

Text Processing in APL

Dyalog '22

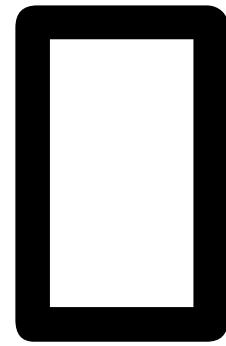
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Is APL only about
numbers?

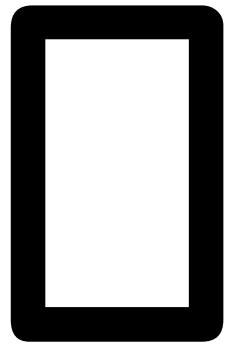
Te**x**t

IN → Trees → **Out**

IN → Trees



S



R

Limited

Sharp
Corners

Comp. Sci.?

Grammars

Context-free

Context-
sensitive

PEG

Parsing Expression Grammar

Seq \rightarrow S1 S2
Choice \leftarrow A | B

Recursive Descent

$S \rightarrow \epsilon \mid (\text{char} \mid \text{Par} \mid \text{Brk})\ S$

$\text{Par} \rightarrow '(' \ S \ ')'$

$\text{Brk} \rightarrow '[' \ S \ ']'$

Usability?

**Errors
AST Creation
Auxiliary Data**

Tracking Flow

$S \rightarrow \epsilon \mid (\text{char} \mid \text{Par} \mid \text{Brk})\ S$

$\text{Par} \rightarrow '(' \ S \ ')'$

$\text{Brk} \rightarrow '[' \ S \ ']'$

$S \leftarrow (\text{char} \mid \text{Par} \mid \text{Brk})^* \mid \epsilon$

$\text{Par} \leftarrow '()' \mid '[]'$

$\text{Brk} \leftarrow '()' \mid '[]'$

$S \rightarrow (\text{Par} \mid \text{Brk} \mid \text{char})^*$

$\text{Par} \rightarrow '()' ,$

$\text{Brk} \rightarrow '['] ,$

Performance?

Easy to Explode,
Hard to Catch

Interpreter Overhead

```
old<-{OP.ps  █SRC t0009}
new<-{codfns.PS █SRC t0009}
cmpx 'newθ' 'oldθ'
newθ → 2.4E-2 | 0% █
* oldθ → 1.5E0 | +6151% ████
```

Sharp Corners, still.

Data-parallel
Idiomatic
Flexible/Scalable

Error Handling Context Sensitivity

Avoids sharp corners

Linear Data-flow “Micro pass”

Linearize the
Grammar
Dependencies

$S \rightarrow (\text{Par} \mid \text{Brk} \mid \text{char})^*$

$\text{Par} \rightarrow '()' ,$

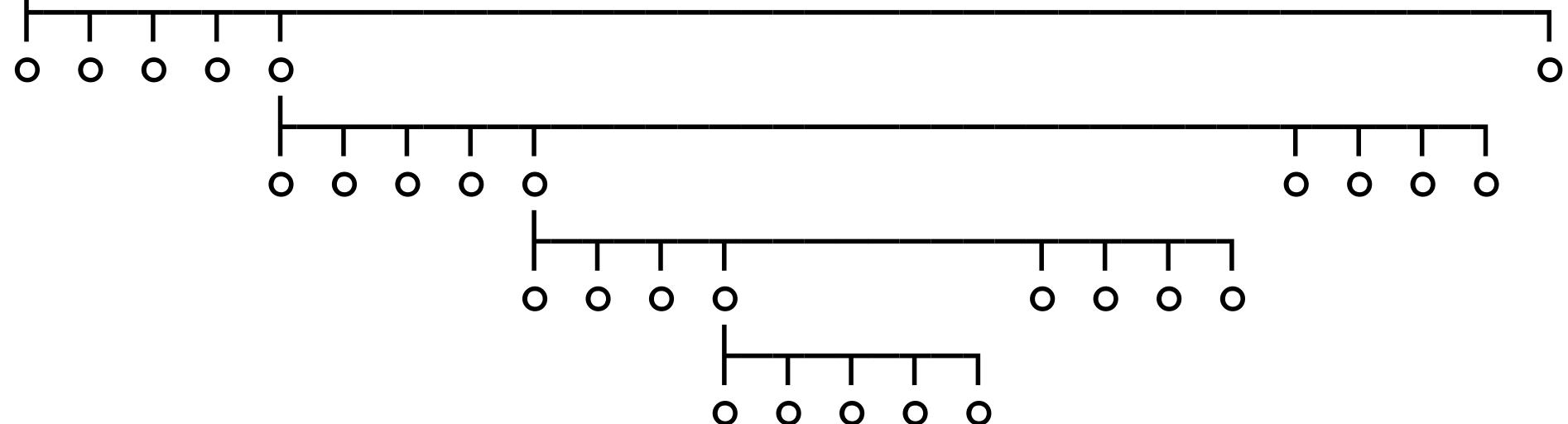
$\text{Brk} \rightarrow '['] ,$

```
kdf l(kkdf(ksd[ksd(ksfl]ksk)ksd))  
kdf l(((((((([[[[((((([[[[(((((  
= '()' ^ . = c o f ^ x [ p ] x
```

0 0 1 1

codfns.(dwv pp3) p

○ ○ ○ ○ ○



PEG'Mop	$\leftarrow \text{Pmop}, \text{Afx}$: $20^\circ\phi$	'
PEG'Pdop1	$\leftarrow \text{dop1}$: $3P$	'
PEG'Dop1	$\leftarrow \text{Pdop1}, \text{Afx}$: $80^\circ\phi$	'
PEG'Pdop2	$\leftarrow \text{dop2}$: $3P$	'
PEG'Vop	$\leftarrow \text{Atom}, \text{Pdop2}, \text{Afx}$: $50^\circ\phi$	'
PEG'Pdop3	$\leftarrow \text{dop3}$: $3P$	'
PEG'Dop3	$\leftarrow \text{Pdop3}, \text{Atom}$: $70^\circ\phi$	'
PEG'Bop	$\leftarrow \text{rbrk}, \text{Ex}, \text{lbrk}, (\text{4 Lbrk}), \text{Afx}$: $50^\circ\phi$	'
PEG'JotDP	$\leftarrow \text{dot}, \text{jot}$: $3P^\circ\phi$	'
PEG'JotDot	$\leftarrow \text{Fnp}, \text{JotDP}$: 20	'
PEG'Fop	$\leftarrow \text{Fnp}, (\text{Dop1} \mid \text{Dop3}?)$: MkAST	'
PEG'Afx	$\leftarrow \text{Mop} \mid \text{JotDot} \mid \text{Fop} \mid \text{Vop} \mid \text{Bop}$		'
PEG'Trn	$\leftarrow \text{Afx}, (\text{Afx} \mid \text{Idx} \mid \text{Atom}, (\nabla ?)?)$: $5F^\circ\phi$	'
PEG'Bind	$\leftarrow \text{gets}, \text{Symbol} [\alpha\alpha]$: $\alpha\alpha B$	'
PEG'Gets	$\leftarrow \epsilon$: $\neg\alpha\alpha P\{\text{,}'\text{'-}'\text{'}\}$	'
PEG'Mname	$\leftarrow \text{Afx}, (\text{1 Name})$: $4E \text{ Atn}^\circ\phi$	'
PEG'Ogets	$\leftarrow \text{Afx}, (\text{3 Gets})$: 20	'
PEG'Mbrk	$\leftarrow \text{Ogets}, \text{Brk}, (\text{1 Name})$: $4E^\circ(1^\circ\downarrow) \text{ Atn}^\circ\phi$	'
PEG'Mget	$\leftarrow \text{Mname} \mid \text{Mbrk}$		'
PEG'Bget	$\leftarrow \text{2 Gets}, \text{Brk}, (\text{1 Name})$: $4E^\circ(1^\circ\downarrow) \text{ Atn}^\circ\phi$	'
PEG'ExHd	$\leftarrow \text{Asgn} \mid (\text{1 Bind}) \mid \text{App}, \nabla ?$		'
PEG'Ex	$\leftarrow \text{IAx}, \text{ExHd}$: MkAST	'

```

Fn←{a(i d)←ω ◊ 0=≠a:0 θ α(i d)
  0=≠ss←(4▷z)▷~m←(((NΔι'F')=1▷r) ∧ 1=2▷r)▷z←, /↑a:0(,cz)α(i d)
  0<c<r▷~0, pi←▷~ψ▷r←↓ψ↑ps←α◦Fa◦ss, ◊ccd:pi▷ps
  0(,c(<...z)((▷,/)→@{m})◊~↓(m▷0▷z)+@0ψ↑▷1▷r)α(i d)}
FnType←{[+2,3 4×¬1≠(¬1,~1▷ω)[ 'αα' 'ωω' i ~▷ω]}

PEG'ClrEnv ← (Alp[¬1]),(Alp,Alp[¬1]),(Omg[¬1]),(Omg,Omg[¬1])↓
PEG'Fax ← lbrc , (Gex | Ex | Fex StmtS rbrc) → Fn : (FnType α)F
PEG'FaFnW ← Omg[1]↓ , Fax []
PEG'FaFnA ← Omg[1] , (Alp[1])↓ , Fax []
PEG'FaFn ← FaFnW | FaFnA
PEG'FaMopV ← Alp,Alp[1]↓ , FaFn []
PEG'FaMopF ← Alp,Alp[2]↓ , FaFn []
PEG'FaMop ← FaMopV , (FaMopF ?) | FaMopF
PEG'FaDopV ← Omg,Omg[1]↓ , FaMop []
PEG'FaDopF ← Omg,Omg[2]↓ , FaMop []
PEG'FaDop ← FaDopV , (FaDopF ?) | FaDopF
PEG'Fa ← ClrEnv , (FaFn | FaMop | FaDop) []
PEG'Nlrp ← sep | rbrc ↑ Slrp (lbrc Blrp rbrc)
PEG'Stmt ← sep | (αα , (sep | lbrc) φ Nlrp)
PEG'SmtS ← ωω | (αα Stmt , ∇)
PEG'Ns ← nss , (Ex | Fex StmtS nse) , eot → Fn : (¬1+¬)OFH

```

Compute parent vector from d
Compute the nameclass of dfns
Nest top-level root lines as Z nodes
Wrap all dfns expression bodies
Drop any Z nodes that are empty
Parse :Namespace
Parse guards
Parse brackets and parentheses
Parse ;
Mark system variables
Mark primitives
Parse niladic tokens

Unify atomic array values
Mark bindable nodes
Wrap bindings into B nodes
Wrap functions as closures
Link variables to their bindings
Infer types of bindings
Parse strands
Parse [] operator
Parse function expressions
Parse assignments
Parse expressions
Simplify and Optimize the AST

```

    a Link variables to their bindings
mk←{α[ω],;n[ω]}
_←{
    a Link local variables with their local bindings
vb[i]←fb[frirf mk- i←l(t=V)∧vb=¬1]
vb[i]←fb[frirfn mk- i←l(t=V)∧vb=¬1]
b←vb[i←i/≈vb[i]≠¬1]
vb[i/≈(rz[i]<rz[b])∨(rz[i]=rz[b])∧i≥b]←¬1

    a Mark free variables with their scope before binding
lx[i←l(t=V)∧vb=¬1]←1

    a Add free variables to closures
i←i/≈k[rfn[i]]≠0 ◊ ci←p[rfn[i]] ◊ vb[i]←(≠p)+i≠i
p,←ci ◊ vb lx,←(≠ci)p◦¬1 0 ◊ rf rfn(¬,I)←cci
t k n pos end(¬,I)←ci
i }≈{0=≠α}θ

```

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mk←{α[ω],;n[ω]}
_←{
    a Link local variables with their local bindings
vb[i]←fb[frirf mk- i-l(t=V)∧vb=-1]
vb[i]←fb[frirfn mk- i-l(t=V)∧vb=-1]
b←vb[i←i/≈vb[i]≠-1]
vb[i/≈(rz[i]<rz[b])∨(rz[i]=rz[b])∧i≥b]←-1

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p,←ci ◊ vb lx,←(≠ci)p“-1 0 ◊ rf rfn(¬,I)←cci
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p,←ci ◊ vb lx,←(#ci)p“-1 0 ◊ rf rfn(¬,I)←cci
t k n pos end(¬,I)←ci
i }≈{0=≠α}θ

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i←i/≈k[rfn[i]]≠0 ◊ ci←p[rfn[i]] ◊ vb[i]←(#p)+l≠i
p,←ci ◊ vb lx,←(#ci)p--1 0 ◊ rf rfn(¬,I)←cci
t k n pos end(¬,I)←ci
i }≈{0=≠α}θ

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p,←ci ◊ vb lx,←(≠ci)p^"-1 0 ◊ rf rfn(¬,I)←cci
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```

a Parse plural value sequences to A7 nodes
i<| i¬km¬0<i<εp[i](c-ö-,+) ⊕ i<_t[p]=z
msk¬↔¬1 ¬1 v. φ<msk¬km¬(t[i]=A) v (t[i]εP v Z)¬k[i]=1
np¬(¬p)+i¬ai¬i¬~am¬2>¬msk¬0 ◊ p¬(np@ai i¬p)[p] ◊ p,¬ai
t k n lx pos end(¬,I)¬ca
t k n lx pos(¬@ai ~)¬A 7(c'')0(pos[i¬~km¬2<¬0,msk])
p[msk¬i]¬ai[¬1++¬km¬~msk¬msk¬~am]

```

¶ Parse plural value sequences to A7 nodes

i \leftarrow | i \dashv km \leftarrow 0 $<$ i \leftarrow ep[i](c- $\ddot{\text{o}}$ -,+) \boxplus i \leftarrow t[p]=z

msk $\wedge\leftarrow$ 1 \neg 1 \vee . ϕ \subset msk \leftarrow km \wedge (t[i]=A) \vee (t[i] \in P V Z) \wedge k[i]=1

np \leftarrow (\neq p)+i \neq ai \leftarrow i \neq am \leftarrow 2 $>$ +msk,0 ◊ p \leftarrow (np@ai i \neq p)[p] ◊ p, \leftarrow ai

t k n lx pos end(\dashv ,I) \leftarrow cai

t k n lx pos(\dashv @ai $\ddot{\text{o}}$) \leftarrow A 7(c'')0(pos[i \neq km \leftarrow 2< \neq 0,msk])

p[msk \neq i] \leftarrow ai[\neg 1++ \dashv km \neq msk \leftarrow msk \wedge \sim am]

¶ Parse plural value sequences to A7 nodes

$i \leftarrow i \neg km \leftarrow 0 < i \leftarrow \epsilon p[i] (c - \ddot{o} - , \vdash) \boxplus i \leftarrow \underline{z} t[p] = z$

$msk \wedge \neg \exists i \neg km \leftarrow 1 \neg 1 \vee \phi \subseteq msk \leftarrow km \wedge (t[i] = A) \vee (t[i] \in P \vee Z) \wedge k[i] = 1$

$np \leftarrow (\#p) + i \neq ai \leftarrow i \neq \ddot{am} \leftarrow 2 \not\models msk, 0 \diamond p \leftarrow (np @ ai \#p)[p] \diamond p, \leftarrow ai$

$t k n l x pos end(\vdash, I) \leftarrow \epsilon ai$

$t k n l x pos(\vdash @ ai \ddot{\ }) \leftarrow A 7(c ' ') 0(pos[i \neq \ddot{km} \leftarrow 2 \not\models 0, msk])$

$p[msk \neq i] \leftarrow ai[-1 ++ \vdash km \neq \ddot{msk} \leftarrow msk \wedge \sim am]$

a Parse plural value sequences to A7 nodes

i \leftarrow i \neg km \leftarrow 0 $<$ i \leftarrow ep[i](c \neg , \neg) \boxplus i \leftarrow t[p]=z

msk $\wedge\leftarrow$ 1 \neg 1 \vee . ϕ \subset msk \leftarrow km \wedge (t[i]=A) \vee (t[i] \in P V Z) \wedge k[i]=1

np \leftarrow (\neq p)+i \neq ai \leftarrow i \neg am \leftarrow 2 \neg msk,0 ◊ p \leftarrow (np@ai i \neq p)[p] ◊ p, \leftarrow ai

t k n lx pos end(\neg ,I) \leftarrow cai

t k n lx pos(\neg @ai \neg) \leftarrow A 7(c'')0(pos[i \neg km \leftarrow 2 \neg 0,msk])

p[msk+i] \leftarrow ai[\neg 1++\km \neg msk \leftarrow msk \wedge ~am]

Flexible
Easy to grow

Avoids:
Cognitive context-switching
Domain segregation

Maps well to APL
performance model

Fear not.

Thank you.