# ElixirFM Functional Arabic Morphology

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إِجتِمَاعُ خُبَرَاءِ المُحَلِّلَاتِ الصَّرفِيَّةِ الحَاسُوبِيَّةِ لِلُّغَةِ العَرَبِيَّةِ

مَجمَعُ اللُّغَةِ العَرَبِيَّةِ بِدِمَشقَ

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## Introduction

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Definition of lexemes includes the derivational root and pattern information if appropriate. Modeling of the written language as well as spoken dialects is expected methodologically identical.

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`"al-lA-silkIyu"` *al-lā-silkīyu* اللاسلكي اَللَّاسِلكِيُّ اَللَّاسِلْكِيُّ

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```
"s l k"    `merge`    al >| lA >| FiCL |< Iy |<< "u"
```

```
|> "s l k" <| [
    FaCaL                    `verb`    [ "proceed", "behave" ]
        `imperf`  FCuL,
    FiCL                     `noun`    [ "wire", "thread" ]
        `plural`  HaFCAL,
    FiCL |< Iy               `adj`     [ "wire", "by wire" ],
    lA >| FiCL |< Iy         `adj`     [ "wireless", "radio" ],
    FuCUL                    `noun`    [ "behavior", "conduct" ],
    FuCUL |< Iy              `adj`     [ "behavioral" ],
    MaFCaL                   `noun`    [ "road", "method" ]
        `plural`  MaFACiL                                      ]
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```

| | | | |
|---|---|---|---|
| proceed, behave | I(*u*) *salak* سَلَك | behavior, conduct | *sulūk* سُلُوك |
| wire, thread | (*ʾaslāk* أَسلَاك) *silk* سِلك | behavioral | *sulūkīy* سُلُوكِيّ |
| wire, by wire | *silkīy* سِلكِيّ | road, method | *maslak* مَسلَك |
| wireless, radio | *lā-silkīy* لَاسِلكِيّ | | (*masāliku* مَسَالِكُ) |

| | | |
|---|---|---|
| Form | All~Asilokiy~apu | اللّاسِلْكِيَّةُ |
| Morph | Al + lAsilokiy~ + ap + u | |
| Tag | DET+ADJ+NSUFF_FEM_SG+CASE_DEF_NOM | |
| Gloss | the + wireless / radio + (fem.sg.) + (def.nom.) | |
| Lemma | lAsilokiy~_1 | لَاسِلْكِيّ |

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.................................................................................................

| | | |
|---|---|---|
| Form | *al-lA-silkIyaTu* | *al-lā-silkīyatu* اَللّاسِلْكِيَّةُ |
| Morph | al >\| lA >\| FiCL \|< Iy \|< aT \|<< *"u"* | |
| Tag | A-----FS1D | |
| Form | *lA-silkIy* | *lā-silkīy* لَاسِلْكِيّ |
| Morph | lA >\| FiCL \|< Iy | |
| Root | *"s l k"* | |
| Reflex | wireless, radio | |
| Class | adjective | |

|  |  |  |
|---|---|---|
| Form | waOuxoraY | وَأُخْرَى |
| Morph | wa + OuxoraY |  |
| Tag | CONJ+ADJ |  |
| Gloss | and + other / another / additional |  |
| Lemma | OuxoraY_1 | أُخْرَى |

| | | |
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. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

| | | | | | |
|---|---|---|---|---|---|
| Form | 'u_hrY | ʾuḫrā أُخْرَى | wa | wa وَ |
| Morph | FuCLY \|<< "u" | | "wa" | |
| Tag | A-----FS1I | | C---------- | |
| Form | 'A_har | ʾāḫar آخَر | wa | wa وَ |
| Morph | HACaL | | "wa" | |
| Root | "' _h r" | | "w" | |
| Reflex | other, another | | and | |
| Class | adjective | | conjunction | |

| | | |
|---|---|---|
| Form | `sayad~aEiy` | سَيَدَّعِي |
| Morph | `sa` + `ya` + `d~aEiy` + `(null)` | |
| Tag | `FUT+IV3MS+IV+IVSUFF_MOOD:I` | |
| Gloss | will + he / it + allege / claim / testify + (ind.) | |
| Lemma | `Aid~aEaY_1` | اِدَّعَى |

| | | |
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| | | | | |
|---|---|---|---|---|
| Form | yadda'I | *yaddaʿī* يَدَّعِي | sa | *sa* سَ |
| Morph | "ya" >>\| FtaCI \|<< "u" | | "sa" | |
| Tag | VIIA-3MS-- | | F--------- | |
| Form | idda'Y | *iddaʿā* اِدَّعَى | sa | *sa* سَ |
| Morph | IFtaCY | | "sa" | |
| Root | "d ' w" | | "s" | |
| Reflex | allege, claim, testify | | *future marker* | |
| Class | verb | | particle | |

ElixirFM carefully designs the morphophonemic patterns of the templates, along with the phonological rules hidden in the `>|` or `|<<` operators. This greatly simplifies the morphological rules proper, inflectional or derivational. ElixirFM implements many generalizations of classical grammars, and suggests some new ones.

| | | |
|---|---|---|
| `"ya" >>| FtaCI |<< "u"` | `yadda'I` | yaddaʿī يَدَّعِي |
| `"ya" >>| FtaCI |<< "a"` | `yadda'iya` | yaddaʿiya يَدَّعِيَ |
| `"ya" >>| FtaCI |<< ""` | `yadda'i` | yaddaʿi يَدَّعِ |

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| `"ya" >>\| FtaCI \|<< ""` | `yadda'i` | *yaddaʿi* يَدَّعِ |
| `"ya" >>\| FCuL \|<< "u"` | `yaktubu` | *yaktubu* يَكْتُبُ |
| `"ya" >>\| FCuL \|<< "a"` | `yaktuba` | *yaktuba* يَكْتُبَ |
| `"ya" >>\| FCuL \|<< ""` | `yaktub` | *yaktub* يَكْتُبْ |

## Functionality

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lookup (lA >| FiCL |< Iy)    lookup "lA-silkIy"    lookup "لاسلكي"

 lookup (words "wireless")      lookup (words "village school")
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 derive ("w .s y" <-> HaFCY `verb` ["recommend"]) "A--P------"
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  derive ("w .s y" <-> HaFCY `verb` ["recommend"]) "A--P------"

        resolve "mU.saNY bihi"     resolve "mūṣan bihi"
          resolve "مُوصًى بِهِ"     resolve "موصى به"
```

## Interfaces

There are various interfaces to ElixirFM, ranging from command-line interpreters or executables up to graphical linguistic annotation environments or user-friendly web applications, like the recently published ElixirFM Online Interface.

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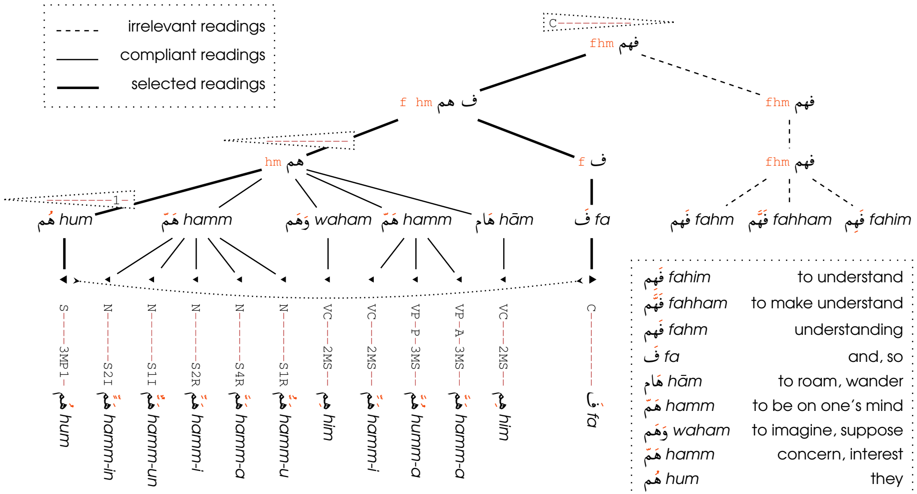
The TrEd tree editor is designed and implemented by Petr Pajas, with numerous annotation contexts contributed by other authors. Examples of our work include the ElixirFM and MorphoTrees contexts, or miscellaneous conversion templates or scripts for error detection and consistency checking.

`http://ufal.mff.cuni.cz/~pajas/tred/`

# Multi-Modal Annotation



| | |
|---|---|
| فَهِم *fahim* | to understand |
| فَهَّم *fahham* | to make understand |
| فَهْم *fahm* | understanding |
| فَ *fa* | and, so |
| هَام *hām* | to roam, wander |
| هَمّ *hamm* | to be on one's mind |
| وَهَم *waham* | to imagine, suppose |
| هَمّ *hamm* | concern, interest |
| هُم *hum* | they |

## Prague Arabic Dependency Treebank

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PADT 2.0 is due in 2009 and will cover over one million words of text. It merges original Prague Arabic Dependency Treebank annotations with converted and enhanced Penn Arabic Treebank.

## References

ElixirFM plus lexicons, Encode Arabic, MorphoTrees, and ArabTEX extensions are open-source software licensed under GNU GPL:

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ElixirFM Online Interface is the multi-modal user-end application:

`http://quest.ms.mff.cuni.cz/elixir/`

`http://ufal.mff.cuni.cz/padt/online/`

- Buckwalter, Tim. Buckwalter Arabic Morphological Analyzer 1.0. LDC2002L49, ISBN 1-58563-257-0. 2002
- Forsberg, Markus and Aarne Ranta. Functional Morphology. Proceedings of ICFP 2004, pages 213–223. ACM Press. 2004
- Lagally, Klaus. ArabTEX: Typesetting Arabic and Hebrew, User Manual Version 4.00. Technical Report 2004/03, Fakultät Informatik, Universität Stuttgart. 2004
- Smrž, Otakar. Functional Arabic Morphology. Formal System and Implementation. Ph.D. thesis, Charles University in Prague. 2007
- Smrž, Otakar et al. Prague Arabic Dependency Treebank: A Word on the Million Words. LREC 2008 Workshop on Arabic and Local Languages. 2008