Development of Sindhi Lexical Functional Grammar

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CLT-16

Outline

- Introduction
  - Background
  - Finite State Morphology
  - Lexical Functional Grammar
- Overall Development Model
- Implementing Sindhi Morphology
- Implementing Sindhi Syntax
- Coverage
- Conclusion

Background

- Presented work is about development of Sindhi Grammar

- Frameworks used include: Finite State Morphology and Lexical Functional Grammar

- Xerox Finite State Morphology Tools (XFST) and Xerox Linguistic Environment (XLE) are used for Implementation

Finite State Morphology

Singular	Intermediate	Plural	Rule
CRY	CRYS	CRIES	y→ie / ^____s#
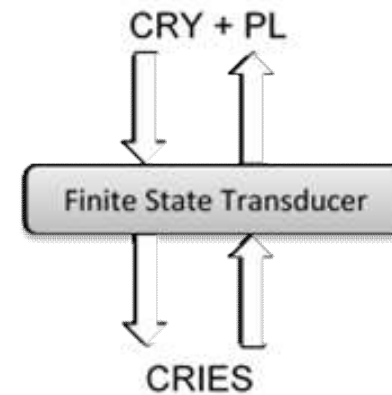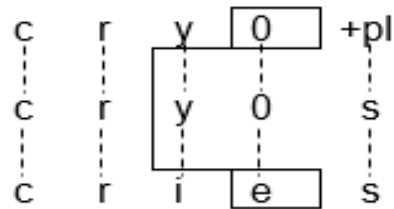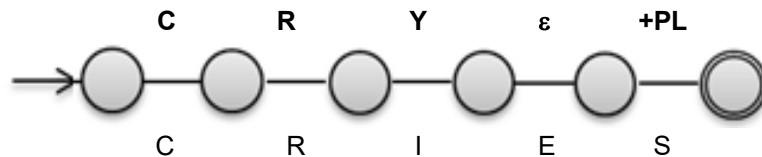
Lexical Functional Grammar

- Grammar based on generative grammars (Steedman, 1989), (Dalrymple, 2001)
- Defines linguistic structure at three different levels
  - Lexicon
  - C-structure (Constituent Structure)
  - F-structure (Functional Structure)

Lexical Functional Grammar

Lexicon

mAryO V (↑ PRED)   = 'mAru<(↑ SUBJ), (↑ OBJ)>'
         (↑ TENNSE)   = Past
         (↑ SUBJ NUM) = SG
         (↑ SUBJ PERS) = 3

Ali   N (↑ PRED)   = 'Ali'
         (↑ NUM) = SG
         (↑ PERS) = 3

C-Structure Rules

1. S →   NP   VP
         (↑ SUBJ= ↓)   ↑=↓

2. NP →   N
              ↑=↓

3. VP →   NP   V
4. - - - - - - - - - - - - - - - - - -

F-Structure

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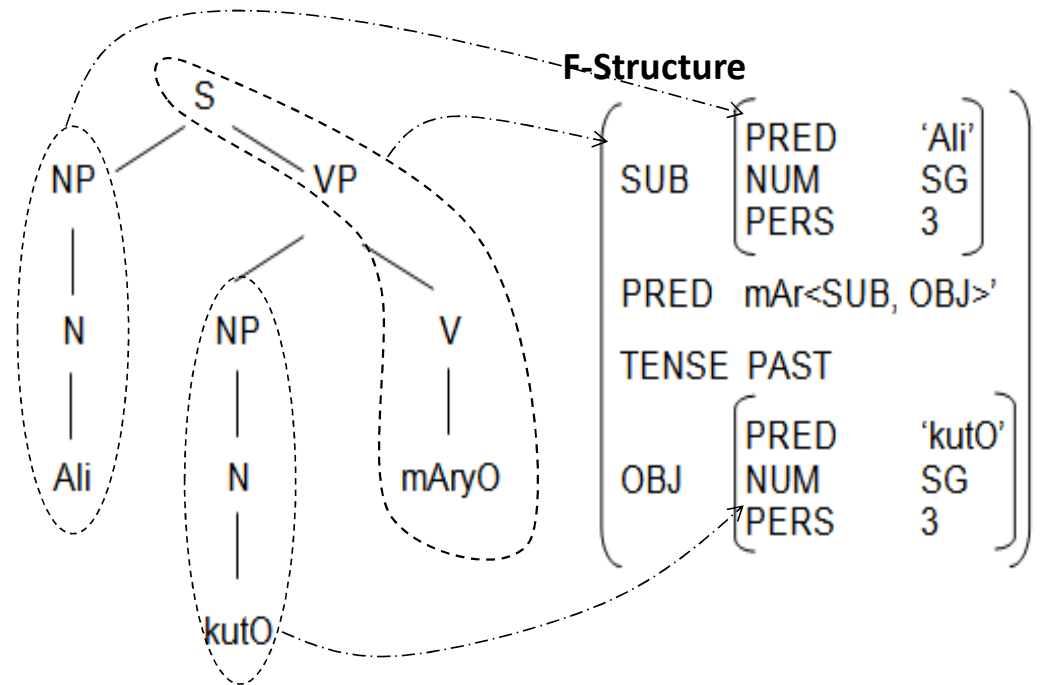
Grammar Engineering Process
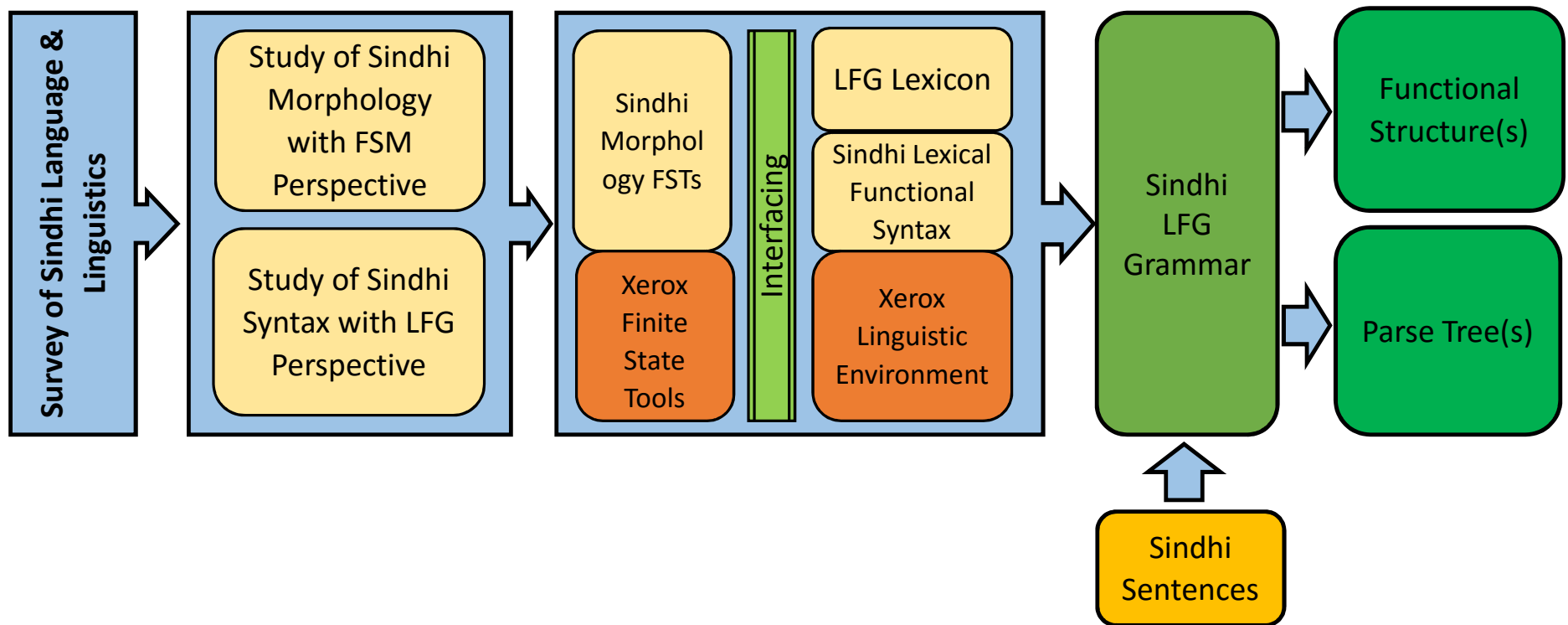
Implementing Morphology

- Morphological paradigms of different POS classes are modeled by incorporating the inflection rules in FSTs using XFST scripts

Implementing Morphology

```
!SINDHI NOUN MORPHOLOGY
Multichar_Symbols
+Noun +Adjective +Adverb +Verb
+Common +Proper +Abstract !Noun Types
+Animate +Inanimate !Noun Concept
```

Upper: CHOkir+Noun+Common+Count+Animate+Sg+Masc+Nominative

Intermediate: CHOkir

O

Lower: CHOkirO

```
Nouns;

LEXICON Nouns
     !Boy (Animate Common Noun)
CHOkir+Noun+Common+Count+Animate:CHOkir N_Cat1;
     ...
LEXICON N_Cat1
     +Sg+Masc+Nominative:O        #;
     +Sg+Masc+Oblique:E           #;
     +Sg+Masc+Vocative:A          #;
     +Sg+Fem+Nominative:Ia        #;
```

Morphological analysis of surface form "CHOkirO"

```
CHOkir   {"+Noun"   "+Common"   "+Count"
"+Animate"        "+Sg"        "+Masc"
"+Nominative"}
```

Implementing Morphology

- Following inflections are handled (wherever applicable)
  - Number (`CHOkirO, CHOkirA`)
  - Gender (`CHOkirO, CHOkirIa`)
  - Case (`CHOkirO, CHOkirE`)

  Noun, Pronoun, Ajd, Adv, Postposition, Verb

  - Tense (`likHu, likHAN,likHiyO`)
          (`AhE, huO, hUNdO`)
  - Aspect (`likHu, likHando`)
  - Mood (`likHu, likHijANi`)

  Verb

Tense Aspect and Mood not yet analyzed by Sindhi Grammarians

Noun Cases

- Case

Case	Case Marker	Example	
Nominative	∅	CHOkirO	CHOkirO
Accusative / Dative	-E	CHOkirO	CHOkir-E
Postpositional	-E		CHOkir-E
Locative	-E		CHOkir-E
Instrumental	-E		sONT-E sAN
Possessive / Genetive	-E		CHOkir-E JO
Ablative	-AN	gHaru	gHar-AN:
Vocative	-A	CHOkirO	CHOkirA

Oblique Form

- Noun case morphology is further complicated by number and gender inflections in combination with cases

Pronouns

- Pronouns are declined for number and gender
- Marked by Nominative, Oblique and Genitive Cases

Case	Masculine	Feminine
Nom.Sg.	`kehRO: CHOkirO`	`kehRI CHOkirI`
Nom.pl.	`kehRA CHOkirA`	`kehRyUN CHOkirUN`
Obl.sg	`kehRE CHOkirE`	`kehRIa CHOkirIa`
Obl.pl	`kehRani CHOkirani`	`kehRiyuni CHOkiruni`
Gen.sg.	`muhiNjO CHOkirO`	`muhiNJI: CHOkirI`
Gen.pl.	`muhiNjA CHOkirA`	`muhiNjUN CHOkiriUN`

Pronominal Suffixes

- Sindhi is one of few Indo-Aryan languages with pronominal suffixes
- Three types of pronominal suffixes are

S.No.	Pronominal Suffix Type		Syntactic Role	Example	
1	Nominal Suffix	اسميہ ضمير متصل	Noun	پُٽم، پُٽس، چاچھين	`puTa-mi`
2	Verbal Suffix	فعليہ ضمير متصل	Verb	ماريانس ، اٿئون، لکندم	`mAri-yAN-si`
3	Postpositional Suffix	جري ضمير متصل	Pronoun	کين، ساڻس، وٽئون	`kHE-na`

Verbs

- Verbs are further classified into
  - Main Verbs (Transitive & Intransitive)
    - Compound / Complex Verbs
    - Participles (Present Participle, Past Participle, Future Participle, Verbal Noun, Conjunctive Participle)
    - Infinitives
  - Auxiliary
  - Copula
  - Modal

Implementing Syntax

- Nominal Elements
  - Nouns, Pronouns, Adjectives, Adverbs
  - Phrases constituted by above elements
  - Complicated by coordination, postpositional phrases and relative clauses and Cases Marking

- Verbal Elements
  - Verb Subcategorization
    - SUBJ, OBJ, OBJ2, OBL, PREDLINK, COMP, XCOMP
- Adjuncts
  - ADJUNCT, XADJUNCT (Open Adjuncts)

NP Constructions

- Noun (CHOkirO)
- Pronoun-Noun (ihO CHOkirO)
- Adj-Noun (suTHO CHOkirO)
- Pronoun-Ajd-Noun

  (ihO suTHO CHOkirO)


```
"ihO CHOkirO"

     ⎡ PRED   'CHOkirO'                                              ⎤
     ⎢ NSEM   [N-CONCEPT animate]                                    ⎥
     ⎢                                                               ⎥
     ⎢        ⎡ NSEM [COMMON count] ⎤                                ⎥
     ⎢ NTYPE  ⎢                     ⎥                                ⎥
     ⎢        ⎣ NSYN common         ⎦                                ⎥
     ⎢                                                               ⎥
     ⎢              ⎡      ⎡ PRED  'ihO'                          ⎤ ⎤⎥
     ⎢ SPEC   DET   ⎢      ⎢ NTYPE [NSYN pronoun]                 ⎥ ⎥⎥
     ⎢           1  ⎢   91 ⎢ CASE nom. DEIXIS proximal.           ⎥ ⎥⎥
     ⎢ 38           ⎣      ⎣ GEND masc, NUM sg, PRON-TYPE demon   ⎦ ⎦⎥
     ⎢ 105                                                           ⎥
     ⎣ 107 CASE nom, GEND masc, NUM sg                               ⎦
```

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Case Marking

- Syntactic Case Marking is handled by using special Case Phrase KP (Bogel., et al, 2009)

- Accusative & Dative Case with "khE" marker

- Genitive case is special as it holds agreement
  - KPPoss is used
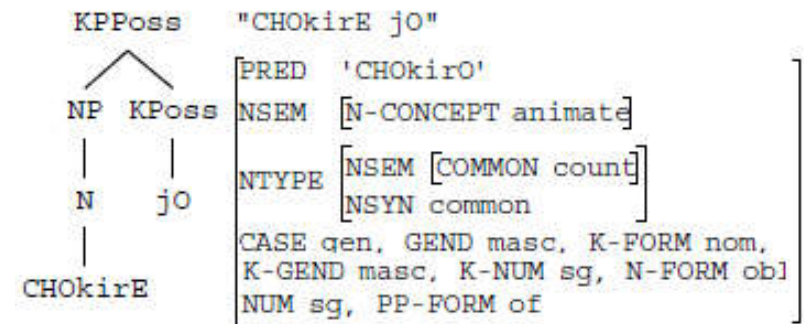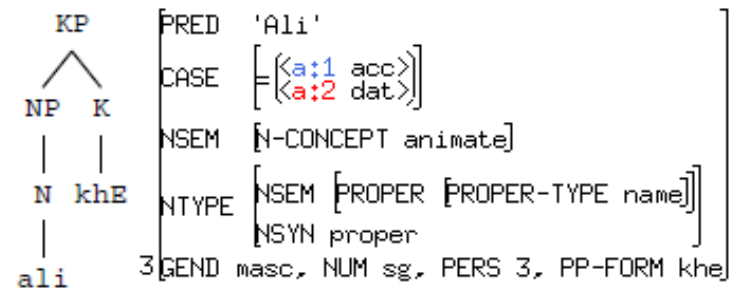
Verb Subcategorization

SUBJECT & OBJECT

ali　　**kitAbu**　**likHE**　　　**tHO**

Ali.NN　　book.NC　　write.Aoirst　　be.Aux.Pres

Ali Writes a book.

($\uparrow$ PRED)='LIKHU<($\uparrow$ SUB) ($\uparrow$ OBJ)>'

"AUN kitAbu likhAN thO"

```
CS 1:          S
            /  |  \
          KP  KP   VC
          |    |   / \
          NP  NP  V  VAUX
          |    |  |    |
         PRON  N likhAN thO
          |    |
         AUN  kitAbu
```
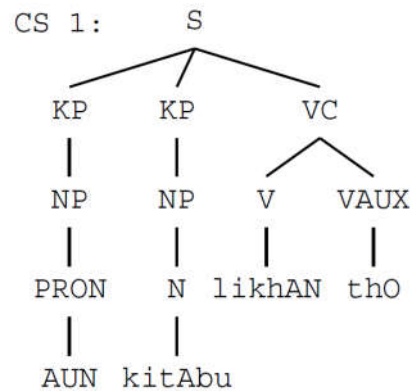
```
        PRED    'likhu<[1:AUN], [34:kitAbu]>'
                [PRED   'AUN'
        SUBJ    NTYPE  [NSYN pronoun]
              1 [CASE nom, GEND masc, NUM sg, PERS 1, PRON-TYPE personal]
                [PRED   'kitAbu'
                 NSEM   [N-CONCEPT inanimate]
        OBJ
                 NTYPE  [NSEM [COMMON count]
                         NSYN common]
             34 [CASE acc, GEND masc, N-FORM obl, NUM sg]
        TNS-ASP [MOOD indicative, PERF -, PROG -, TENSE pres, TENSE-FORM aorist]
     67 [AUXTYPE tho, GEND masc, NUM sg, VTYPE main]
```

Verb Subcategorization

SUBJECT Only

ali   **dORE**   **tHO**

Ali.NN   run.Aoirst   be.Aux.Pres

Ali runs.

(↑PRED)='dORi<(↑SUB)'

Verb Subcategorization

Passives: SUBJ → NULL, OBJ → SUBJ

kitAbu likHijE   thO

book.NC   write.Pass.Aorist be.Aux.Pres

Book is being written/Book writing takes place.

(↑PRED)='LIKHU<(NULL ↑SUB>'

kitAbu likHibO   AhE

book.NC write.Pass.Fut is.Aux.Pres

Book writing takes place.

(↑PRED)='LIKHU<(NULL ↑SUB) >'

```
"kitAbu likhijE"
[PRED    'likhu<NULL, [1:kitAbu]>'
          [PRED   'kitAbu'
          NSEM   [N-CONCEPT inanimate]
                                                          ]
 SUBJ           [NSEM [COMMON count]
          NTYPE [NSYN common          ]
        1[GEND masc, N-FORM obl, NUM sg]
35[GEND masc, NUM sg, PASSIVE +, VTYPE main]
```

Passives: NULL Arguments

likHibO   **AhE**

write.Pass.Fut.Sg.Masc   is.Aux.Pres.Sg

Writing takes place.

(↑PRED)='LIKHU<(NULL) >'

likHijE   **tHO**

write.Pass.Aorist.Sg   be.Aux.Pres.Sg.Masc

(It's) being written.

(↑PRED)='LIKHU<(NULL) >'

Object-2 (OBJ-θ, Secondary OBJ)

```
ali CHOkirE=khE KHatu        likhE
Ali boy.Obl=dat letter.Nom write
```

(↑PRED)='likhu<(↑SUB) (↑ OBJ2) (↑ OBJ)>'

SUB: ali

OBJ2: CHOkirO

OBJ: KHatu

```
F-structure #1

"ali CHOkirE khE KHatu likhE"

PRED      'likhu<[1:Ali], [35:CHOkirO], [71:KHat]>'
          PRED   'Ali'
          NSEM   [N-CONCEPT animate]
SUBJ
          NTYPE  NSEM [PROPER [PROPER-TYPE name]]
                 NSYN proper
        1 GEND masc, NUM sg, PERS 3
          PRED   'CHOkirO'
          NSEM   [N-CONCEPT animate]
OBJ2
          NTYPE  NSEM [COMMON count]
                 NSYN common
       35 CASE dat, GEND masc, N-FORM obl,
                   NUM sg, PP-FORM khe
          PRED   'KHat'
          NSEM   [N-CONCEPT inanimate]
OBJ
          NTYPE  NSEM [COMMON count]
                 NSYN common
       71 CASE nom, GEND masc, NUM sg
TNS-ASP [TENSE-FORM aorist]
GEND masc, NUM sg, VTYPE main
```

Verb Subcategorization

Oblique

tUN CHOkirE=khE ali=khAN KHatu likhArAi

you boy=dat   ali=abl letter write.caus2

(↑PRED)='khAu<(↑ SUB) (↑ OBL) (↑ OBJ2) (↑ OBJ)>'

SUB: tUN

OBL: Ali

OBJ2: CHOkirO

OBJ: KHatu

Verb Subcategorization

"tUN CHOkirE khE ali khAN KHatu likhArAi"
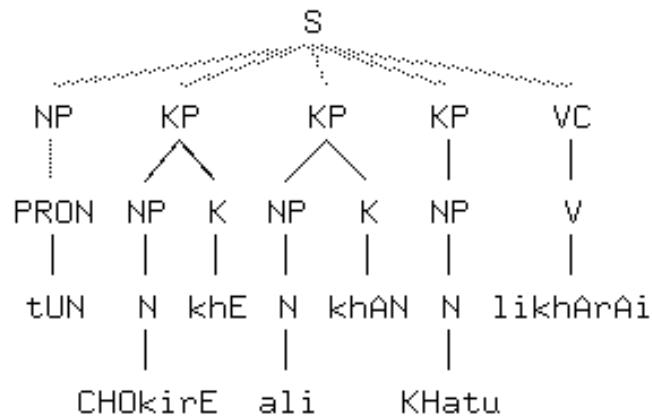

```
F-structure #1
'tUN CHOkirE khE ali khAN KHatu likhArAi"

PRED  'likhu<[1:tUN],[35:CHOkirO],[71:Ali],[108:KHat]>'
        PRED   'tUN'
SUBJ    NTYPE  [NSYN pronoun]
        [CASE nom, GEND masc, NUM sg, PERS 2, PRON-TYPE personal]
        PRED   'CHOkirO'
        NSEM   [N-CONCEPT animate]
OBJ2    NTYPE  [NSEM [COMMON count]]
               [NSYN common]
        [CASE dat, GEND masc, N-FORM obl, NUM sg, PP-FORM khe]
        PRED   'Ali'
        NSEM   [N-CONCEPT animate]
OBL     NTYPE  [NSEM [PROPER [PROPER-TYPE name]]]
               [NSYN proper]
        [CASE agent, GEND masc, NUM sg, PERS 3, PP-FORM khan]
        PRED   'KHat'
        NSEM   [N-CONCEPT inanimate]
OBJ     NTYPE  [NSEM [COMMON count]]
               [NSYN common]
        [CASE nom, GEND masc, NUM sg]
GEND masc, V-Formimperative, V-Form2 causative, VTYPE main
```

Complement (COMP)

Ali   sOchyO   [**ta   Ahmed kelA   khAE thO**]

ali.Nom thought [that Ahmed bananas eat be.PresAux

(↑PRED)='soch<(↑SUB) ↑COMP>'

SUB: Ali

COMP: 'khau<(↑SUB) ↑OBJ>'

SUB: Ahmed

OBJ: kelA

Complement (COMP)

CS 1:

```
                    S
        ┌───────────┼───────────┐
        KP          VC          CP
        │        ┌───┴───┐    ┌──┴──┐
        NP       V     VAUX   C     S
     ┌──┴──┐     │      │     │  ┌──┼──────┐
   PRON    PPP likhAN  thO   ta  KP  VC    CP
     │    ┌─┴─┐                  │ ┌─┴─┐  ┌─┴─┐
    AUN   N  PP                  NP V VAUX C   S
     │    │                      │ │   │  │ ┌─┴──┐
   mEZa  tE                      N dORE hA ta KP VC
                                 │              │ ┌┴──┐
                              gaDahu            NP V VAUX
                                                │  │   │
                                                N sumhE hA
                                                │
                                               ali
```
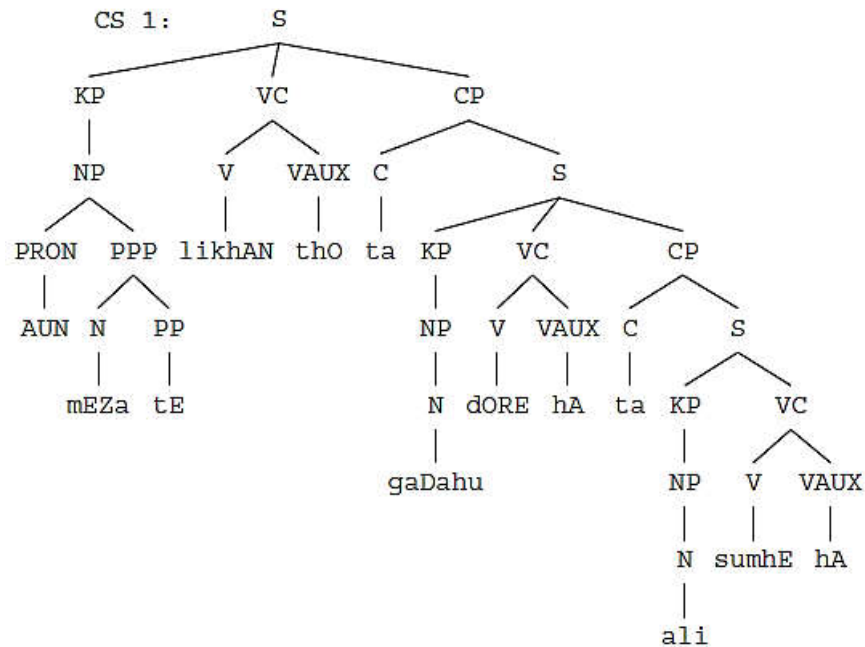
"AUN mEZa tE likhAN thO ta gaDahu dORE hA ta ali sumhE hA"

```
PRED     'likhu<[1:AUN], [119:dORi]>'
         PRED      'AUN'
                            ┌ ┌ ┌ PRED   'mEZa'                    ┐ ┐ ┐
                            │ │ │ NSEM   [N-CONCEPT inanimate]     │ │ │
SUBJ     ADJUNCT  {         │ │ │        ┌ NSEM [COMMON count] ┐   │ │ │ }
                            │ │ │ NTYPE  │ NSYN common          │  │ │ │
                            │ │ └ 67 CASE loc, PP-FORM on       ┘  │ │
                            └ 34 GEND fem, N-FORM obl, NUM sg       ┘ ┘
         NTYPE    [NSYN pronoun]
       1 CASE nom, GEND fem, NUM sg, PERS 1, PRON-TYPE personal

         PRED      'dORi<[121:gaDahu], [187:sumhu]>'
                            PRED   'gaDahu'
                            NSEM   [N-CONCEPT animate]
         SUBJ               NTYPE  ┌ NSEM [COMMON count] ┐
                                   └ NSYN common          ┘
                        121 CASE acc, GEND masc, N-FORM obl, NUM sg, PERS 3

COMP                        PRED   'sumhu<[189:Ali]>'
                                   PRED   'Ali'
                                   NSEM   [N-CONCEPT animate]
         COMP    SUBJ              NTYPE  ┌ NSEM [PROPER [PROPER-TYPE name]] ┐
                                          └ NSYN proper                       ┘
                               189 CASE acc, GEND masc, NUM sg, PERS 3
                 TNS-ASP  [MOOD contrafactual, TENSE-FORM aorist]
             187 C-TYPE that, NUM sg, VTYPE main
         TNS-ASP  [MOOD contrafactual, TENSE-FORM aorist]
     119 C-TYPE that, NUM sg, VTYPE main
TNS-ASP  [MOOD indicative, PERF -, PROG -, TENSE pres, TENSE-FORM aorist]
  69 AUXTYPE tho, GEND masc, NUM sg, VTYPE main
```

Verb Subcategorization

Open Complement (XCOMP)

Ali KHatu likhaNra **gHurE thO**

Ali letter write.inf want be.AuxPres

(↑PRED)='gHuru<(↑ SUBJ) (↑ XCOMP)>'

SUB: Ali

XCOMP: 'kara<(↑SUBJ) ↑OBJ>'
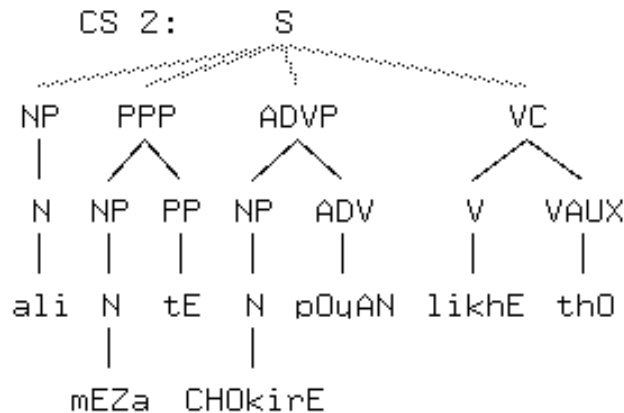
SUB: Ali

OBJ: KHatu

```
"ali KHatu likhaNra ghurE thO"
PRED      'ghuru<[1:Ali], [69:likhu]>'
                PRED    'Ali'
                NSEM    [N-CONCEPT animate]
SUBJ
                        NSEM  [PROPER [PROPER-TYPE name]]
                NTYPE
                        NSYN  proper
              1 GEND masc, N-FORM obl, NUM sg, PERS 3
                PRED    'likhu<[1:Ali], [35:KHat]>'
                SUBJ    [1:Ali]
                        PRED    'KHat'
                        NSEM    [N-CONCEPT inanimate]
XCOMP
                OBJ
                        NTYPE   NSEM [COMMON count]
                                NSYN common
                   35 GEND masc, N-FORM obl, NUM sg
             69 GEND masc, NUM pl, VFORM inf, VTYPE main

TNS-ASP [MOOD indicative, PERF -, PROG -, TENSE pres.
AUXTYPE tho, GEND masc, NUM sg, VTYPE main, TENSE-FORM aorist]
```
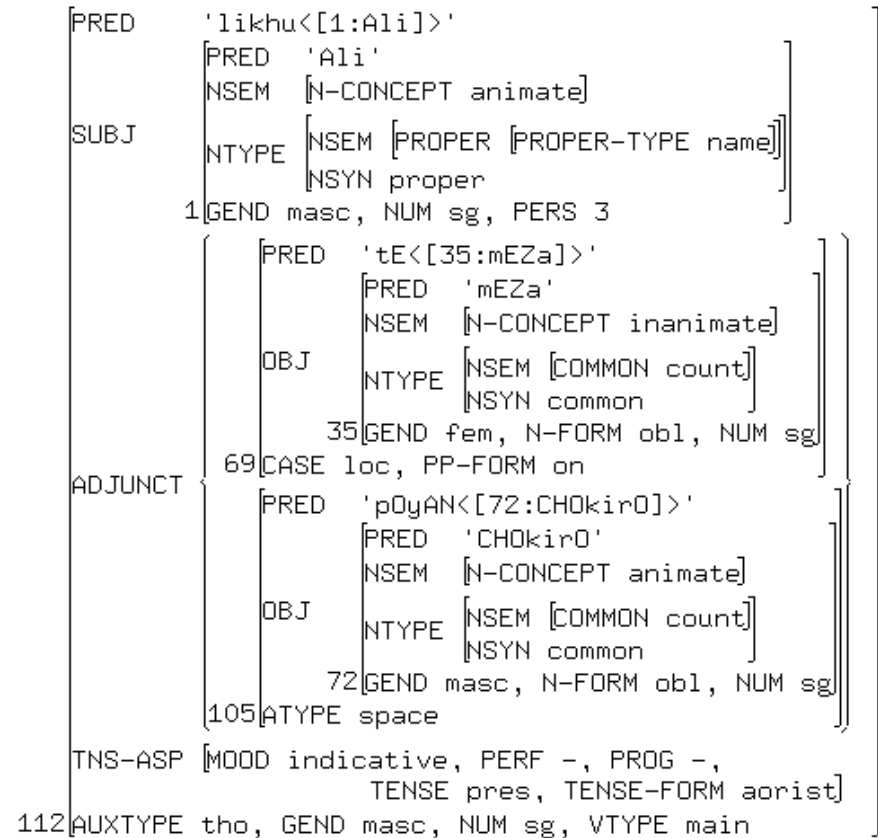
ADJUNCT

- Postpositional and adverbial phrases which do not fit in verb sub-categorization frames are called adjuncts
  - bHOlRO bAG mEN kHAE tHO
  - bHOlRO bAG mEN vaNra tE kHAE tHO
- Phrasal level Adjuncts
  - suTHO aiN suhiNrU CHOkirO

ADJUNCT

"ali mEZa tE CHOkirE pOyAN likhE thO"

```
                    CS 2:        S
                          _____
                         /  / /  \    \
                    NP  PPP   ADVP    VC
                    |   /\    /\      /\
                    N  NP PP NP ADV  V  VAUX
                    |  |  |  |   |    |   |
                   ali N  tE N pOyAN likhE thO
                       |     |
                      mEZa  CHOkirE
```

"ali mEZa tE CHOkirE pOyAN likhE thO"

```
PRED      'likhu<[1:Ali]>'
          ┌PRED  'Ali'
          │NSEM   [N-CONCEPT animate]
SUBJ      │
          │NTYPE  [NSEM [PROPER [PROPER-TYPE name]]
          │       [NSYN proper
         1│GEND masc, NUM sg, PERS 3

          ┌        ┌PRED  'tE<[35:mEZa]>'
          │        │       ┌PRED  'mEZa'
          │        │       │NSEM   [N-CONCEPT inanimate]
          │        │OBJ    │
          │        │       │NTYPE  [NSEM [COMMON count]
          │        │       │       [NSYN common
          │        │    35 │GEND fem, N-FORM obl, NUM sg
          │     69 │CASE loc, PP-FORM on
ADJUNCT  <
          │        ┌PRED  'pOyAN<[72:CHOkirO]>'
          │        │       ┌PRED  'CHOkirO'
          │        │       │NSEM   [N-CONCEPT animate]
          │        │OBJ    │
          │        │       │NTYPE  [NSEM [COMMON count]
          │        │       │       [NSYN common
          │        │    72 │GEND masc, N-FORM obl, NUM sg
          │    105 │ATYPE space

TNS-ASP  [MOOD indicative, PERF -, PROG -,
                 TENSE pres, TENSE-FORM aorist]
    112│AUXTYPE tho, GEND masc, NUM sg, VTYPE main
```

XAJUNCT

- XADJUNCTs are embedded sentences where SUBJ is controlled from outside

- The only pattern found is marked by conjunctive participles
  - hU dORI gHaru vayO
  - Ali kitAbu likhI mAnI kHAdHI

hU dORI gHaru vayO

Ali kitAbu likHI mAnI kHAdHI

More Research is required on XADJUNCT Patterns in Sindhi

XAJUNCT


```
"CHOkirO kitAbu likhI dORyO"

PRED          'likhu<[1:CHOkirO], [34:kitAbu]>'
              PRED   'CHOkirO'
              NSEM   [N-CONCEPT animate]
SUBJ
              NTYPE  [NSEM [COMMON count]]
                     [NSYN common       ]
            1[CASE nom, GEND masc, NUM sg, PERS 3]
              PRED   'kitAbu'
              NSEM   [N-CONCEPT inanimate]
OBJ
              NTYPE  [NSEM [COMMON count]]
                     [NSYN common       ]
           34[CASE nom, GEND masc, NUM sg]
              PRED   'dORi<[1:CHOkirO]>'
XADJUNCT      SUBJ   [1:CHOkirO]
           91[GEND masc, NUM sg, VTYPE main]
 68[GEND masc, PTCPL-TYPE conjunctive, VTYPE main]
```

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Pronominal Suffixes

Suffixes attached to verbs, construct different morphological forms, syntactically cause pro-drop


```
CS 2:  S
       |
       VC
       |
       V
       |
    likhiyame
```
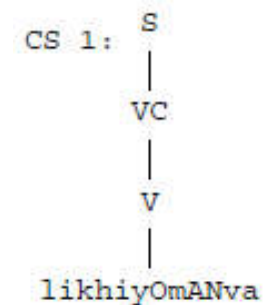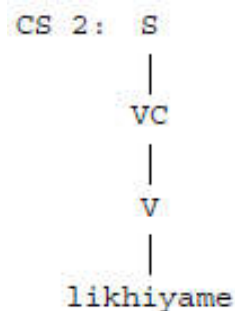
```
"likhiyame"

[PRED      'likhu<[1-SUBJ:pro]>'                                    ]
[                                                                   ]
[SUBJ      [PRED 'pro'                                          ]   ]
[          [GEND fem, N-FORM obl, NUM sg, PERS 1]               ]
[                                                                   ]
[TNS-ASP   [PERF +]                                                 ]
[1 NUM sg, PTCPL-TYPE past, VTYPE main                              ]
```

```
CS 1:  S
       |
       VC
       |
       V
       |
   likhiyOmANva
```

```
"likhiyOmANva"

[PRED      'likhu<[1-SUBJ:pro], [1-OBJ:pro]>'                        ]
[                                                                    ]
[SUBJ      [PRED 'pro'                                          ]    ]
[          [GEND fem, N-FORM obl, NUM sg, PERS 1]               ]
[                                                                    ]
[OBJ       [PRED 'pro'                                          ]    ]
[          [CASE acc, GEND fem, NUM pl, PERS 2]                 ]
[                                                                    ]
[TNS-ASP   [PERF +]                                                  ]
[1 NUM sg, PTCPL-TYPE past, VTYPE main                               ]
```

coverage

- Morphology
  - FST Models (Nouns, Pronouns, Adjectives, Verbs)
  - LFG Lexicon Postpositions, Conjunctions, Adverb
  - Features
    - Gender, Number, Case, Mood, Aspect, Tense
- Syntax
  - Partially Free Word Order
  - SUB, OBJ, OBL, OBJ2, COM, XCOMP, ADJUNCT, XADJUNCT, PREDLINK
  - Coordination, Subordination, Mood, Case, Aspect, Tense, Agreement

Coverage

Word Class	Stems	Morphological Forms / Inflections	Average Inflections / Stem
Verbs	100	5013	50.13
Nouns	323	1729	5.35
Pronouns	79	283	3.58
Adjectives	71	394	5.55
Adverbs	38	38	1.00
Total	611	7457	12.20

Conclusion & Future Work

- Development in current state covers the morphological and syntactic constructions discussed in above.

- Basic morphology and syntax constructs in Sindhi are identified and modeled.

- Morphological analysis shows interesting results like adjectives have more average inflections than nouns

- Pronouns have 3.58 average inflections per word.

- Also verb can have up to 75 different morphological forms (or even more)

Conclusion & Future Work

- Though the basic constructs of Sindhi morphology and Syntax are implemented yet many complexities are subject to further research and development including:
  - pronominal suffixation with nominal elements,
  - pronominal suffixation with postpositions,
  - NP coordination model,
  - verbal complex constructions which form complex predicates,
  - Adverbial agreement
  - Prodrop phenomenon in Sindhi.

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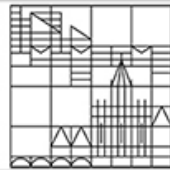
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