DYALOG

APL Array Notation

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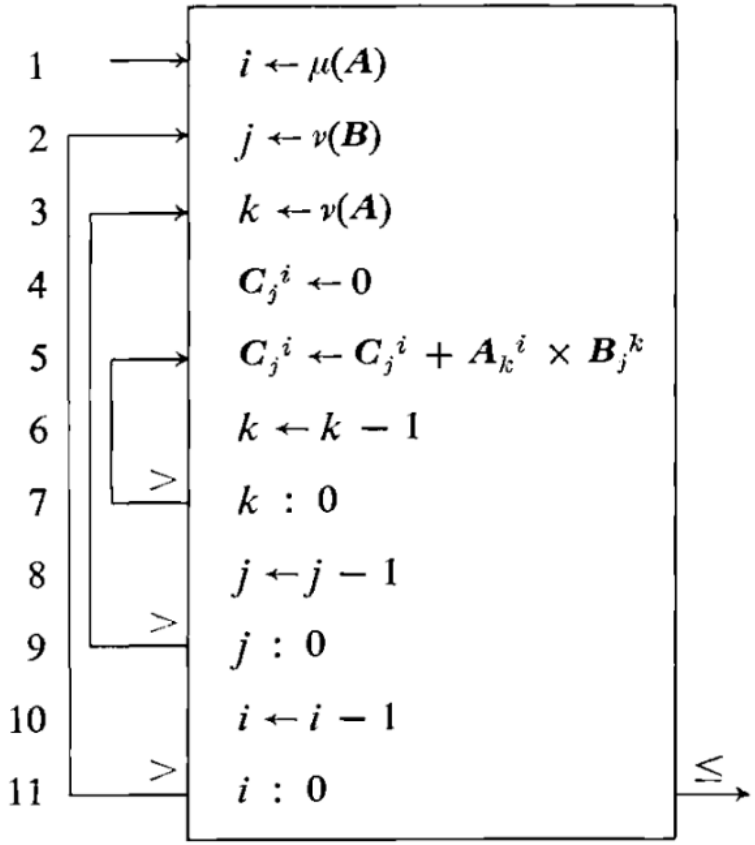
Dyalog Ltd.

A Plan?

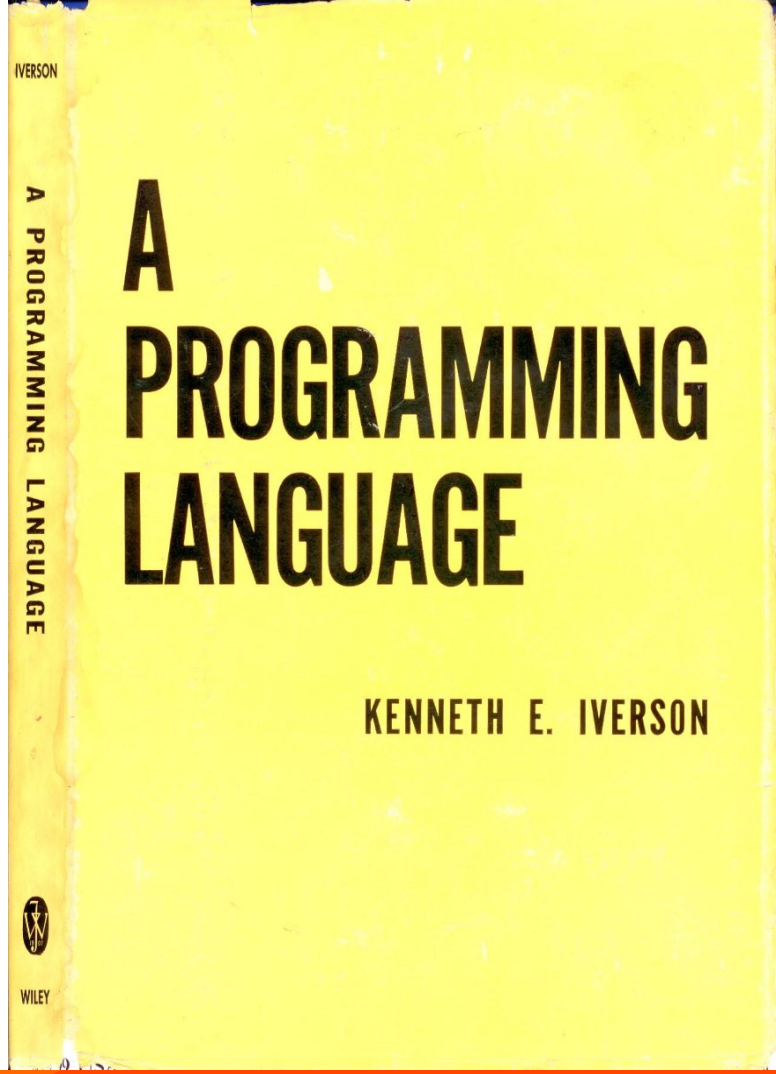
- History
- APL
- Problem
- Design Iteration
- Specification
- Implementation
- Standardisation?
- Take-aways?

History

- 1962:



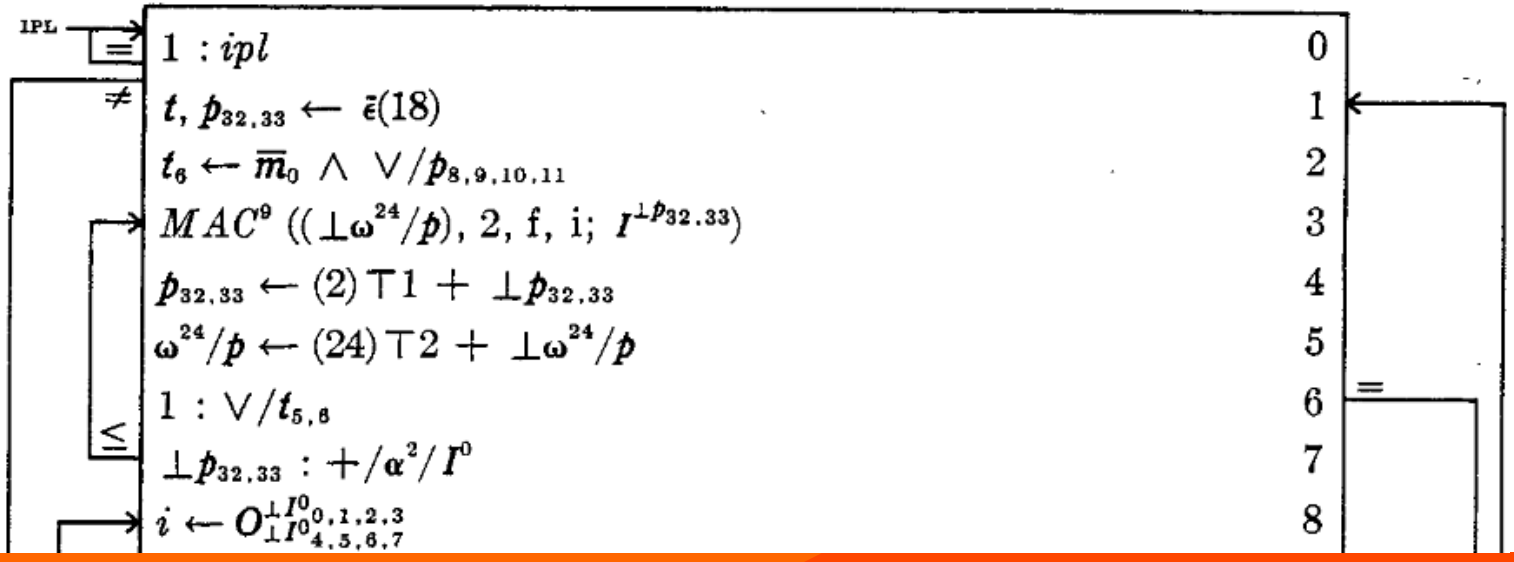
Program 1.5 Matrix multiplication



History

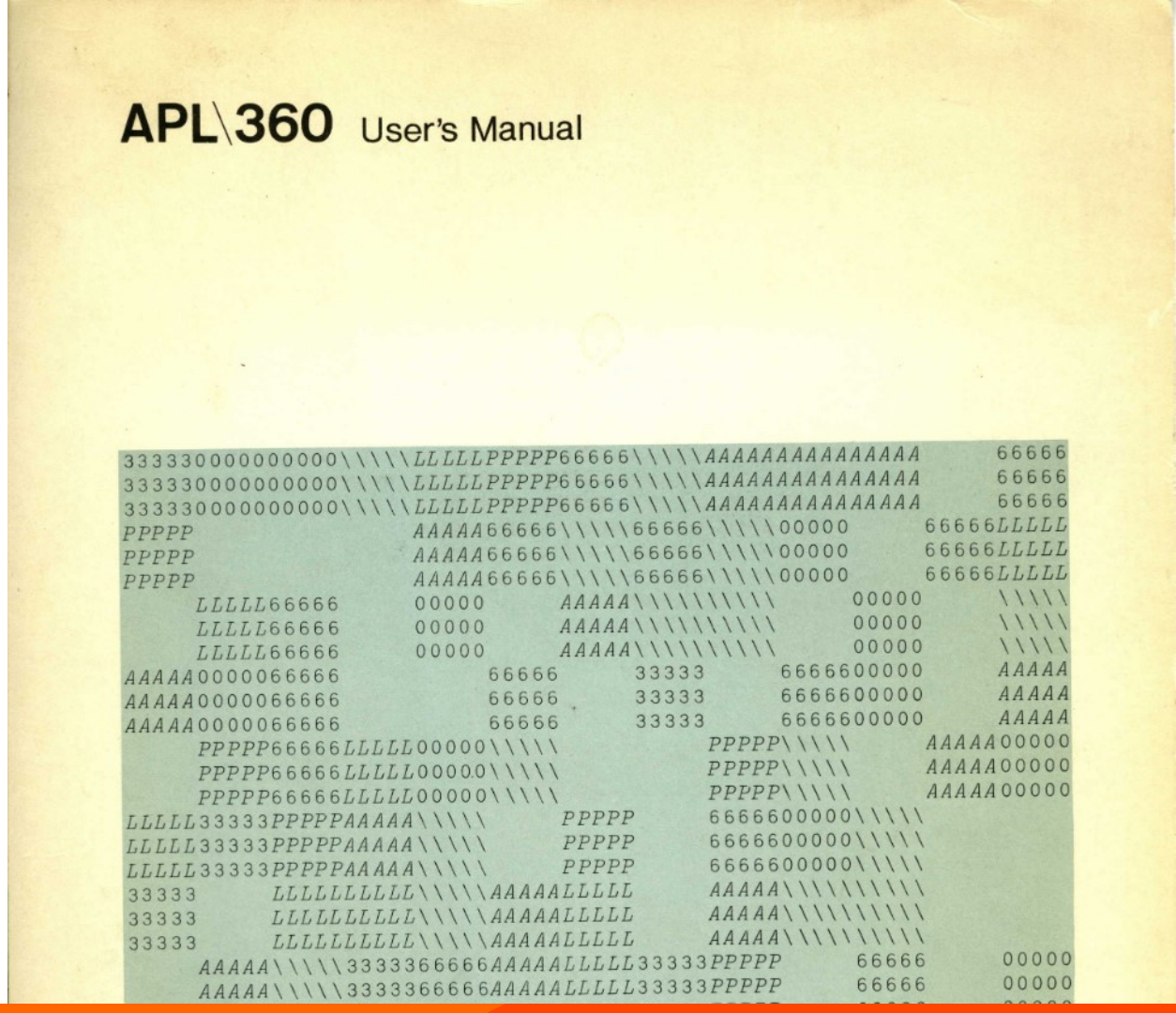
- 1964: IBM *System/360* design

CPU, central processing unit *system program*



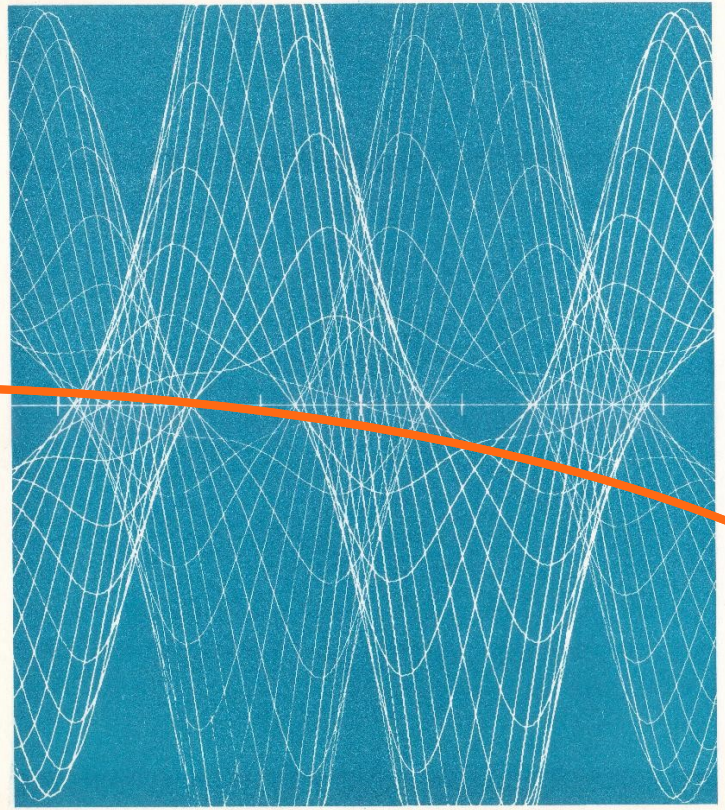
History

- 1966: IBM in-house



History

- 1968: Father



RC 1922

THE APL\360 TERMINAL SYSTEM

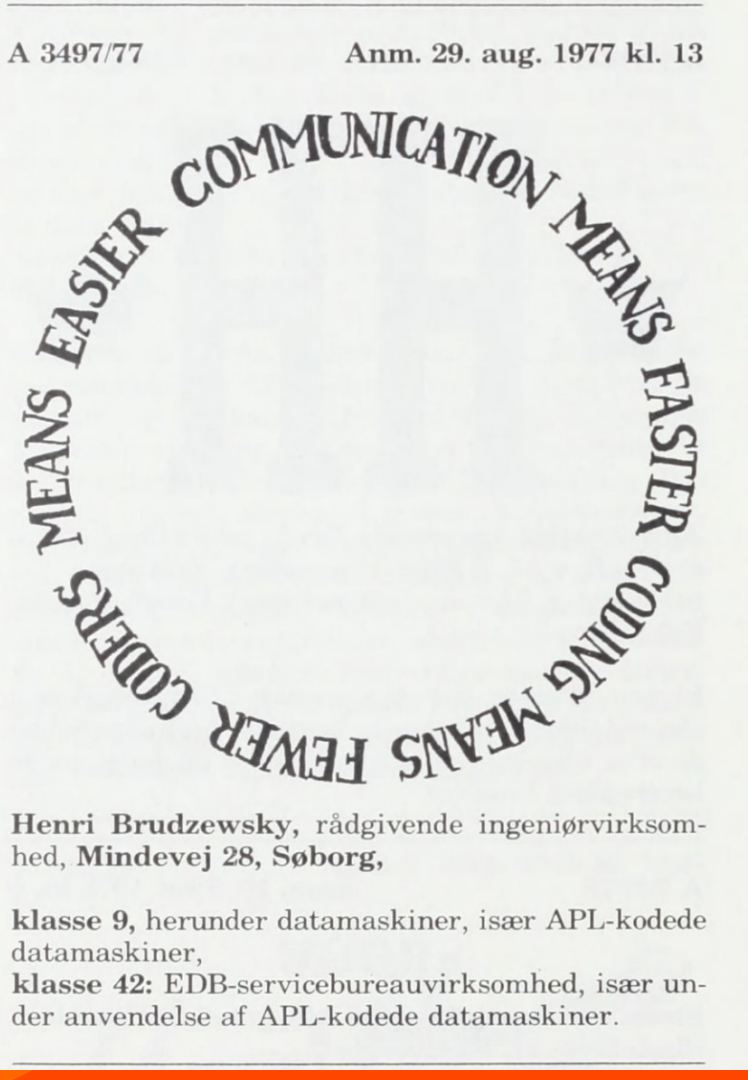
A. D. Falkoff/ K. E. Iverson

October 16, 1967
Third Printing, March, 1968

IBM RESEARCH

History

- 1972: Father teaches and consults



A 3497/77 Anm. 29. aug. 1977 kl. 13

EASIER COMMUNICATION MEANS FASTER CODING MEANS FEWER CODERS MEANS

Henri Brudzewsky, rådgivende ingeniørvirksomhed, **Mindevej 28, Søborg,**

klasse 9, herunder datamaskiner, især APL-kodede datamaskiner,
klasse 42: EDB-servicebureauvirksomhed, især under anvendelse af APL-kodede datamaskiner.

History

- 1986: My first APL conference

History

- 2014: I join Dyalog

History

youtu.be/9-HAvTMhYao

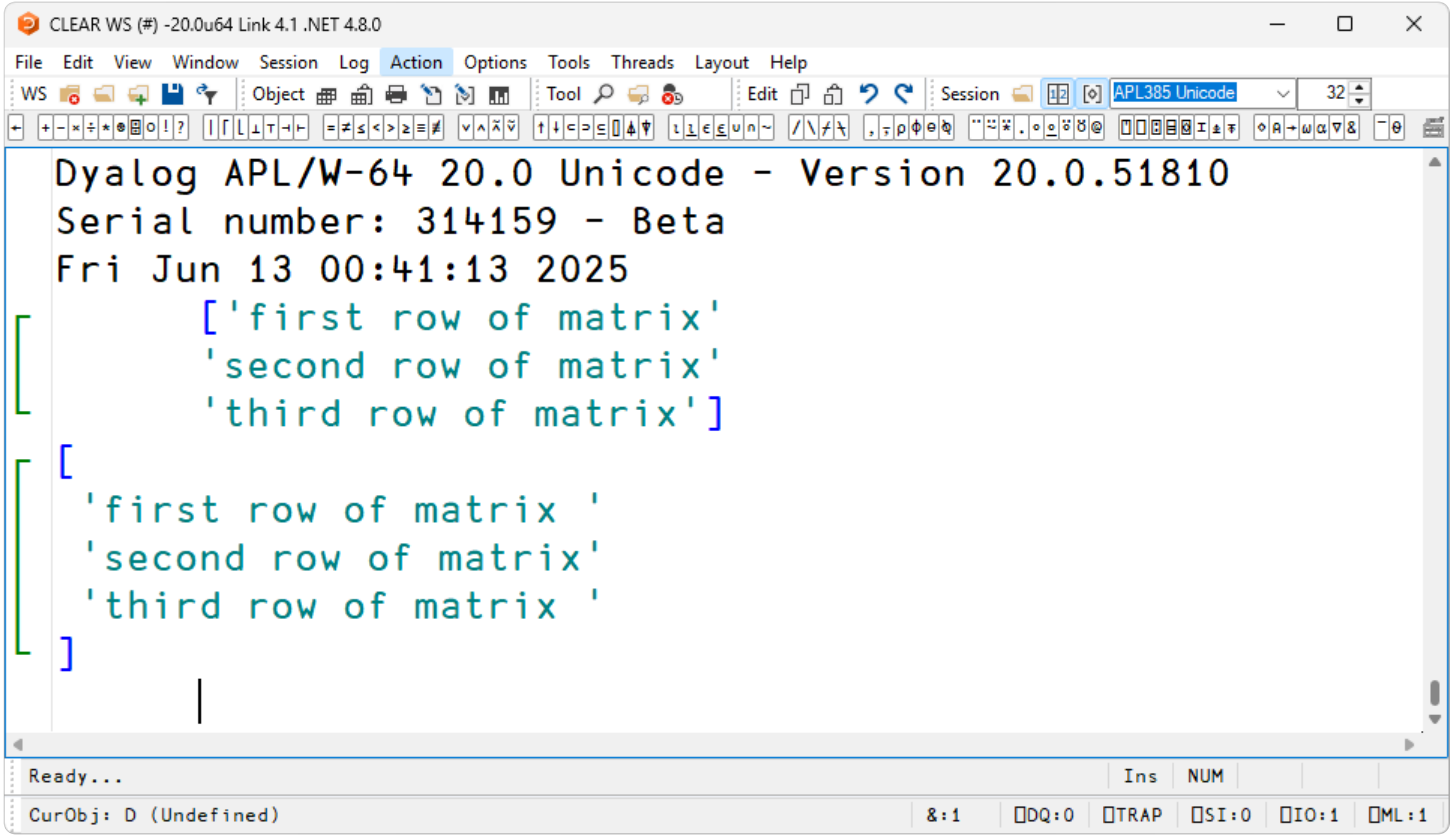
-2015:

```
(…)
'second row of matrix'
'third row of matrix']
(…)
⍝ Doesn't have to be brackets - many reasons why not
⍝     [ ⋄ ]     ( ⋄ )     [[ ⋄ ]]     ([ ⋄ ])     ⟦ ⋄ ⟧
⍝ Problem with digraphs - human parsing - unicode - many bracketing pairs.
(…)
My hope is that Dyalog and as many as possible of other APL vendors will
consider these proposals and questions and perhaps come to some kind of
agreement to include at least the basic concepts into their products.

Phil Last, <phil.last@4xtra.com> Wiltshire, Wednesday 9 Sept 2015
```

History

- 2025: PLSS



History

- 1962: Kenneth E. Iverson, *A Programming Language*
- 1964: IBM *System/360* design
- 1966: IBM in-house APL\360
- 1968: Father joins IBM Research
- 1972: Father teaches and consults
- 1986: My first APL conference
- 2014: I join Dyalog
- 2015: Phil Last, *APL Array Notation*
- 2025: PLSS

APL

```
      ⍳ 6
1 2 3 4 5 6
      2 3
2 3
      2 3 + 40
42 43
      2 3 + 40 50
42 53
      2 3 + (40 50) (60 70)
 42 52  63 73
```

APL

```
      2 3 ⍴ ⍳ 6
1 2 3
4 5 6
```

APL

```
      2 3 ⍴ ⍳ 6  ⋄  2 3 ⍴ 6 + ⍳ 6
1  2  3
4  5  6
 7   8   9
10 11 12
```

APL

```
      (2 3 ⍴ ⍳ 6) (2 3 ⍴ 6 + ⍳ 6)
1 2 3   7  8  9
4 5 6  10 11 12
```

APL

```
      (2 3 ⍴ ⍳ 6) (2 3 ⍴ 6 + ⍳ 6)
 1  2  3    7   8   9
 4  5  6   10  11  12

       X
(  1  2  3   (   7   8   9
   4  5  6)     10  11  12)
```


The variable *X* contains a two-item vector, each of whose items is a two-row, three-column matrix

APL

```
      (2 3 ⍴ ⍳ 6) (2 3 ⍴ 6 + ⍳ 6)
 1 2 3   7  8  9
 4 5 6  10 11 12

        X
( 1 2 3   (  7  8  9
                4  5  6)   10 11 12)
```



```
1 2 3 (2 3 ⍴ 7 8 9 4 5 6) 10 11 12
```

APL

```
      (2 3 ⍴ ⍳ 6) (2 3 ⍴ 6 + ⍳ 6)
 1 2 3   7  8  9
 4 5 6  10 11 12

        X
( 1 2 3   (  7  8  9
                4  5  6)   10 11 12)
```



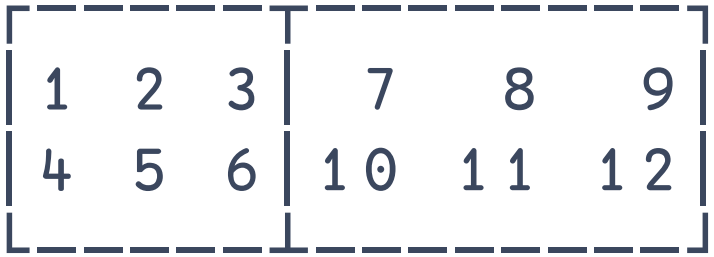
```
      1 2 3 (2 3 ⍴ 7 8 9 4 5 6) 10 11 12
1 2 3  7 8 9  10 11 12
       4 5 6
```

Problem

```
      (2 3 ⍴ ⍳ 6) (2 3 ⍴ 6 + ⍳ 6)
1 2 3   7  8  9
4 5 6  10 11 12
```

Problem

```
      (2 3 ⍴ ⍳ 6) (2 3 ⍴ 6 + ⍳ 6)
```



1	2	3	7	8	9
4	5	6	10	11	12

Problem

```
(2 3 ⍴ ⍳ 6) (2 3 ⍴ 6 + ⍳ 6)
```

1	2	3	7	8	9
4	5	6	10	11	12

Problem

- Intuitive
- Easy to type
- Ideally ASCII
- Versatile (single/multi-line, Table, nested, object)
- Unambiguous — consider:

```
list[i]  table[i;j]  (1 2)(3 4)  {lambda}
```

Design Iteration

- 2015 — Acre, *Mk I*

  Table: `[1 2 3 ◇ 4 5 6]`

Design Iteration

2015 Acre, *Mk I*

Table:

```
[1  2  3
 4  5  6]
```

Design Iteration

2015 Acre, *Mk I*

Table:

```
1 2 3
4 5 6
```

Design Iteration

2015 Acre, *Mk I*

Table: `[1 2 3 ◇ 4 5 6]`

Design Iteration

2015 Acre, *Mk I*

Table: `[1 2 3 ◇ 4 5 6]`
List: —

Design Iteration

2015 Acre, *Mk I*

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[[name1←val1 ⋄ name2←val2]]`

Design Iteration

2015 Acre, *Mk I*

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[[name1←val1 ⋄ name2←val2]]`
Value:	`6×a←7`

Design Iteration

2015 Acre, *Mk I*

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[[name1←val1 ⋄ name2←val2]]`
Value:	`6×a←7`
Table:	`[a←7 ⋄ b←8]`

Design Iteration

2015 Acre, *Mk I*

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[[name1←val1 ⋄ name2←val2]]`
Value:	`6×a←7`
Table:	`[a←7 ⋄ b←8]`
Indexing:	`list[indices]`

Design Iteration

2015 Acre, *Mk I*

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[[name1←val1 ⋄ name2←val2]]`
Value:	`6×a←7`
Table:	`[a←7 ⋄ b←8]`
Indexing:	`list[indices]`
Ambiguous:	`list [[a←7 ⋄ b←8]]`

Design Iteration

2015 Acre, *Mk I*

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[[name1←val1 ⋄ name2←val2]]`
Value:	`6×a←7`
Table:	`[a←7 ⋄ b←8]`
Indexing:	`list[indices]`
Ambiguous:	`list([[a←7 ⋄ b←8]])`

Design Iteration

2018

Acre, *Mk II*

Table: `[1 2 3 ⋄ 4 5 6]`

List: —

Object: `[name1←val1 ⋄ name2←val2]`

Design Iteration

Acre, *Mk II*

2018

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[name1←val1 ⋄ name2←val2]`
Empty obj?	`[ ]`

Design Iteration

Acre, *Mk II*

2018

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[name1←val1 ⋄ name2←val2]`
Empty obj?	`[]`
All rows:	`table[;42]`

Design Iteration

2018

Acre, *Mk II*

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[name1←val1 ⋄ name2←val2]`
Empty obj?	`[]`
All rows:	`table[;42]`
Ambiguous:	`list []`

Design Iteration

Acre, *Mk II*

2018

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[name1←val1 ⋄ name2←val2]`
Empty obj?	`[]`
All rows:	`table[;42]`
Ambiguous:	`list([])`

Design Iteration

Acre, *Mk II*

2018

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	—
Object:	`[name1←val1 ⋄ name2←val2]`
Empty obj?	`[]`
All rows:	`table[;42]`
Ambiguous:	`list []`
Empty obj:	`[ ← ⋄ ]`

Design Iteration

Dyalog, *Mk I*

2017

Table:	`(1 2 3 ⋄ 4 5 6)`
List:	—
Object:	`(name1:val1 ⋄ name2:val2)`

Design Iteration

Dyalog, *Mk I*

2017	Table:	`(1 2 3 ⋄ 4 5 6)`
	List:	—
	Object:	`(name1:val1 ⋄ name2:val2)`
	List:	`(1 ⋄ 4 ⋄ 7)`

Design Iteration

Dyalog, *Mk I*

2017	Table:	`(1 2 3 ⋄ 4 5 6)`
	List:	—
	Object:	`(name1:val1 ⋄ name2:val2)`
	List:	`(1 ⋄ 4 ⋄ 7)`
	Column:	`((1 ⋄) ⋄ (4 ⋄) ⋄ (7 ⋄))`

Design Iteration

Dyalog, *Mk I*

2017

Table:	`(1 2 3 ⋄ 4 5 6)`
List:	—
Object:	`(name1:val1 ⋄ name2:val2)`
List:	`(1 ⋄ 4 ⋄ 7)`
Column:	`((1 ⋄) ⋄ (4 ⋄) ⋄ (7 ⋄))`
Column?	`(1 ⋄ 4 ⋄ 7)`

Design Iteration

		Dyalog, *Mk I*
2017	Table:	`(1 2 3 ⋄ 4 5 6)`
	List:	—
	Object:	`(name1:val1 ⋄ name2:val2)`
	List:	`(1 ⋄ 4 ⋄ 7)`
	Column:	`((1 ⋄) ⋄ (4 ⋄) ⋄ (7 ⋄))`
	Column?	`(1 ⋄ 4 ⋄ 7)`
	List?	—

Design Iteration

Dyalog, *Mk III*

2020

Table:	`[1 2 3 ⋄ 4 5 6]`
List:	`(1 2 3 ⋄ 1 2)`
Object:	`(name1:val1 ⋄ name2:val2)`

Design Iteration

Dyalog, *Mk III*

2020

Table: `[1 2 3 ◇ 4 5 6]`

List: `(1 2 3 ◇ 1 2)`

Object: `(name1:val1 ◇ name2:val2)`

Column: `[1 ◇ 4 ◇ 7]`

Design Iteration

Dyalog, *Mk III*

2020

Table:
```
[1 2 3 ⋄ 4 5 6]
```
List:
```
(1 2 3 ⋄ 1 2)
```
Object:
```
(name1:val1 ⋄ name2:val2)
```
Column:
```
[1
 4
 7]
```

Design Iteration

Dyalog, *Mk III*

2020

```
Table:     [1  2  3 ⋄ 4  5  6]
List:      (1  2  3 ⋄ 1  2)
Object:    (name1:val1 ⋄ name2:val2)
Column:    [1
            4
            7]
Empty obj: ( )
```

Design Iteration

- 2015: Phil Last, *APL Array Notation* model
- 2016: Acre-3, *Mk I* APL model; Dyalog, *Mk I* internal
- 2017: Dyalog, *Mk II* presentation
- 2018: Acre-4, *Mk II* APL model; Dyalog, *Mk III* presentation
- 2020: Dyalog, *RC1* presentation
- 2021: Dyalog Formal Specification & Community Feedback
- 2022: Dyalog, *RC1* APL model
- 2023: Dyalog, *RC1* C prototype
- 2025: Dyalog, *RC2* implementation

Design Iteration

- 2015: Phil Last, *APL Array Notation* model
- 2016: Acre-3, *Mk I* APL model; Dyalog, *Mk I* internal
- 2017: Dyalog, *Mk II* presentation
- 2018: Acre-4, *Mk II* APL model; Dyalog, *Mk III* presentation
- 2020: Dyalog, *RC1* presentation
- 2021: Dyalog Formal Specification & Community Feedback
- 2022: Dyalog, *RC1* APL model
- 2023: Dyalog, *RC1* C Prototype
- 2025: Dyalog, *RC2* Implementation

Specification

abrudz.github.io/aplan

Formal Proposal: APL Array Notation

> ***Note:*** *This proposal's specification for scoping in literal namespaces has been changed based on feedback received after its initial publication. Affected sections are marked by a vertical bar on the left, with removed text ~~struck through~~ and added text underlined.*

One of the defining features of the APL language is the ability to denote numeric vectors directly through juxtaposition — separating the elements by spaces, as in `0 1 1 2 3 5 8`. The notation for character “vectors” is similar to that for “strings” in most other languages, using quotes to denote the start and end of a list of characters. When generalised arrays were added to the language in the early 1980s, the most popular APL dialects extended the vector notation to allow nested arrays to be written using so-called *strand notation*, allowing the juxtaposition of subexpressions producing arrays to form a one-dimensional array — as in `(2+2) (FOO 42) MAT`

Specification

abrudz.github.io/aplan

Technical specification

The notation consists of syntax that was invalid in every mainstream APL implementation before its introduction, thus causing no issues for backwards compatibility. The added syntax consists of these constructs that are currently SYNTAX ERRORs:

- *broken* round parentheses/parenthesised *name–value pair*: `(…)`
- *broken* square brackets: `[…]`
- empty round parentheses: `()`

where *broken* means interrupted by one or more statement separators (diamonds `⋄` or line breaks).

- A statement here means a value expression, optionally separated with a colon (`:`) from a preceding valid APL identifier.
- Empty statements make parentheses and brackets *broken*, but do not otherwise influence the result.
- A *broken* round parenthesis creates a namespace if every* separated statement is a *name–value pair*; every such pair defines a member of the resulting

Specification

abrudz.github.io/aplan

Formal syntax

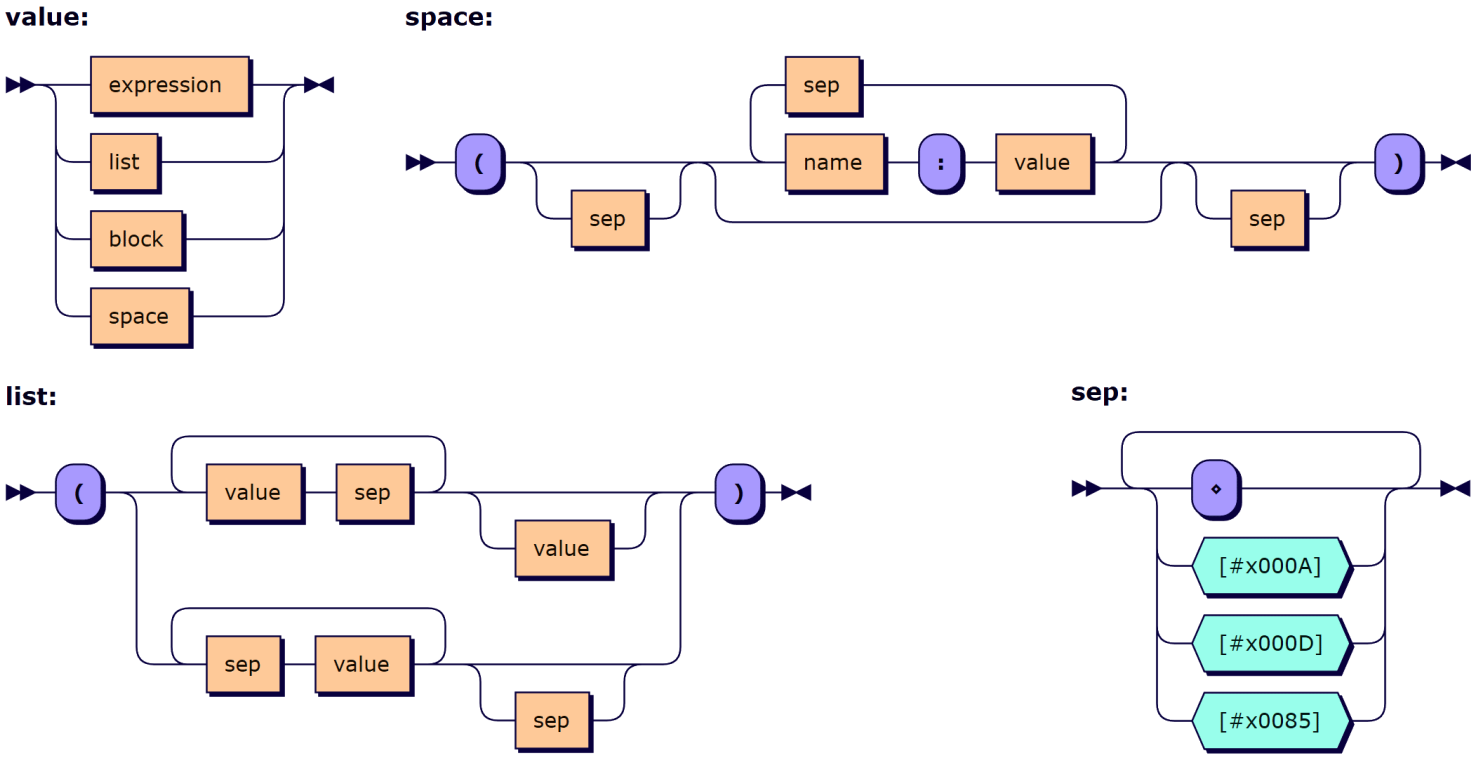
The array notation can be described using Extended Backus–Naur form, where an `expression` is any traditional APL expression:

```
value ::= expression | list | block | space
list  ::= '(' ( ( value sep )+ value? | ( sep value )+ sep? ) ')'
block ::= '[' ( ( value sep )+ value? | ( sep value )+ sep? ) ']'
space ::= '(' sep? ( name ':' value ( sep name ':' value )* )? sep? ')'
sep   ::= [⋄#x000A#x000D#x0085]+
```

The list of `sep` values is for illustration purposes and is to match the line breaks recognised by the APL implementation. However, these three `sep` values should be handled when reading Unicode text files.

Specification

abrudz.github.io/aplan



APL Array Notation

DYALOG

Implementation youtu.be/4cEqsBRMdW0

```
Parse←{
      0=≢⍵:''
      bot←0=⍺
      (2≤≢⍵)>∨/¯1↓bot:⍺ SubParse ⍵
      p←bot×SepMask ⍵
      ∨/p:∈{1=≢⍵:',⊂',⍵ ◇ ⍵}⍺(Paren ∇)EachNonempty
      p←2(1,>/∨¯1↓0,</)bot
      ∨/1↓p:∈(p⊂⍺)∇¨p⊂⍵
      ⍵
}
```

Implementation

youtu.be/ToQoJ1Bbpus


```
parseloop: while (sp) switch(pop()) {
    case ST_BEG: {
        DEBUG;
        // Initial state:
        // [ => go to ST_LB
        // ( => go to ST_LP
        // ANY* => go to ST_EXPR
        if (tok.type == TOKLB) { push(ST_LB); break; }
        if (tok.type == TOKLP) { push(ST_LP); break; }
        if (tok.type == TOKANY || tok.type == TOKSTR || to
        errorxf(ESYNTAX, DMXAPLAN_UNEXPTOK, tok.offset, to
```

Implementation

youtu.be/bSDStXeKsos

```
do
    {
    sp=KwNext(sp);
    affirm(sp[1]==KEYWORD);
    switch (*sp)
        {
        case KwANDiamond: count++; break;
        case KwANNewLine: count++; break;
        case KwANCloseVector:  count++; break;
        case KwANCloseMix:  count++; break;
        case KwANAssign: break;
        }
    } while (sp!=start);
```

Standardisation?

abrudz.github.io/aplan

Experimental implementations using APL models are available within some tools in the Dyalog eco-system, such as the Link tool which supports the representation of code and data in Unicode text files and the functions `Serialise` and `Deserialise` within the namespace `⎕SE.Dyalog.Array`. You can also try it out in the interactive online sandbox.

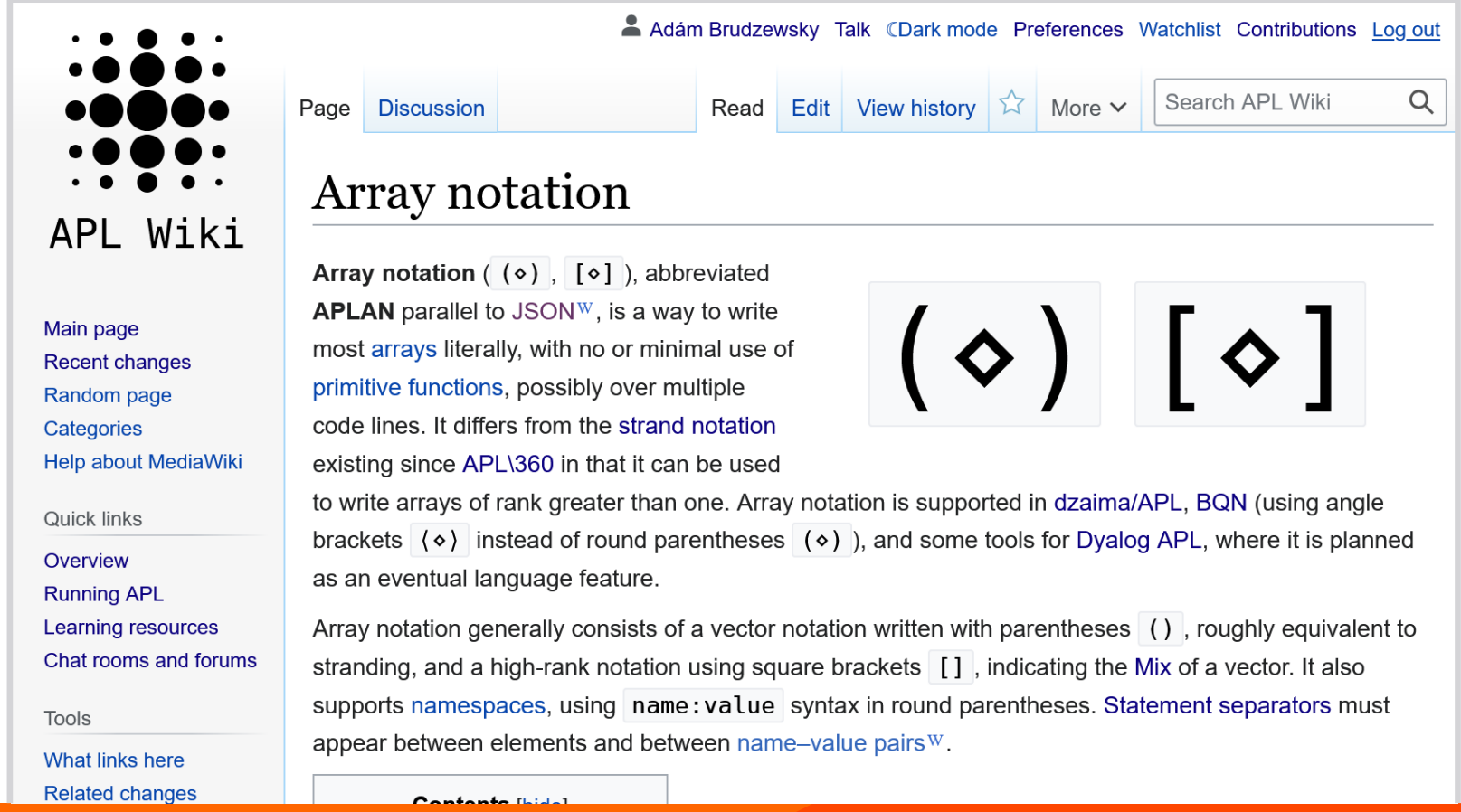
Providing feedback

Dyalog is keen to have feedback from the array language community on the notation proposed here so that we can feel confident about the design, before we proceed with our implementation. Our hope is that we will be able to keep the differences between future array notations within the family of array languages to a minimum.

We will monitor the APL Orchard chatroom, the APL Farm's #apl channel, the r/apl and r/apljk subreddits, and the comp.lang.apl newsgroup for feedback. (See APL Wiki for information about these forums.) In addition, we have created a topic in our own forum. If you prefer not to comment in public, please send comments by e-mail. Dyalog will update the discussion page for APL Wiki's Array notation design considerations article to contain a record of significant feedback.

Standardisation?

apl.wiki/aplan



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Array notation

Array notation (`(⋄)` , `[⋄]`), abbreviated **APLAN** parallel to JSON[W], is a way to write most arrays literally, with no or minimal use of primitive functions, possibly over multiple code lines. It differs from the strand notation existing since APL\360 in that it can be used to write arrays of rank greater than one. Array notation is supported in dzaima/APL, BQN (using angle brackets `⟨⋄⟩` instead of round parentheses `(⋄)`), and some tools for Dyalog APL, where it is planned as an eventual language feature.

(⋄) [⋄]

Array notation generally consists of a vector notation written with parentheses `()`, roughly equivalent to stranding, and a high-rank notation using square brackets `[]`, indicating the Mix of a vector. It also supports namespaces, using `name:value` syntax in round parentheses. Statement separators must appear between elements and between name–value pairs[W].

Contents [hide]

```
      [3  1  4
       2  7  1
       1  6  1] MatPower 3
[
 130  355  111
 193  516  157
 157  425  124
]
```

```
r←m MatPower e
r←m+.×*e⊢[1  0  0
          0  1  0
          0  0  1]
```

Take-aways?

- Good: Lack of standards committee
- Bad: Lack of standard for syntax
- Ugly: Lack of standardisation for result

Want more APL? dyalog.com/getting-started.htm

Recap

- History
- APL
- Problem
- Design Iteration
- Specification
- Implementation
- Standardisation?
- Take-aways?

Resources

- apl.wiki
- dyalog.tv
- abrudz.github.io/aplan
- dyalog.com/getting-started.htm
- apl.chat (Stack Exchange)
- adam@dyalog.com