Interactive Programming with Automated Reasoning

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Research Interests

How do we use software to build more intelligent systems, and how can we use intelligent systems to help us write better software?

Find programmer friction points, formalize them as optimization problems, solve and publish our solutions as developer tools.

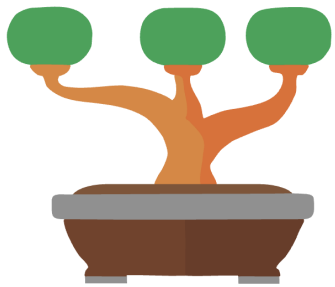
- Realtime developer assistance
- Code completion and program repair
- Documentation search and retrieval
- Editing and refactoring source code
- Assistance for impaired developers

Important: build tools that we personally need or want to use, then *use* the tools we built to identify and improve usability issues.

Tools for assistive programming

Three developer tools and their core optimization problems:

- **AceJump** - A single character search, select, and jump
  - Minimizes finger travel distance in keyboard navigation
- **Tidyparse** - Syntax repair for programming languages
  - Minimizes Levenshtein edit distance subject to a grammar
- **Idiolect** - Handsfree audio development interface
  - Minimizes intent-recognition failures in voice programming



Tag Assignment in AceJump

Helps developers search and navigate code rapidly. To do so, we solve the **Tag Assignment Problem**, i.e., stated formally:

Given a set of indices I in document d, and a set of tags T, find a bijection $f : T^* \subset T \leftrightarrow I^* \subset I$, maximizing $|I^*|$, such that:

$$d[i \ldots k] + t \notin d[i' \ldots (k + |t|)], \forall i' \in I \setminus \{i\}, \forall k \in (i, |d| - |t|]$$

where $t \in T, i \in I$. This can be relaxed to $t = t[0]$ and $\forall k \in (i, i + K]$ for some fixed K, in most natural documents.

Natural language: *Maximizes the number of non-conflicting tags assigned to search results in uniquely-selectable manner.*

AceJump Usage

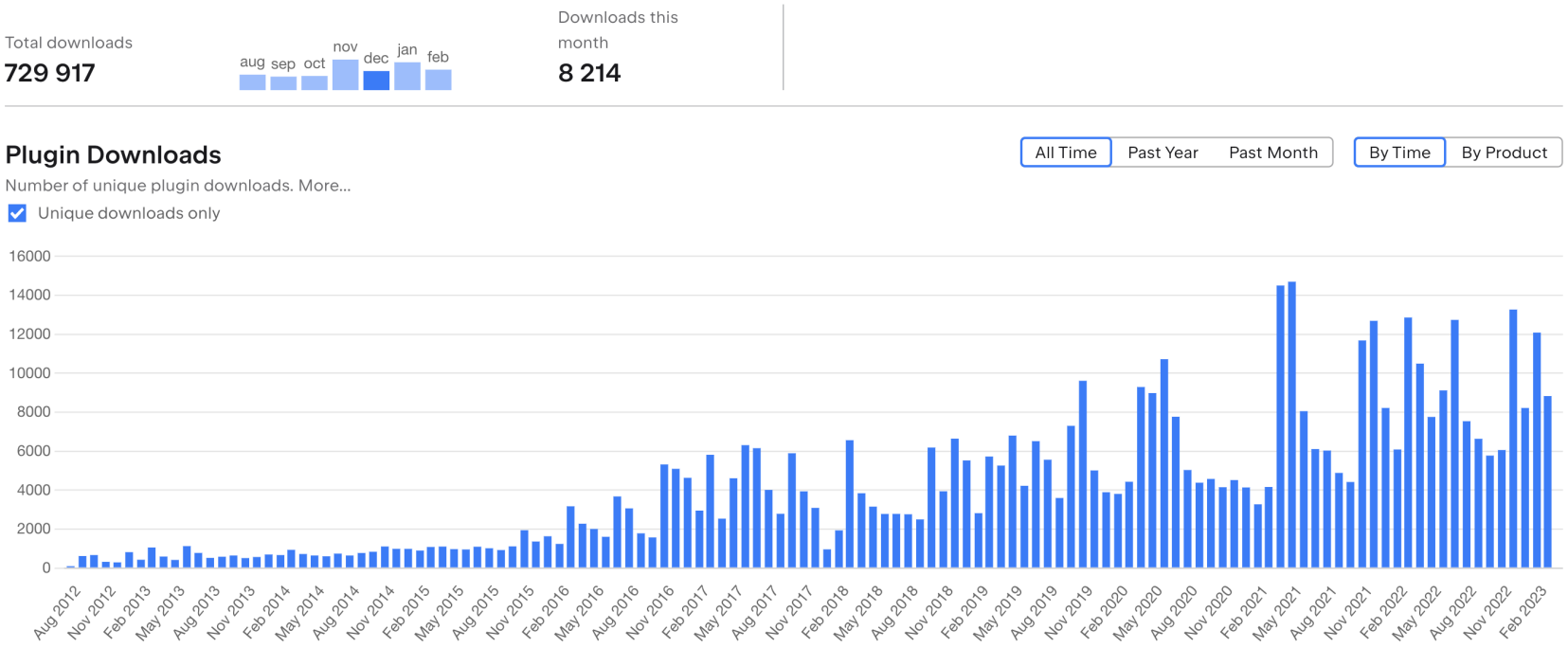
```
fun map(availabXDTags: List<String>, caches: Map<Editor, EditorOffsetCache>): Map<StringJJTag> {
  val eligibleSitesDVTag = HashMap<String, MHtableLisDDTag>>( initialCapacity: 100)
  vaKKtagsByFirstLetter : Map<Char, List<String>> = availabXATags.groupBy { it[0] }

  for ((editor : Editor, offsets : IntList) in newResults) {
    val iter : IntListIterator = offsets.iterator()
    while (iter.hasNext()) {
      val site : Int = iter.nextInt()

      for ((firstLetter : CharMMtags : List<String>) iXXtagsByFirstLetter.entries) {
        if (cDTTagBeginWithChar(editor, site, firstLetter)) {
          forQQtag : String iPPtags) {
            eligibleSitesMLTag.getOrPuFGtag, ::MUtableListOf).acFDTag(editor, site))
          }
        }
      }
    }
  }
```

AceJump Adoption

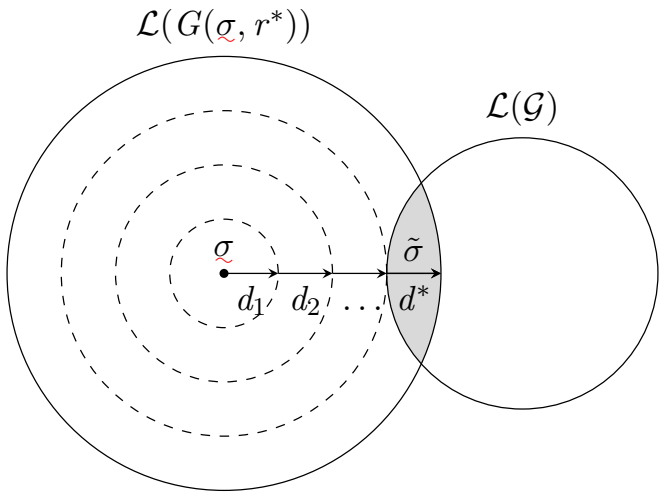
$\sim 7 \times 10^5$ downloads, $\sim 10^4$ monthly active users, $\sim 10^3$ stars.



Error Correction in Tidyparse

Helps novice programmers fix syntax errors in source code. We do so by solving the **Bounded Levenshtein Reachability Problem**:

Given a conjunctive grammar $\mathcal{G}$, a fixed edit distance r, and a malformed string $\underset{\sim}{\sigma} : \Sigma^*$, find all syntactically well-formed strings $\{\tilde{\sigma} \in \mathcal{L}(\mathcal{G}) \mid \Delta(\underset{\sim}{\sigma}, \tilde{\sigma}) < r\}$, ranked by Levenshtein edit distance.



Natural language: *Finds all syntactically valid repairs within a small edit distance, ranked by similarity to the original input.*

Tidyparse Usage

```
 S -> X
 X -> I | F | P
 P -> I O I
 F -> IF | BF
IF -> if B then I else I
BF -> if B then B else B
 O -> + | - | * | /
 I -> 1 | 2 | 3 | 4 | I I | IF
 B -> true | false | B BO B | ( B ) | BF | N B
BO -> and | or | xor | nand
 N -> !

---

if true or false and false then 1 else 2

if true then if true then 1 else 3 else true

if ( true and false ) then if true then true else 2 1 else 1
if ( true and false ) then if true <BO> true then <I> else  1 else 1

if ( true or false ) + then true else 1 true
if ( true or false ) then true else ! false

_ true

( true or true )

_ true _ _ _ _

if ( true or false ) + + then true else 2

true 1 or false 3

true 1 or false 2
```

1

Current line invalid, possible fixes:

```
if ( true or false )    then <I> else 2
if ( true or false )    then true else <B>
if ( true or false ) <BO> <B> then <I> else 2
if ( true or false ) <BO> <B> then true else <B>
if ( true or false )    then <I> <I> else 2
if ( true or false )    then true else <N> <B>
if ( true or false ) <BO> <B> then <I> <I> else 2
if ( true or false ) <BO> <B> then true else ! <B>
if ( true or false ) <BO> <B> then true else <N> <B>
if ( true or false ) <BO> <N> <B> then true else <B>
if ( true or false ) <BO> ( <B> ) then true else <B>
if ( true or false ) <BO> <N> <B> then <I> <I> else 2
if ( true or false ) <BO> <N> <B> then true else ! <B>
if ( true or false ) <BO> <N> <B> then true else <N> <B>
if ( true or false ) <BO> <N> <N> <B> then true else <B>
if ( true or false ) <BO> <B> <BO> <B> then true else <B>
if ( true or false ) <BO> ( <B> ) then true else <N> <B>
if ( true or false ) <BO> <N> <N> <B> then true else ! <B>
if ( true or false ) <BO> <B> <BO> <B> then true else ! <B>
if ( true or false ) <BO> <N> <N> <B> then true else <N> <B>
if ( true or false ) <BO> <B> <BO> <B> then true else <N> <B>
```

: INSERTION : SUBSTITUTION : DELETION

Parseable subtrees (6 leaves / 1 branch)

```
└─ if [0]   └─ + [6]   └─ + [7]

└─ then [8] └─ else [10] └─ 2 [11]

└─ B [1..5]
   ├─ ( [1]
   ├─ B [2..4]
   │  ├─ true [2]
   │  ├─ or [3]
   │  └─ false [4]
   └─ ) [5]
```

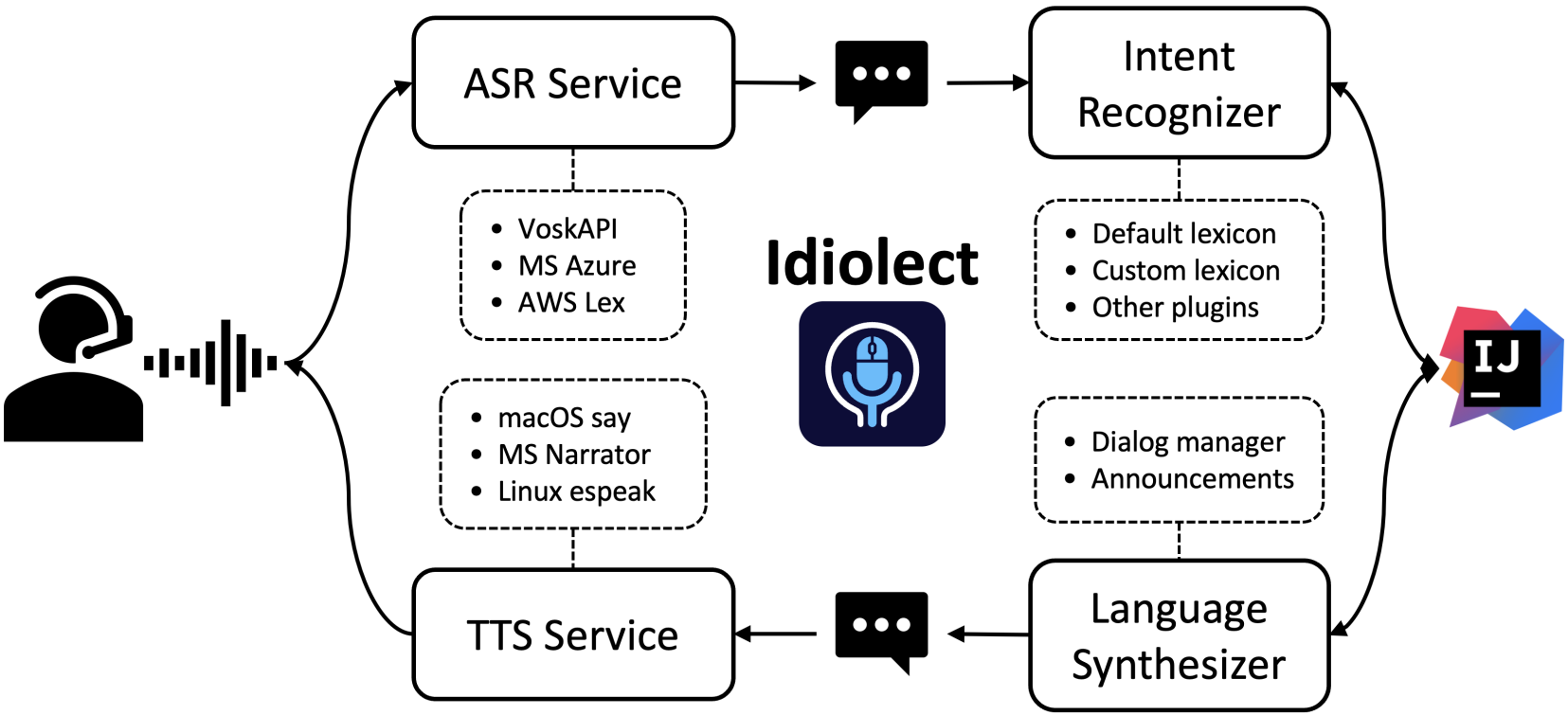
Intent Recognition in Idiolect

Helps programmers with motor and visual impairments write code. We do so by solving the **IDE-intent recognition problem**:

Given an audio signal containing an arbitrary stream of words, $S(\Sigma) = 1 + \Sigma \cdot S(\Sigma)$ consisting of subsequences from a context-free grammar find the optimal alignment of non-overlapping commands from that grammar satisfying the given command.

Natural language: *Given a series of spoken voice commands, find the optimal alignment of actions satisfying the user's intent.*

Idiolect Overview



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