1) None: Hardly any meaning is conveyed

BLEU score computed

- One reference sentence per UNL graph
- More reference sentence creation in progress

Bleu score= 0.41

Correlation with fluency=0.59

Multilingual Wordnets for Indian Languages

Wordnet work at IIT Bombay

- http://www.cfilt.iitb.ac.in
- Follow the design principle(s) of the Princeton Wordnet for English paying particular attention to language specific phenomena (such as *complex predicates*)
- **Hindi Wordnet**
  - Total Number of Synsets: 23,067
  - Total Number of Unique Words: 48,725
- **Marathi Wordnet**
  - Total Number of Synsets: 11,908
  - Total Number of Unique Words: **18,093**

Status of other WNs

	Total Number of Synsets	Total Unique Words
WordNet (2.1)	117597	155327
GermaNet (2004)	53312	76563
Multi Word Net (1.39)	32,700	58,000

HWN and MWN Created Using Different Principles

(Tatsam, *i.e.*, Sanskrit words borrowed as such: very often)

HWN entry:
{peR, vriksh, paadap, drum, taru, viTap, ruuksh, ruukh, adhrip, taruvar}
'tree'
jaR,tanaa, shaakhaa, tathaa pattiyo se yukt bahuvarshiya vanaspati
'perennial woody plant having root, stem, branches and leaves'
peR manushya ke lie bahut hi upayogii hai 'trees are useful to men'

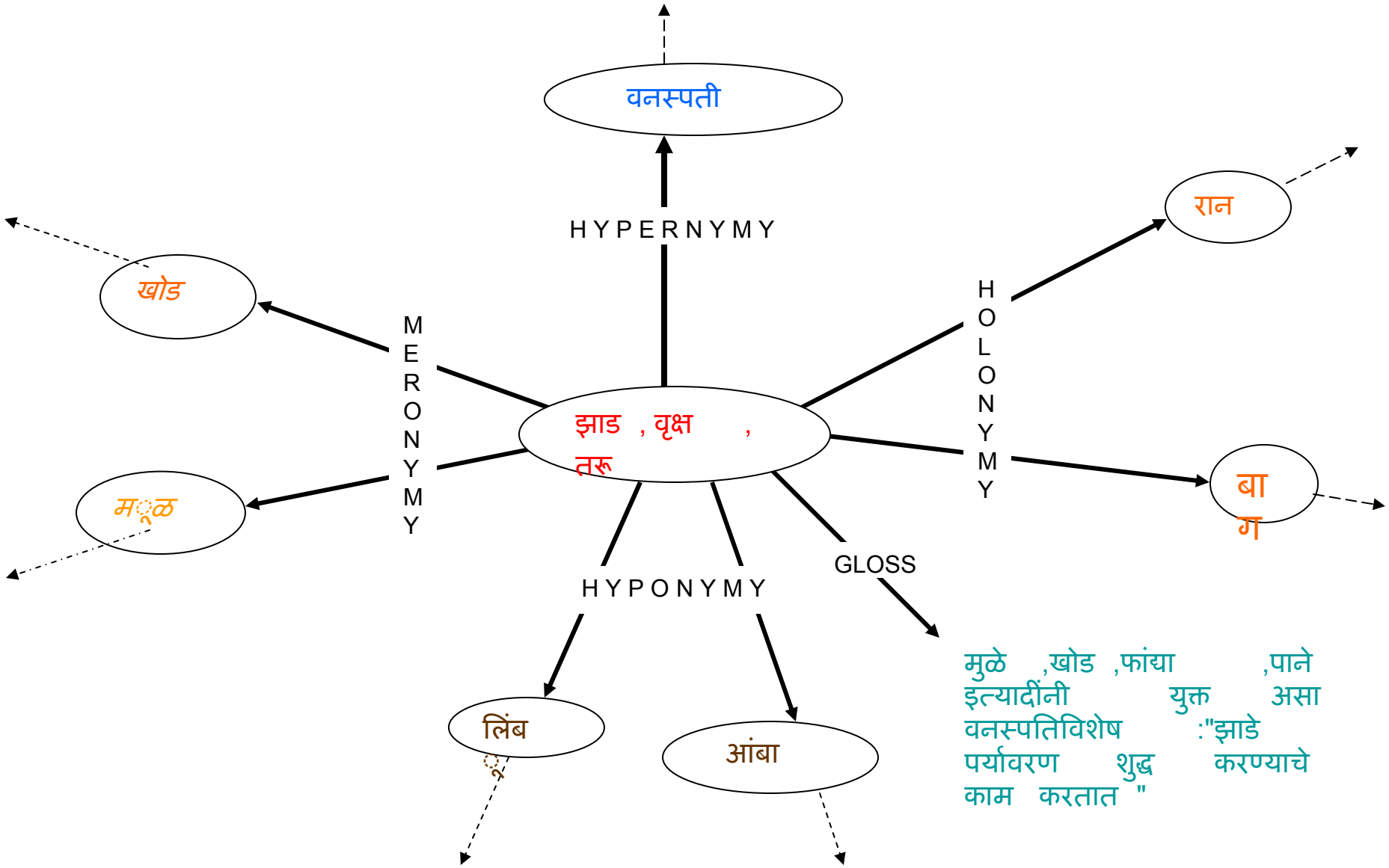
MWN entry:
{jhaaR, vriksh, taruvar, drum, taruu, paadap} 'tree'
mule, khoR, phaanghaa, pane ityaadiinii yokt asaa vanaspativishesh
'perennial woody plant having root, stem, branches and leaves'
tii damuun jhaadacyaa saavlit baslii 'Being tired/exhausted she sat
under the shadow of the tree'

Lexico-semantic relations in wordnet

Semantic relations in WordNet:

- Synonymy
- Hypernymy / Hyponymy
- Antonymy
- Meronymy / Holonymy
- Gradation
- Entailment
- Troponymy

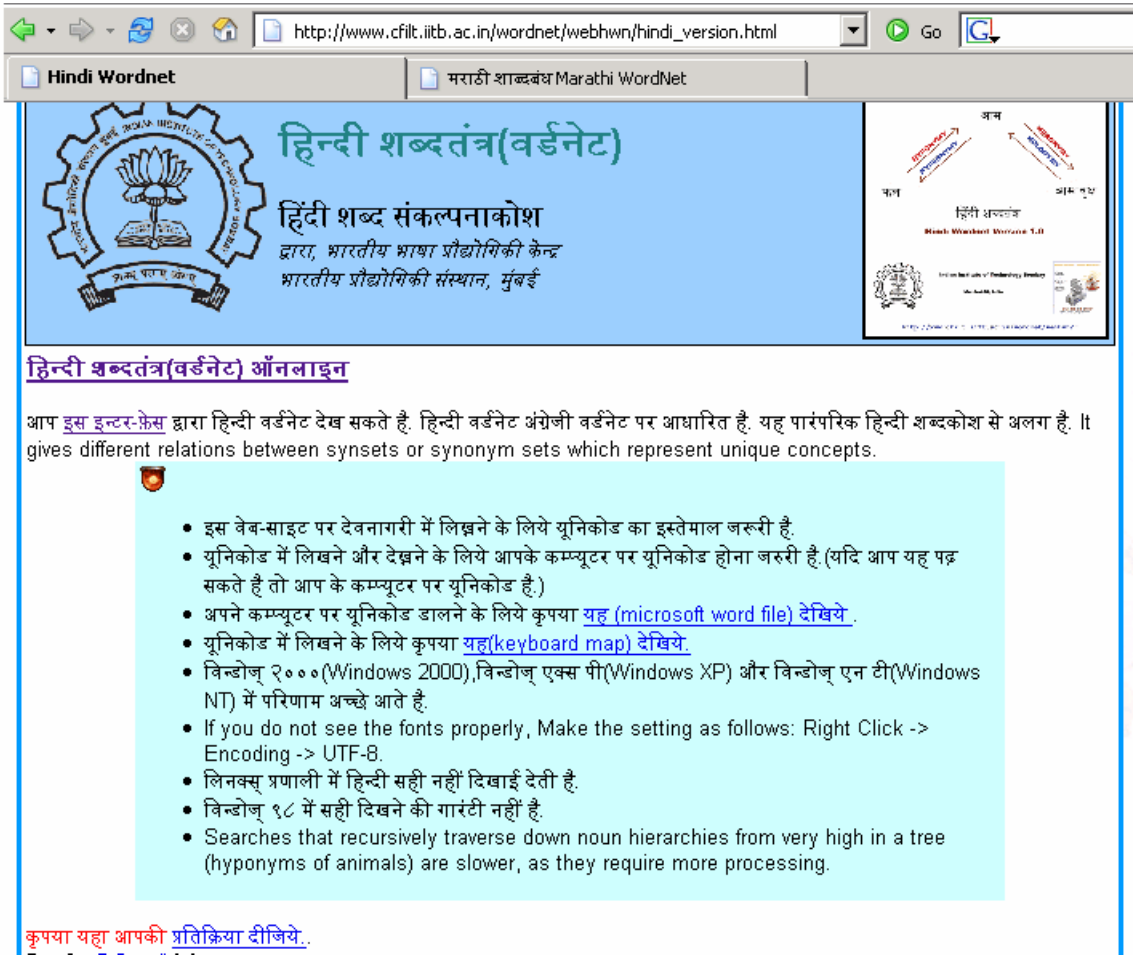
Semantic Relation subgraph (Noun)



Cross Part of Speech Linkages (important for word sense disambiguation)

- **Links between nouns and verbs:**
  - **Ability link** specifies the features inherited by a nominal concept
    - {machlii, macchii, matsya, miin, maahii} '*fish*'→ {tairnaa, pairnaa, paunrnaa} '*swim*'
  - **Capability link** specifies features acquired by a nominal concept
    - {vyakti, maanas}'*person*' → {tairnaa, pairnaa, paunrnaa} '*swim*'
  - **Function link** specifies function(s) associated with a nominal concept
    - {adhyaapak, shikshak}'*teacher*' → {paRhanaa, shikshaa denaa} '*teach*'
- **Links between nouns and adjectives**: indicate typical properties of a noun
  - {sher} '*tiger*' → {maansaahaarii} '*carnivorous*'.
- **Links between morphologically derived forms**
  - {bhaaratiiyataa} '*indianness*' is derived from {bhaaratiiya} '*Indian*' and is linked to it.

Hindi WN: just recently **made free**



Towards Multilingual Indo-WN

- Through *Relation Borrowing* (illustrated through HWN and MWN)
- **When the meaning is found in both Hindi and Marathi**: This is the most common case, since Hindi and Marathi are sister languages
- **When the meaning is found in Hindi but not in Marathi**: Relation borrowing is not possible
  - For instance, {दादा [daadaa, grandfather], बाबा [baabaa, grandfather], आजा [aajaa, grandfather], दद्दा [daddaa, grandfather], पितामह [pitaamaha, grandfather], प्रपिता [prapitaa, grandfather]} are words in Hindi for paternal grandfather. There are no equivalents in Marathi.
- **When the meaning is not found in Hindi but is found in Marathi**: The relations must be set up manually
  - For example, {गुढीपाडवा [gudhipaadvaa, newyear], वर्षप्रतिपदा [varshpratipadaa, new year]} are words in Marathi which do not have any equivalents in Hindi.

Hindi Verb Knowledge Base (HVKB)

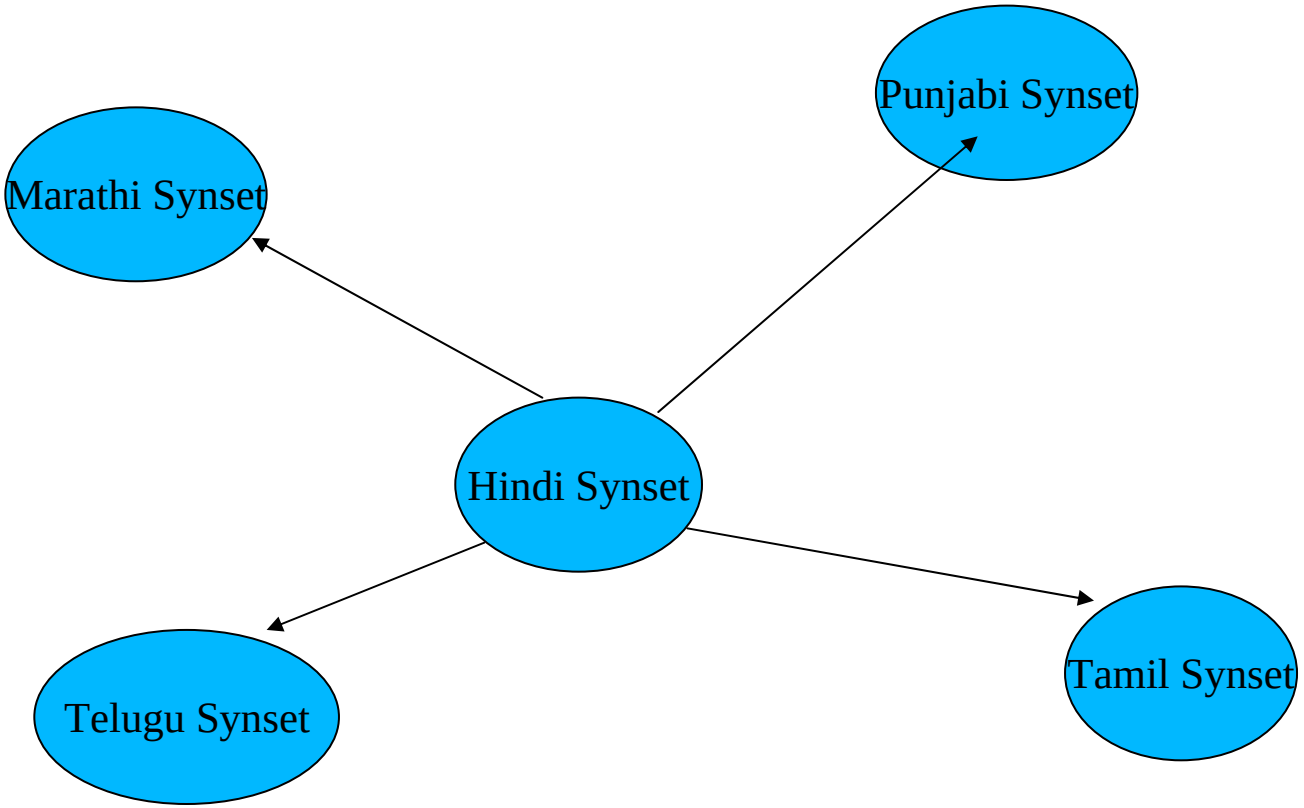
Chakrabarti, Sarma and Bhattacharyya, Lexical Resources Engineering Journal (accepted)

calanaa 'move'
(icl>act(agt>person))
***ve loga dhiire dhiire chal rahe hai*. 'They are moving slowly'.**
(gaman karnaa) 'to move'
Frame:NP1; NP1_NOM
[VINT, VOA, VOA-BACT]
→ *caRhanaa* '*climb*'
(icl>move{>act}(agt>person)
***ve loga dhiire dhiire chaRha rahe hai*. '*They are climbing slowly.*'**
***upar ki or jaanaa* 'to move upwards'**
Frame:NP1; NP1_NOM
[VINT, VOA, VOA-BACT]

MT and Cross lingual IR efforts in India

Dictionaries are based on WNs

- Every word in every language linked with each other through Hindi Synsets



Proposed Standard

Senses	Hindi	Marathi	Bangali	Oriya	Tamil
(W_1, W_2, W_3, W_4, W_5, W_6)	(W_1, W_2, W_3, W_4, W_5, W_6)	(W_1, W_2, W_3)	(W_1, W_2 , W_3)	(W_1, W_2, W_3, W_4)	(W_1, W_2, W_3)
(sun)	(सूर्य, सूरज, भानु, भास्कर, प्रभाकर, दिनकर, अंशुमान, अंशुमाली)	(सूर्य, भानु, दिवाकर, भास्कर, रवि, दिनेश, दिनमणी)	…	…	…
(cub, lad, laddie, sonny, sonny boy)	(लड़क ◌ा, बालक , बच्च ◌ा, छोकड ◌ा, छोर ◌ा, छोकर ◌ा, लौंड ◌ा)	(मुलग ◌ा, पोरग ◌ा, पोर , पोरग े)	…	…	…
(son, boy)	(पुत्र , बेट ◌ा, लड़क ◌ा, लाल , सुत , बच्च ◌ा, नंदन , पूत , चिरंजीव , चिरंज ी)	(मुलग ◌ा, पुत्र , लेक , चिरंजीव , तनय)	…	…	…

Studies on wordnets: *small world properties*

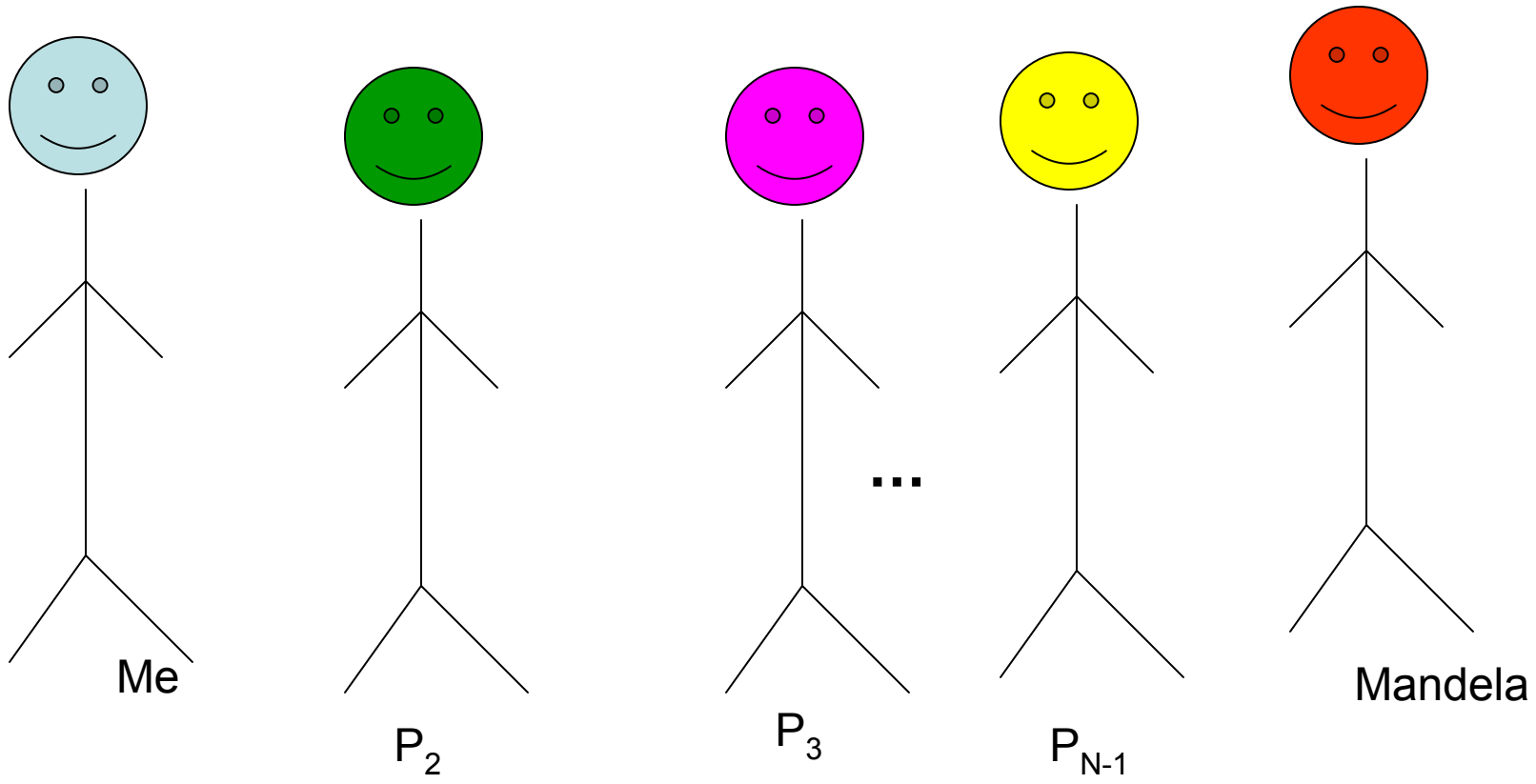
Ramanand, Ukey, Singh and Bhattacharyya, Mapping and Structural Analysis of Multilingual Wordnets, IEEE Data Engineering Bulletin, 30(1), March 2007

Human social graph

- How many links connect you to Adam Gilchrist/Nelson Mandela/Tim Berners-Lee?
- Sociological studies show that the diameter of human social graph is less than 10 (very, very small!)
- The concept of “Six Degrees of Separation”

Distance to Nelson Mandela

N<=10



Graphs and Measures

- Measures
  - Average Shortest Path Length
  - Clustering Coefficient
  - Degree Distribution
- Random Graphs: low Avg. Shortest Path
- Regular Graphs: high Avg. Shortest Path
- Small World Graphs: low Avg. Shortest Path

Cluster Coefficient

- Measures what fraction of neighbours of a node are related to each other
- *Cluster Coefficient C_i for a node i (with degree k_i)* of a directed graph:

$$C_i = \frac{|E(\Gamma_i)|}{2 \times \binom{k_i}{2}}$$

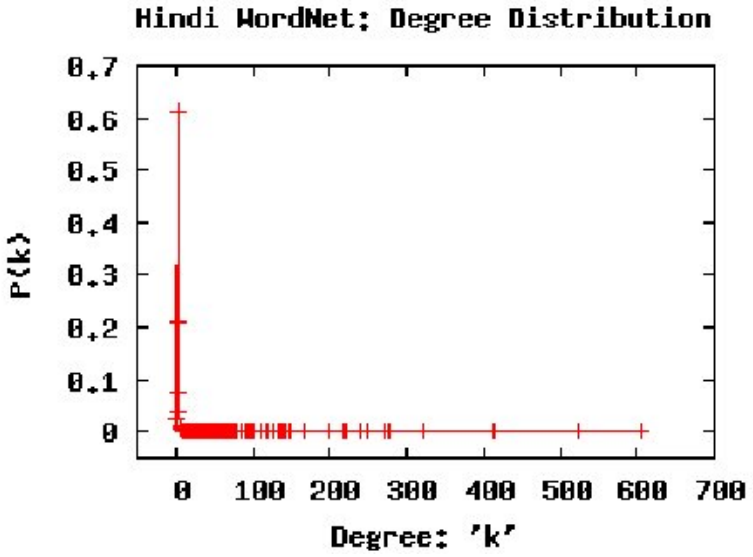
where Γ_i is the subgraph made of i and its neighbours, $|E(\Gamma_i)|$ is the number of edges of the subgraph, and $2 \times \binom{k_i}{2}$ is the total number of possible edges in Γ_i.

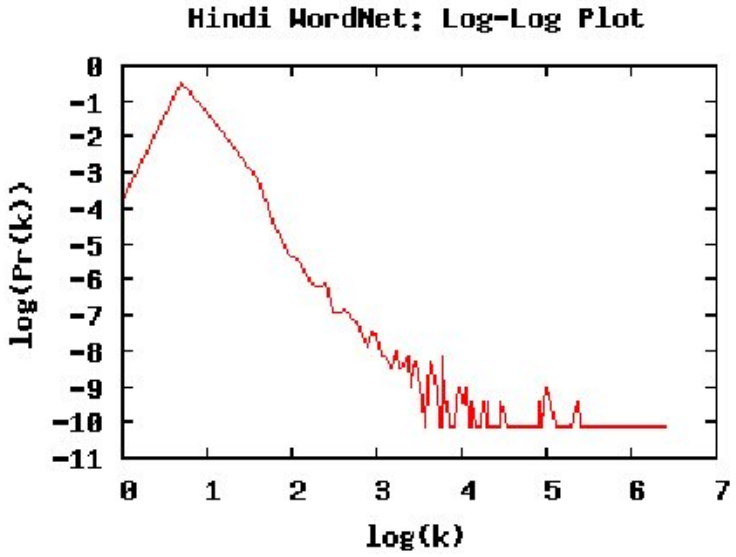
- Random Graphs: low CC (CC << 1)
- Regular Graphs: high CC (0.4 <= CC <= 0.7)
- Small World Graphs: high CC (0.4 <= CC <= 0.7)

But why study Small Worlds for NLP?

- Seen in language organization
- Seen in Wordnets!!

Degree Distribution in Wordnets





- Exponents observed:
  - English WordNet (Nouns): -2.063
  - Hindi WordNet: -2.592
  - Marathi WordNet: -2.841

High-degree nodes in Wordnets

- Eng. WordNet (Nouns):
  - (city,metropolis,urban center): 664, (law,jurisprudence): 611
  - (person,individual,someone,somebody,mortal,soul): 400
- Hindi WordNet:
  - (vyaktii, maanas, shaks, shakhs, ba.ndaa (person)): 607
  - (karm, karanii, kaam, kaarya, krtya, kaarvaaii, kaarvaahii (action)): 524
- Marathi WordNet:
  - (vyaktii, maaNus, isama, manushya, paTThaa, paThyaa (person)): 626
  - (karm, krtii, kriyaa, kaam kaarya, krtya (action)): 546

Cluster Coefficient in Wordnets

- Wordnet Avg. Cluster Coefficient:
  - English WN (Nouns): 0.526
  - Hindi WN: 0.268
  - Marathi WN: 0.358

Average Shortest Path Length in Wordnets

- Average Shortest Path Lengths observed:
  - English WordNet (Nouns): 8.878
  - Hindi: 4.378
  - Marathi: 4.255

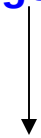
Concluding Remarks

Resource disadvantage: Tackle the problem at the grass root level: *a suggested program*

- **Construct exhaustive and high quality morph analyser, exploiting morphological richness- if the language is endowed with such richness**

- **Construct excellent POS Tagger**

- **Construct very good chunker**



- **Construct good parser**

Our Experience in a Multi Lingual Setting

- There is a strong indication that we will need much less annotated corpora for *Marathi* than for *Hindi.*
- A simple (*almost naïve☺*) example with two tags, say *TINF (to infinitive)* and *GER (gerund)*

  I need to go (to infinitive)

  going is impossible now (gerund)

Observation *1/3*

- Annotation richness: depends on availability of resources- *funds, linguistic expertise, people, time*
- Morphological richness: a language either has it or does not have
- Is a rich body of linguistic work available, at least for morphology?
- If yes (*e.g. for Sanskrit: Panini's Astadhyaayii- a masterpiece of morphology work),* exploit it to the fullest

Observation *2/3*

- A happy situation in the East for many languages
- Rich morphology
- Excellent linguistic tradition
- One could do this:

MA → POS Tagger → Chunker → Parser

Observation *3/3*

- Lets look around in the world of SNLP algorithms
- Aren't they clamoring for *more and more features*?
- MEMM, CRF: don't they say they would benefit from features in large number, judiciously chosen?
- Where will these features come from?
- One source is **Morphology**

Conclusions

- Indian NLP emerging as one of the most active in the world
- Lexical Networks like wordnets are crucial
- So are high accuracy failure resilient tools like POS taggers
- Multilinguality emerging as a norm rather than a fashion
  - Methods needed to tackle the challenges
- Invariances in multilingual computation and resources form an interesting study

URLs

- For resources

  www.cfilt.iitb.ac.in
- For publications

  www.cse.iitb.ac.in/~pb

Merci