Linguagens e Ambientes de Programação

LEI - Licenciatura em Engenharia Informática

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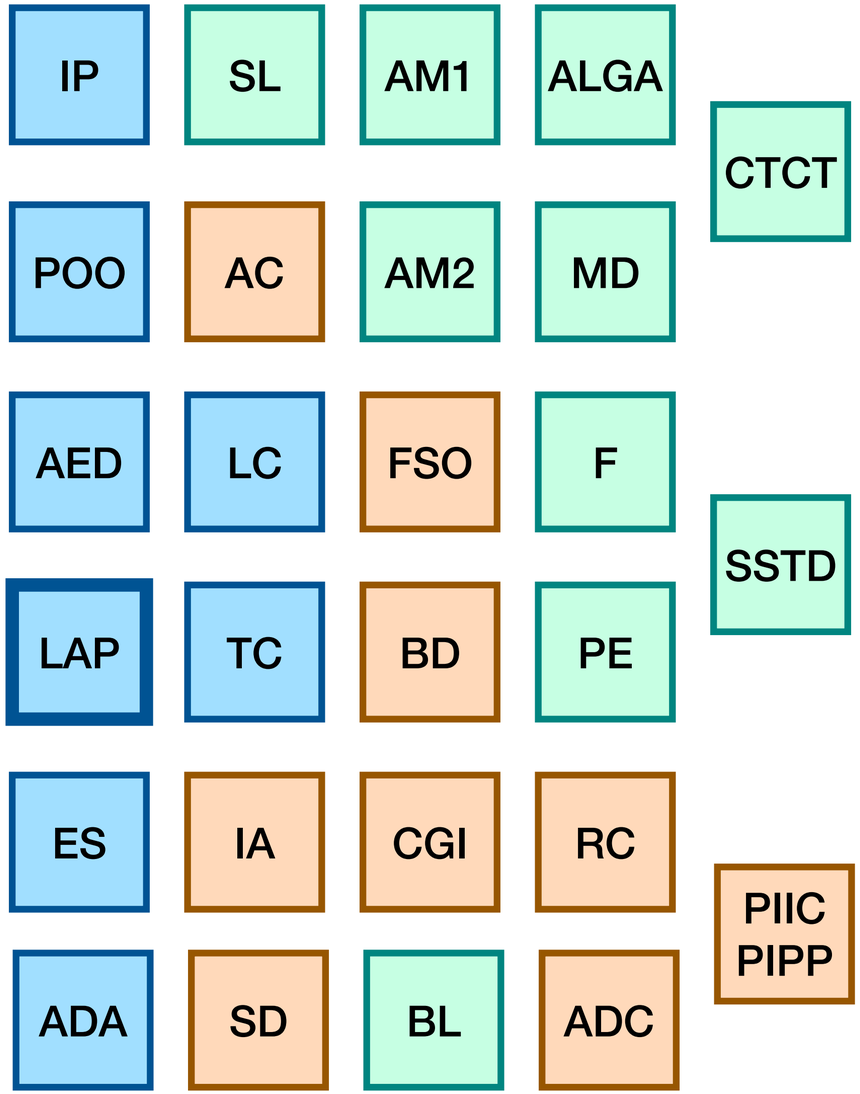
NOVA SCHOOL OF
SCIENCE & TECHNOLOGY

LAP 2024
A Unidade Curricular

LAP na LEI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Linguagens e Ambientes de Programação 2024

1. Estudo de um novo paradigma: programação funcional
2. Estudo dos fundamentos das linguagens de programação
3. A programação funcional é o veículo de comunicação para as LP
4. Aprender Programação Funcional com OCaml
5. Aprender muitas linguagens de programação numa só:
   - fazendo, e comparando.

Porquê estudar linguagens de programação?

Why (1): As linguagens de programação são a “nossa ferramenta”.

Why (2): Cada linguagem é apropriada a um estilo de programas e sistemas. É preciso conhecer bem, para escolher melhor.

Why (3): As linguagens de programação modernas usam/misturam muitos conceitos diferentes (paradigmas).

Why (4): As linguagens também são modelos precisos de raciocínio (programas que simulam sistemas provam que eles são possíveis).

Why (5): Desenhar novas linguagens é mais comum do que se pensa.

Why (6): Quem sabe o porquê das coisas, faz melhor.

Porquê estudar programação funcional (tipificada)?

Why (1): as LP funcionais têm uma semântica precisa

Why (2): os sistemas de tipos permitem raciocínios avançados

Why (3): são linguagens sem interferências e casos especiais

(e.g. visibilidade de nomes, aliasing, efeitos laterais, conversões implícitas).

Why (4): ideais para compreender e desenhar outras linguagens

Why (5): imutabilidade de estado (é possível raciocinar sem ser por debug).

Why (6): modularidade e composicionalidade

Why (7): abstração de ordem superior (código genérico).

Why (8): segurança de tipos (não há nulls, não há (tantos) erros de execução).

Conceitos de linguagens

- Sintaxe, semântica e pragmática
- Linguagens declarativas vs linguagens imperativas
- Declaração e definição de nomes (ligação, ambiente, âmbito)
- Polimorfismo paramétrico e universal
- Abstração e parametrização / Ligação (closures)
- Modularidade e composição
- Tipos algébricos (e indutivos)
- Sistemas de tipos (soundness), inferência de tipos (linguagens com …)
- Raciocínio e correção (testes vs verificação)
- Modelo de execução (stack based) - tail recursive
- Lazy vs Strict
- Estruturas de dados persistentes (why?)
- Estado, aliasing, etc. (pitfalls)
- Interpretadores e Compiladores (Just-in-time)

Programação Funcional em Java

```java
Collections.sort(numbers, new Comparator<Integer>() {
    @Override
    public int compare(Integer n1, Integer n2) {
        return n1.compareTo(n2);
    }
});
```

```java
Collections.sort(numbers, (n1, n2) -> n1.compareTo(n2));
```

https://www.baeldung.com/java-functional-programming

Programação Funcional em C

```c
#include <stdio.h>
#include <stdlib.h>

int values[] = { 88, 56, 100, 2, 25 };

int cmpfunc (const void * a, const void * b) {
   return ( *(int*)a - *(int*)b );
}

int main () {
   int n;

   printf("Before sorting the list is: \n");
   for( n = 0 ; n < 5; n++ ) {
      printf("%d ", values[n]);
   }

   qsort(values, 5, sizeof(int), cmpfunc);

   printf("\nAfter sorting the list is: \n");
   for( n = 0 ; n < 5; n++ ) {
      printf("%d ", values[n]);
   }

   return(0);
}
```

https://www.tutorialspoint.com/c_standard_library/c_function_qsort.htm

Programação Funcional em Scala

```scala
case class ChessPiece(color: Color, name: Name)
val rook = ChessPiece(White, Rook)
```

```scala
sealed trait Color
final case object White extends Color
final case object Black extends Color

sealed trait Name
final case object Pawn extends Name
final case object Rook extends Name
final case object Knight extends Name
final case object Bishop extends Name
final case object Queen extends Name
final case object King extends Name
```

```scala
def isTheMostImportantPiece(c: ChessPiece): Boolean = c match {
    case ChessPiece(_, King) => true
    case _ => false
}
```

https://www.baeldung.com/scala/algebraic-data-types

Programação Funcional em Java >= 17

```java
Object o = ...; // any object
String formatted = null;
if (o instanceof Integer i) {
    formatted = String.format("int %d", i);
} else if (o instanceof Long l) {
    formatted = String.format("long %d", l);
} else if (o instanceof Double d) {
    formatted = String.format("double %f", d);
} else {
    formatted = String.format("Object %s", o.toString());
}
```

```java
Object o = ...; // any object
String formatter = switch(o) {
    case Integer i -> String.format("int %d", i);
    case Long l    -> String.format("long %d", l);
    case Double d  -> String.format("double %f", d);
    case Object o  -> String.format("Object %s", o.toString());
}
```

https://dev.java/learn/pattern-matching/

Programação Funcional em JavaScript

```
const originalArray = [1, 2, 3];
const newArray = [...originalArray, 4];
```

```
const person = { name: 'Alice', age: 30 };
const updatedPerson = { ...person, age: 31 };
```

```
const add = (x, y) => x + y;
const square = (x) => x * x;

function compose(...functions) {
  return (input) => functions.reduceRight((acc, fn) => fn(acc),
input);
}

const addAndSquare = compose(square, add);

console.log(addAndSquare(3, 4)); // 49
```

```
const numbers = [1, 2, 3, 4, 5, 6];

const double = (num) => num * 2;
const isEven = (num) => num % 2 === 0;

const result = numbers
  .map(double)
  .filter(isEven)
  .reduce((acc, num) => acc + num, 0);

console.log(result); // 18
```


https://hackernoon.com/functional-programming-with-javascript-a-deep-dive

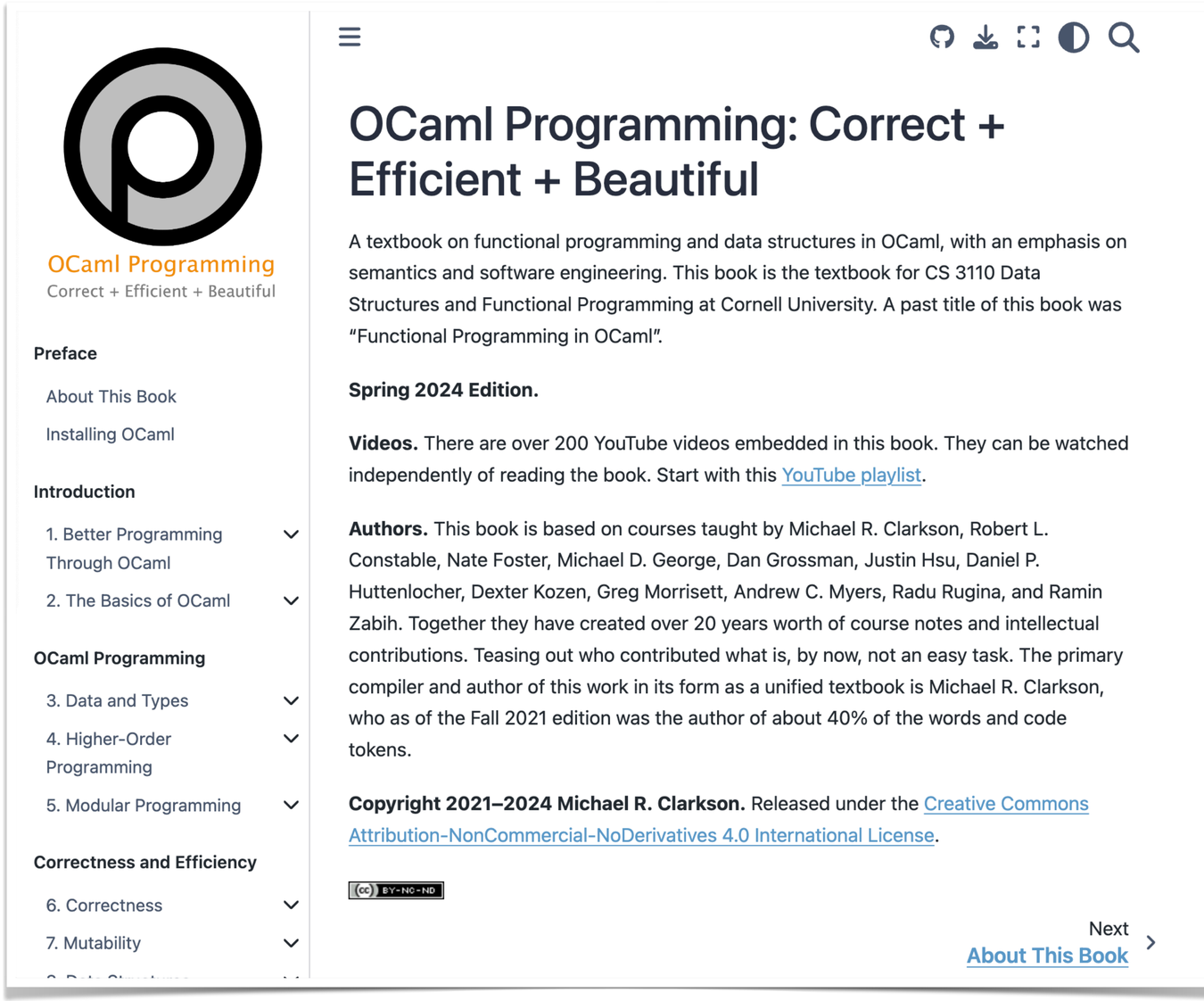
Programação Funcional (reactiva) em ReactJS

```
const BooksList = () => {

    const [books, setBooks] = useState<Book[]>([])
    const [selected, setSelected] = useState<number | undefined>(undefined)

    const [inputTitle, searchTitle, setSearchTitle] = useInput("", "Search Title")
    const [inputAuthor, searchAuthor, setSearchAuthor] = useInput("", "Search Author")

    const loadBooks = () => {
        fetch("/books.json")
            .then(response => response.json())
            .then(data => setBooks(data))

    }
    useEffect(loadBooks, [])

    const filteredBooks = books.filter(b => b.title.includes(searchTitle) && b.author.includes(searchAuthor))

    return <div>
        {inputAuthor}
        {inputTitle}
        <BooksListView books={filteredBooks} selected={selected} setSelected={setSelected} />
    </div>
}
```

Logística

Livro de texto

- OCaml Programming:
  Correct + Efficient + Beautiful
- Cornell University
- Michael R. Clarkson et al.
- Online resources
  (book, exercises, videos)



Ferramentas de laboratório

- Interpretador de OCaml + utop
- Compilador de OCaml: ocamlc + make/dune
- Trabalho com Visual Studio Code + OCaml Extension
- Exercícios com Jupyter Notebook + OCaml kernel + VSCode
- Trabalhos através do GitHub Classroom
- Correção automática dos trabalhos (mooshak ou outro equivalente)

Funcionamento

- Aulas teóricas com conceitos, discussão e exemplos.
- Aulas práticas com exercícios e apoio a projeto.

Programa

O plano para as aulas teóricas é o seguinte:

Semana	Data	Tópicos
1	6/3	Apresentação. Logística e avaliação. A história e o futuro das linguagens de programação.
1	7/3	Programação funcional. A linguagem OCaml. Expressões, Variáveis e tipos. Funções biblioteca. Input/Output básico.
1	P	Instalação das ferramentas. OCaml, Jupyter, VSCode + plugin.
2	13/3	Definição de Funções. O tipo função. Pré e pós condições. Asserções e testes unitários.
2	14/3	Funções como valores. Composição. Polimorfismo. Inferência de tipos.
2	P	Exercícios
3	20/3	Funções recursivas sobre naturais. Execução por substituição. Pensamento Indutivo vs. pensamento Iterativo.
3	21/3	Tipos estruturados: produtos e registos. Exercícios.
3	P	Exercícios
4	27/3	Tipos estruturados: tipos algébricos, pattern matching. Exercícios.
4	28/3	Férias
4	P	Exercícios
5	3/4	Tipos estruturados: Listas e funções recursivas sobre listas. Exercícios.
5	4/4	Programação de ordem superior: map e fold. Exercícios.
5	P	Exercícios. Entrega do primeiro trabalho (5/4).

Avaliação

- Componente laboratorial
  - 3 projetos (P1', P2', P3')
  - D1 - Discussão P1(30min) - 27 de Abril*
  - D2, D3 = Discussão P2, P3 (1h) - 3 de Junho*
  - Pi = min(Pi', Di)
  - CompL = 0.25 x P1 + 0.25 x P2 + 0.5 x P3, CompL >= 9.5
- Componente teórico-prática
  - 1º Teste - T1 (1h30) - 27 de Abril*
  - 2º Teste - T2 (1h30) - 3 de Junho*
  - Exame - Ex (2h30) - ?
  - CompTP = (T1 + T2) / 2 ou CompTP = Ex, CompTP >= 9.5

* datas provisórias

Nota sobre Ferramentas de Inteligência Artificial

- As ferramentas de IA é permitida nos projetos e exercícios da aula e proibida nos testes escritos e discussões.
- O uso de ferramentas de IA têm de ser explicitamente referidas no código e relatório que for entregue.
- Considera-se que um aluno que use estas ferramentas durante a realização de um exercício de avaliação ou projeto e omita que as usou comete plágio.

> “Analysis shows that, when prompted, 52 percent of ChatGPT answers to programming questions are incorrect and 77 percent are verbose. “

https://www.forbes.com/sites/garydrenik/2023/10/18/ai--low-code-can-the-two-work-harmoniously-to-democratize-coding-for-developers/

Linguagens e Ambientes de Programação (Aula Teórica 1)

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Linguagens de Programação

Alonzo Church (1903 - 1995)

- A linguagem de programação fundamental
- O sistema formal cálculo Lambda

$$E ::= \; x \mid \; \lambda x.E \; \mid \; E \; E$$

$$(\lambda x.E) \; E' \longrightarrow E\{E'/x\} \qquad \frac{E \longrightarrow E''}{E \; E' \longrightarrow E'' \; E'}$$

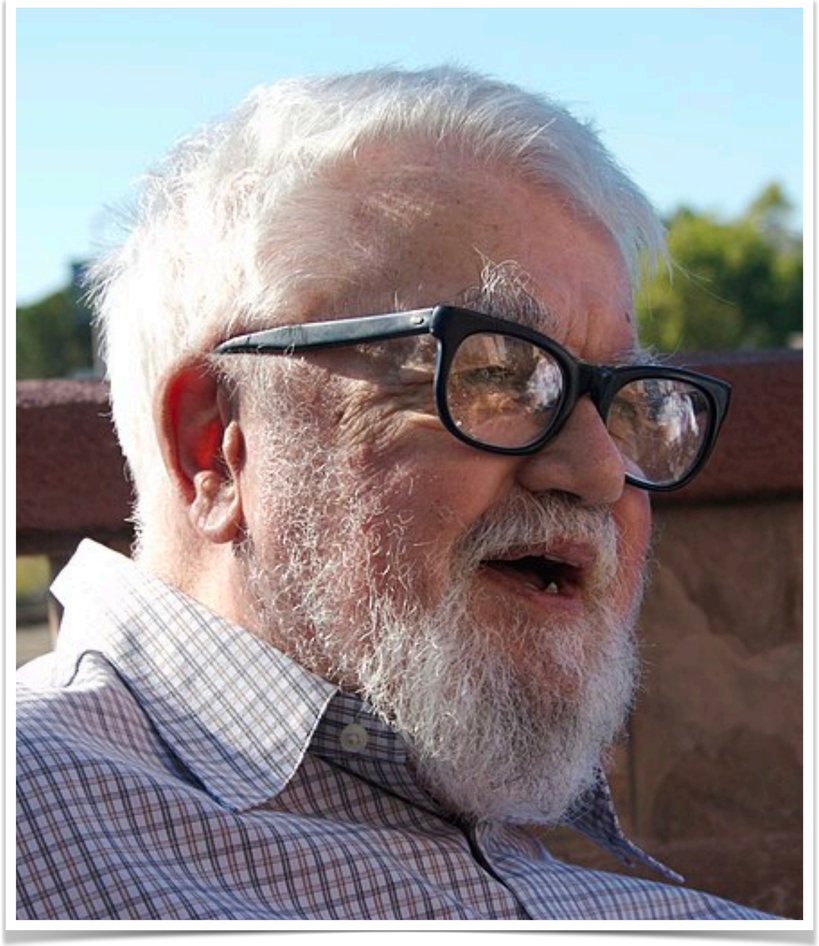
- Provou a impossibilidade de resolver o *Entscheidungsproblem* (problema de decisão)

Alan Turing (1912 - 1954)

- A máquina de Turing
- o primeiro computador (WWII)
- A indecidibilidade do “halting problem”.
- Prova que o cálculo lambda é Turing complete.

John McCarthy (1927 - 2011)

- A linguagem LISP (1960) e *garbage collection*
- LISP = LISt Processor
- Turing award 1971
- LISP já incluía :
  - Estruturas de dados em árvore
  - Garbage collection
  - Tipificação dinâmica
  - Funções de ordem superior
  - Recursão
  - Um REPL

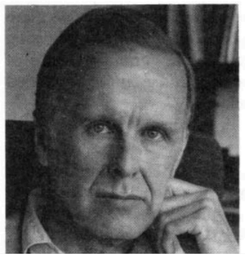


John Backus (1924 - 2007)

- Fortran (1966), BNF e FP
- Comité do ALGOL 58, e ALGOL 60
- Turing award 1977
- FP (Point Free Style) - 1977

Can Programming Be Liberated from the von Neumann Style? A Functional Style and Its Algebra of Programs

John Backus
IBM Research Laboratory, San Jose



Conventional programming languages are growing ever more enormous, but not stronger. Inherent defects at the most basic level cause them to be both fat and weak: their primitive word-at-a-time style of programming inherited from their common ancestor—the von Neumann computer, their close coupling of semantics to state transitions, their division of programming into a world of expressions and a world of statements, their inability to effectively use powerful combining forms for building new programs from existing ones, and their lack of useful mathematical properties for reasoning about programs.

O estilo Point Free não usa os nomes dos parâmetros e define funções só por composição.

```
f = (+ 1)
```

```
f x = x + 1
```

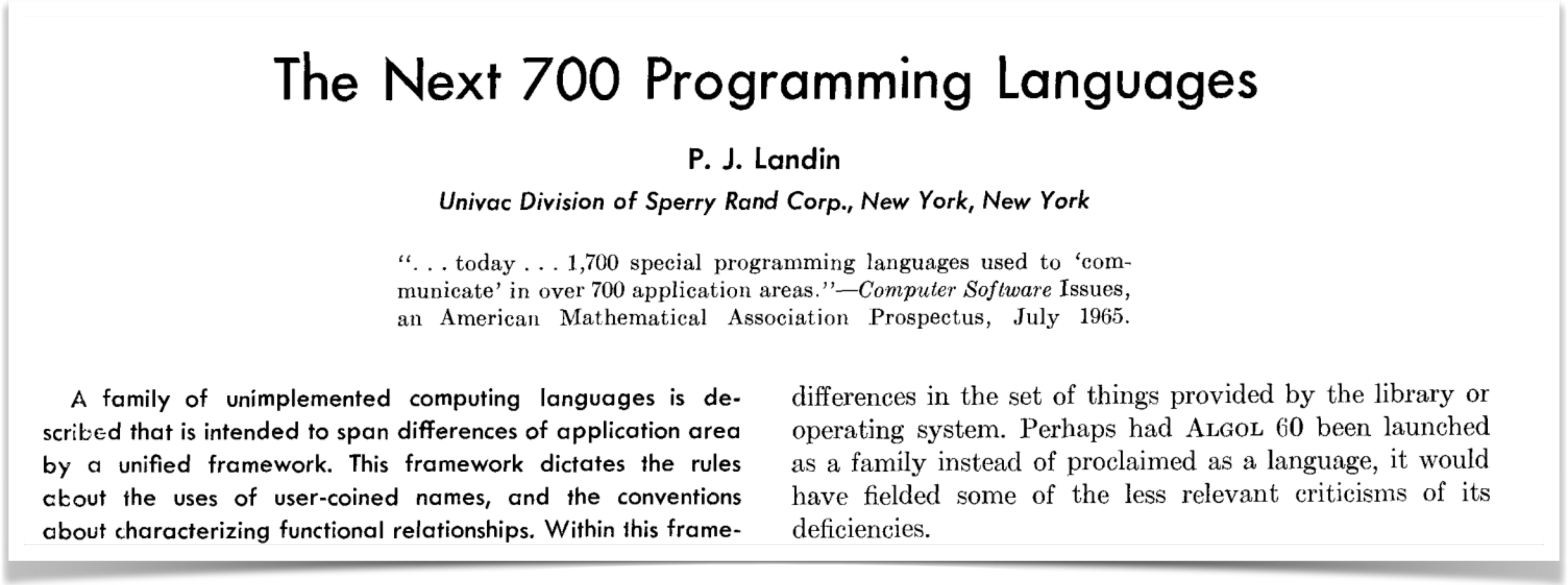
```
sum = foldr (+) 0
```

```
sum' xs = foldr (+) 0 xs
```


https://wiki.haskell.org/Pointfree

Peter Landin (1930 - 2009)

- Máquina SECD para linguagens funcionais
  - Stack, Environment, Control, Dump
  - Registos de pilhas e uma lista associativa (Environment)
  - Instruções: nil, ldc, ld, sel, join, ldf, ap, ret, dum, rap



The Next 700 Programming Languages

P. J. Landin

Univac Division of Sperry Rand Corp., New York, New York

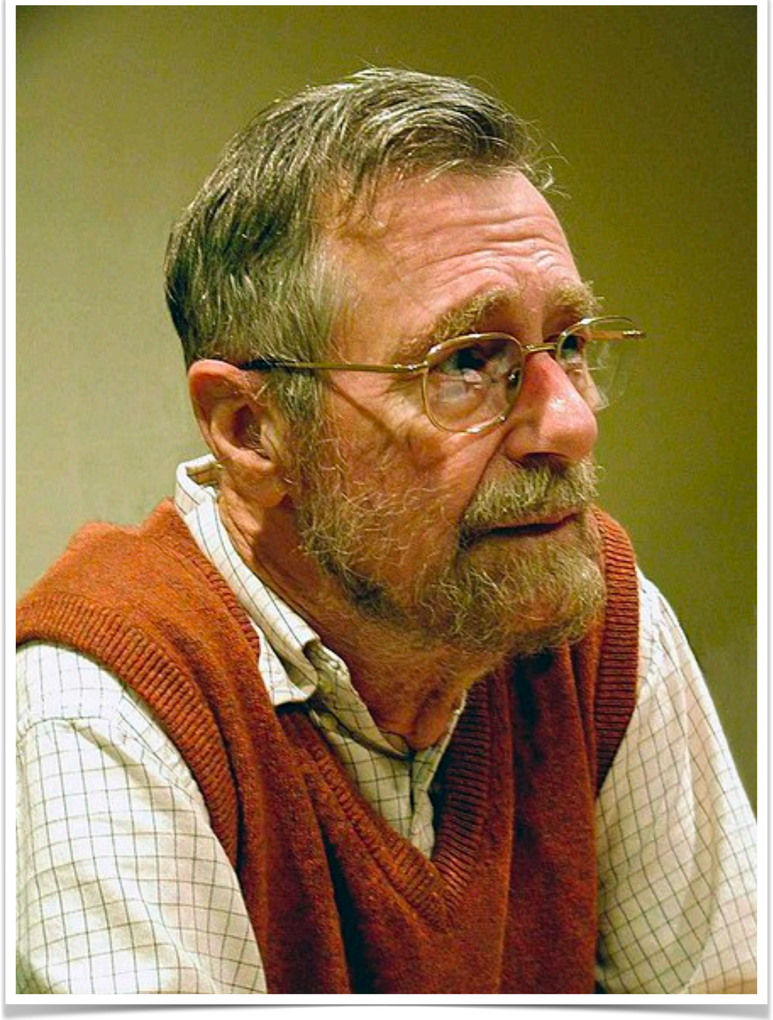
"... today ... 1,700 special programming languages used to 'communicate' in over 700 application areas."—*Computer Software* Issues, an American Mathematical Association Prospectus, July 1965.

A family of unimplemented computing languages is described that is intended to span differences of application area by a unified framework. This framework dictates the rules about the uses of user-coined names, and the conventions about characterizing functional relationships. Within this frame- differences in the set of things provided by the library or operating system. Perhaps had ALGOL 60 been launched as a family instead of proclaimed as a language, it would have fielded some of the less relevant criticisms of its deficiencies.

https://en.wikipedia.org/wiki/Peter_Landin

Edsger W. Dijkstra (1930 - 2002)

- Turing award 1972
- Definiu a noção de *structured programming*
  - Blocos de programa aninhados
  - Sem saltos
- Implementou o primeiro compilador de ALGOL



Edgar Dijkstra: Go To Statement Considered Harmful

Go To Statement Considered Harmful

Key Words and Phrases: go to statement, jump instruction, branch instruction, conditional clause, alternative clause, repetitive clause, program intelligibility, program sequencing
CR Categories: 4.22, 5.23, 5.24

EDITOR:

For a number of years I have been familiar with the observation that the quality of programmers is a decreasing function of the density of **go to** statements in the programs they produce. More recently I discovered why the use of the **go to** statement has such

dynamic progress is only characterized when we also give to which call of the procedure we refer. With the inclusion of procedures we can characterize the progress of the process via a sequence of textual indices, the length of this sequence being equal to the dynamic depth of procedure calling.

Let us now consider repetition clauses (like, **while** *B* **repeat** *A* or **repeat** *A* **until** *B*). Logically speaking, such clauses are now superfluous, because we can express repetition with the aid of recursive procedures. For reasons of realism I don't wish to exclude them: on the one hand, repetition clauses can be implemented quite comfortably with present day finite equipment; on

Tony Hoare (1934)

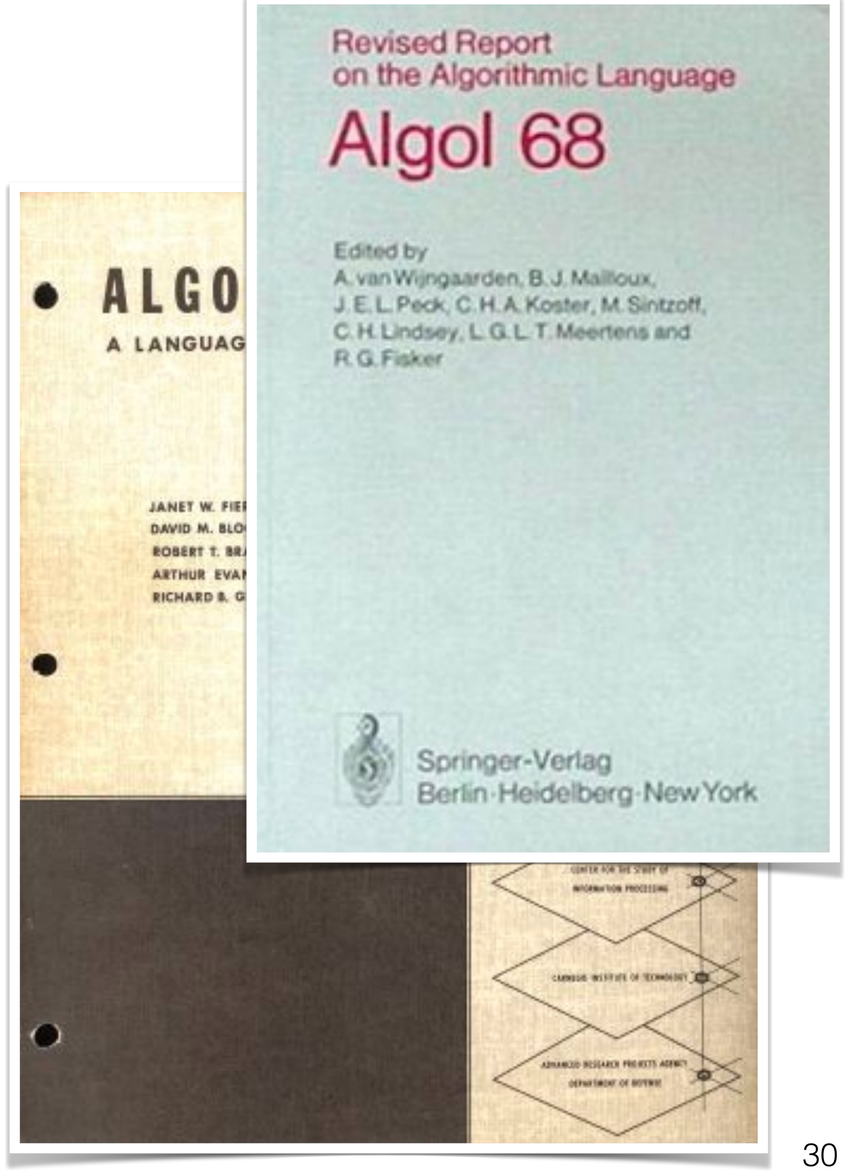
- Turing Award 1980
- Contribuições em:
  - Linguagens de Programação (ALGOL)
  - Algoritmos (Qsort)
  - Sistemas operativos (Monitors)
  - Verificação formal de programas (HL)
  - programação concorrente (CSP)
- “Null References: The Billion Dollar Mistake”

https://en.wikipedia.org/wiki/Tony_Hoare

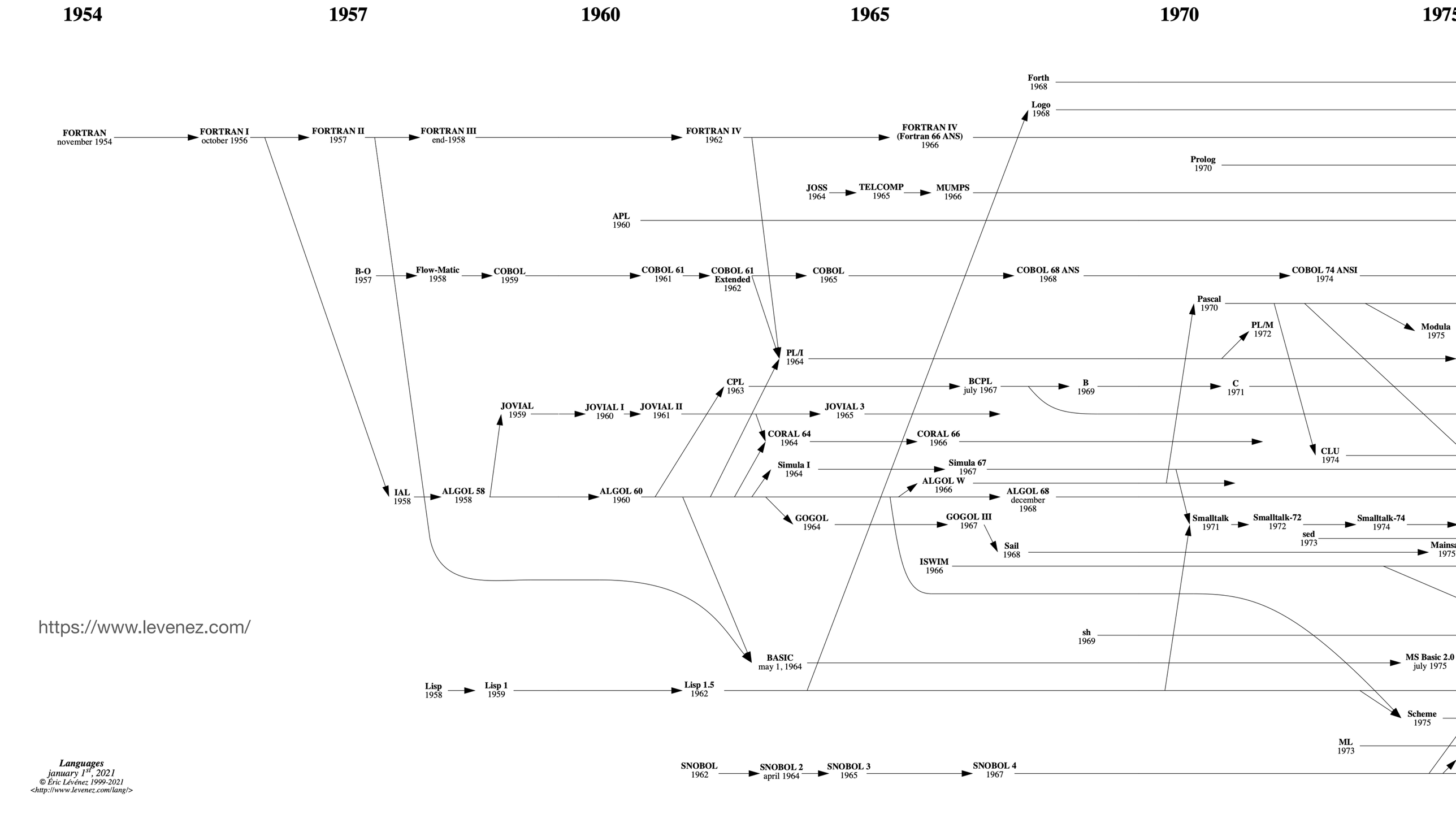
The ALGOL Family

- Linguagem Imperativa concorrente com múltiplos paradigmas.
- Tipificação forte
- Objectos
- Null references

Top: John McCarthy, Fritz Bauer, Joe Wegstein. Bottom: John Backus, Peter Naur, Alan Perlis



https://www-formal.stanford.edu/jmc/pictures.html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Smalltalk
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may 1, 1964
MS Basic 2.0
july 1975
Lisp
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SNOBOL
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SNOBOL 2
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SNOBOL 3
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SNOBOL 4
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https://www.levenez.com/
Languages
january 1st, 2021
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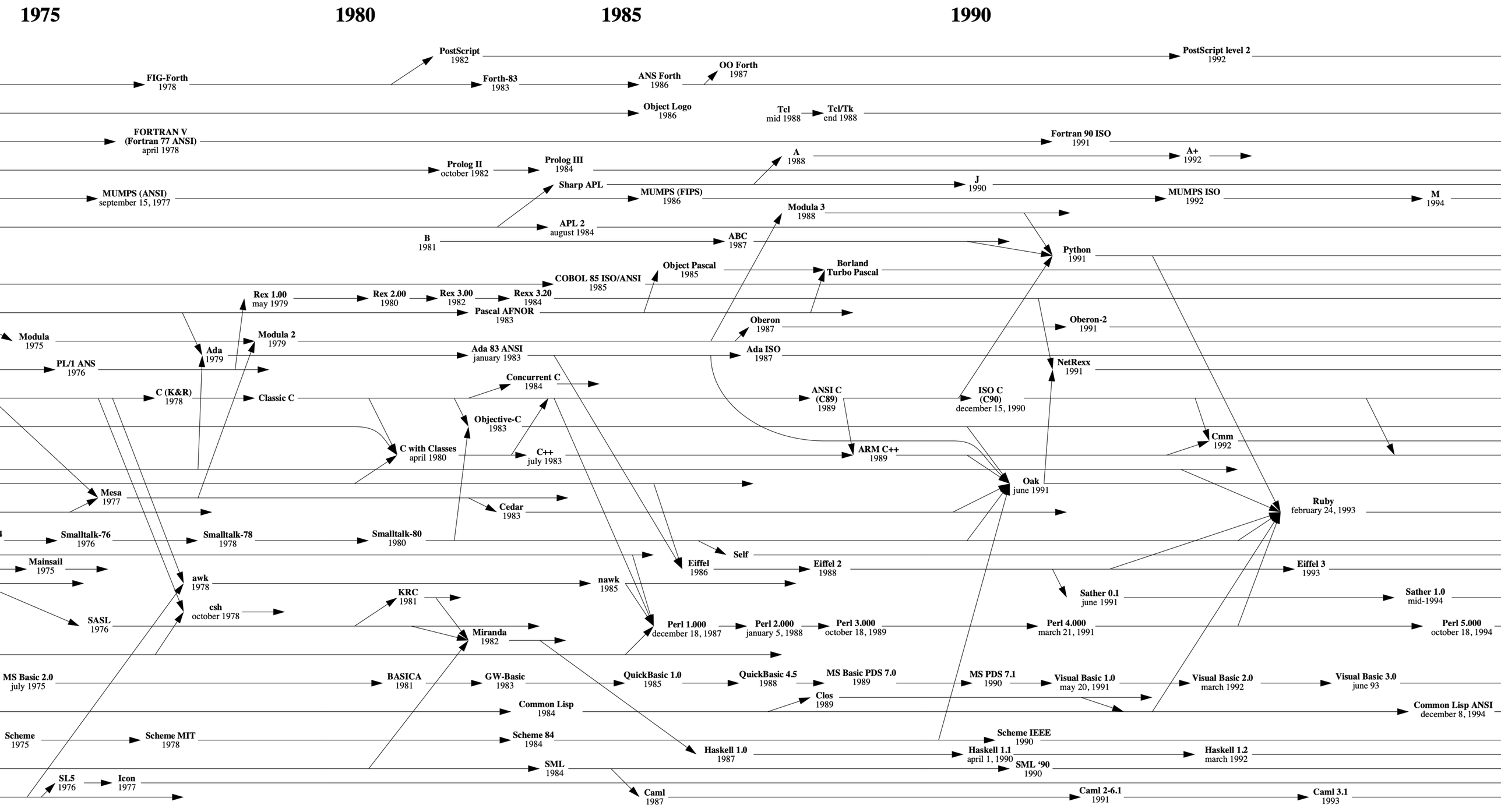
<http://www.levenez.com/lang/>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Tcl
mid 1988
Tcl/Tk
end 1988
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(Fortran 77 ANSI)
april 1978
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Sharp APL
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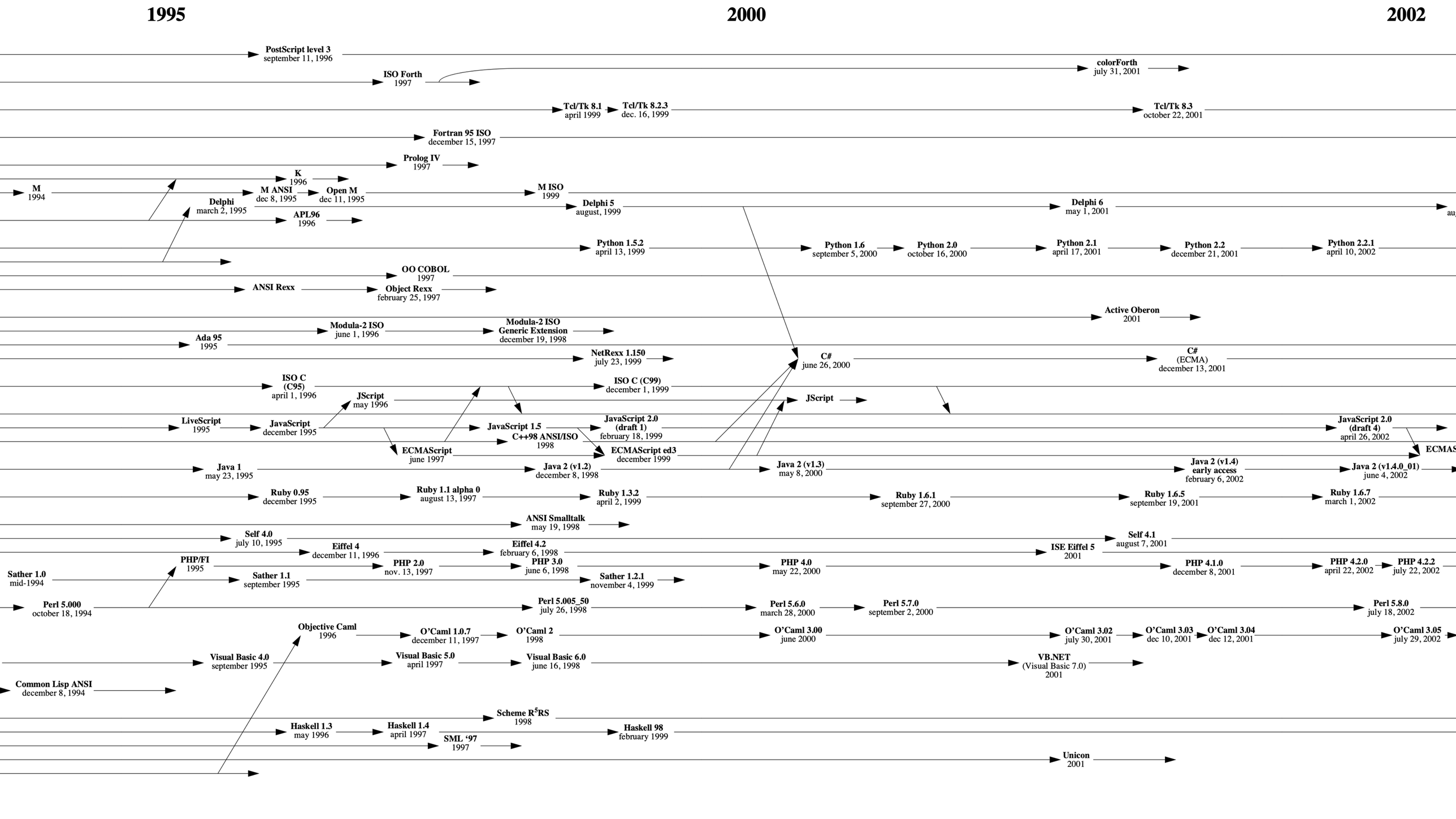
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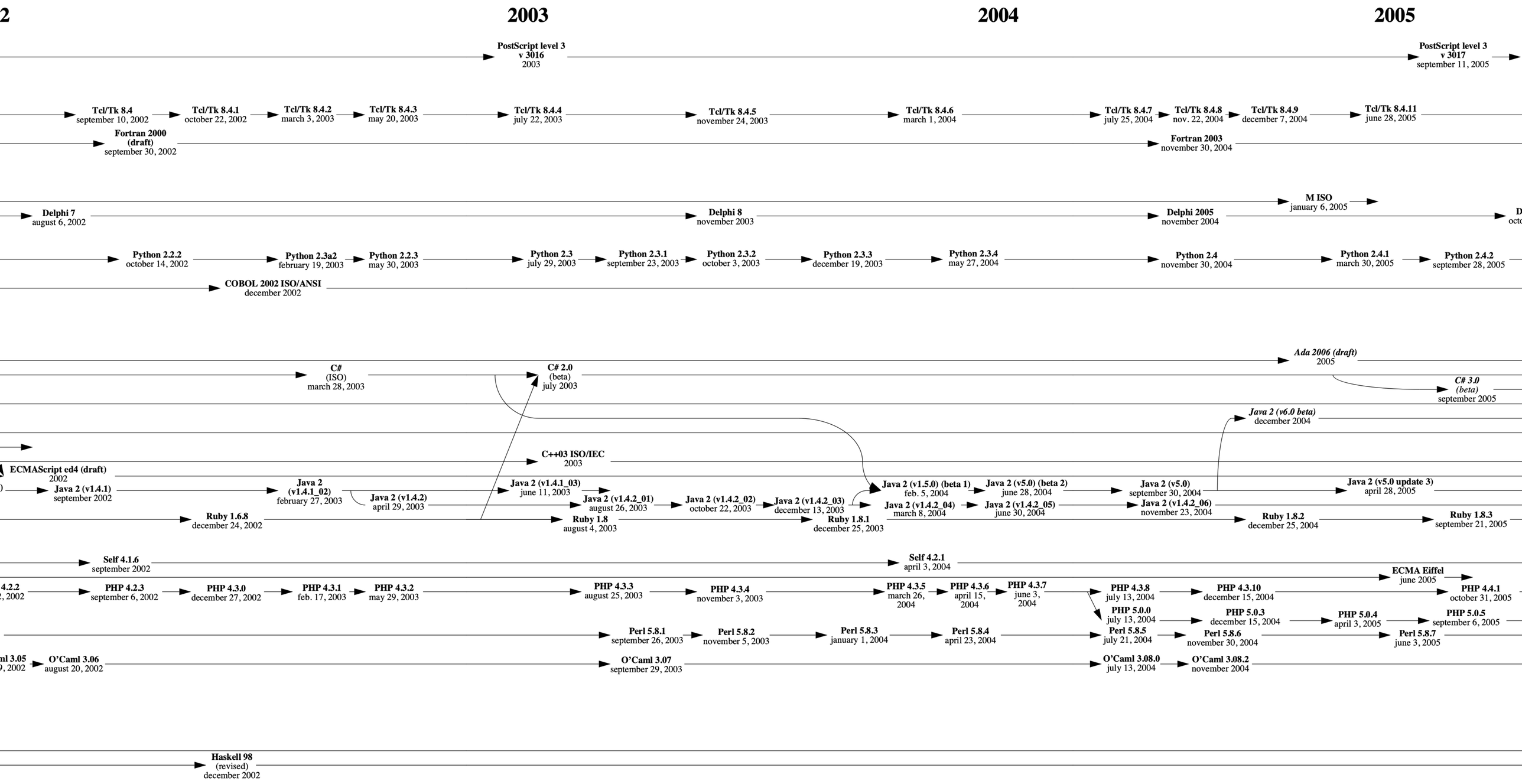
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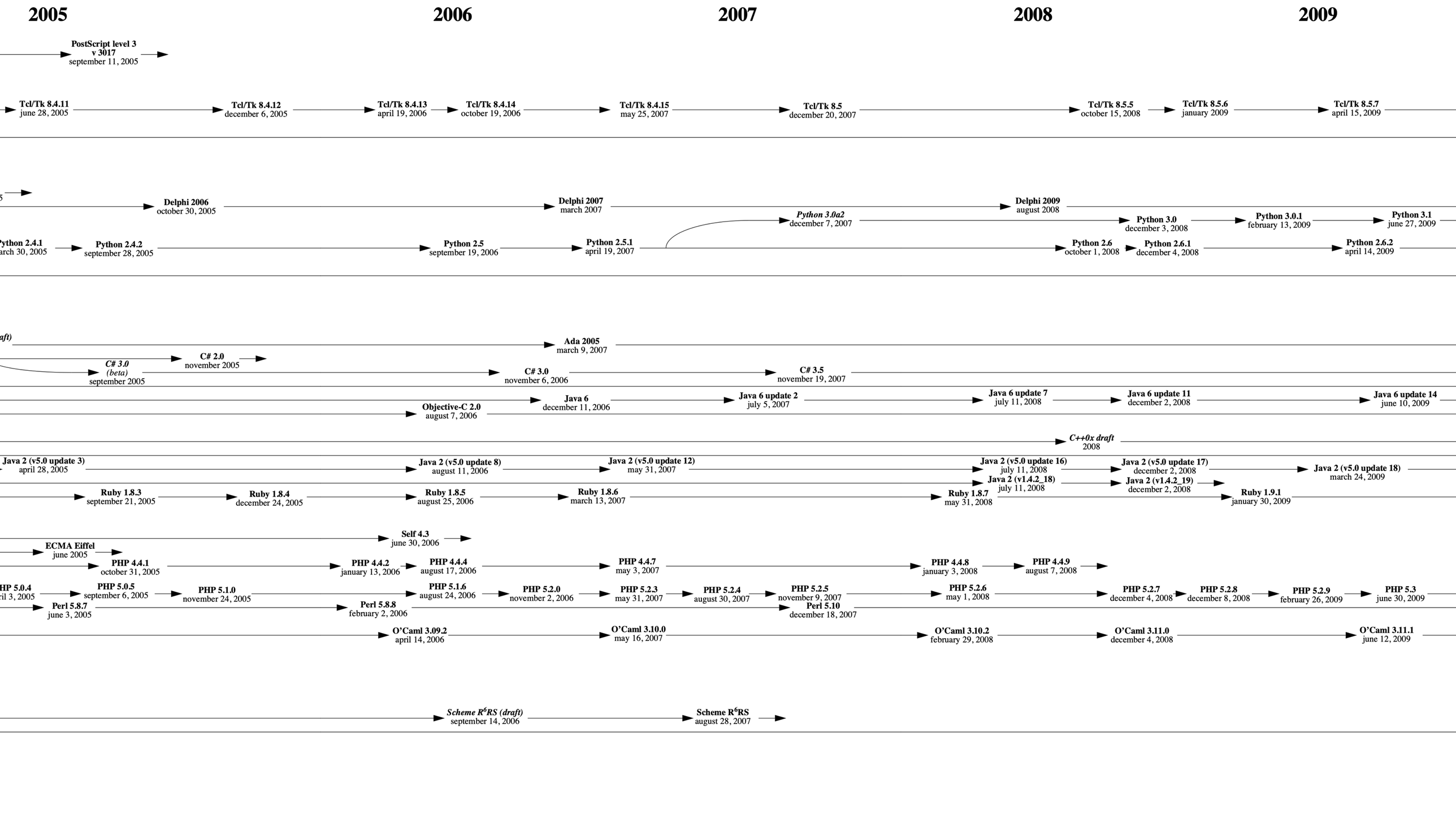
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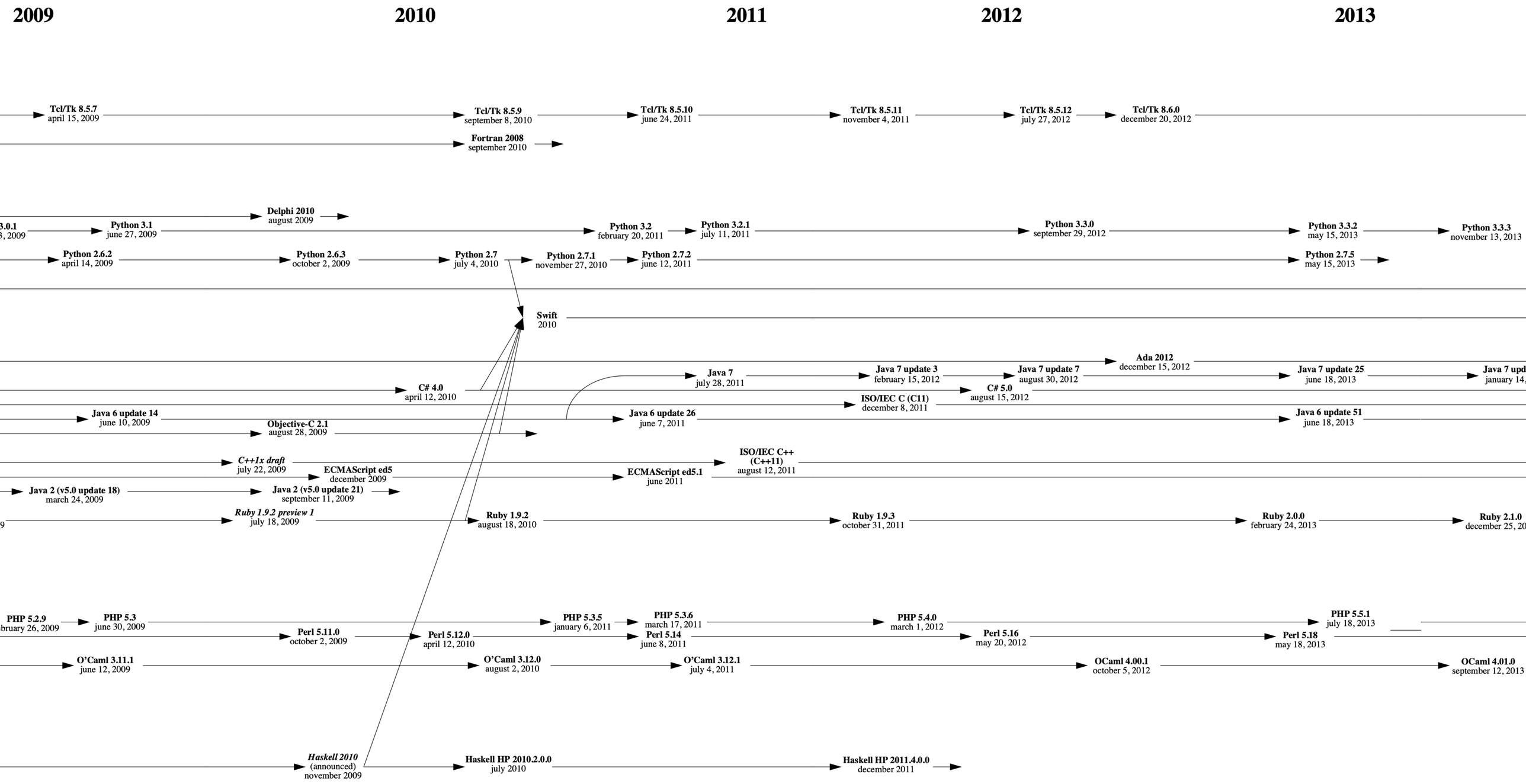
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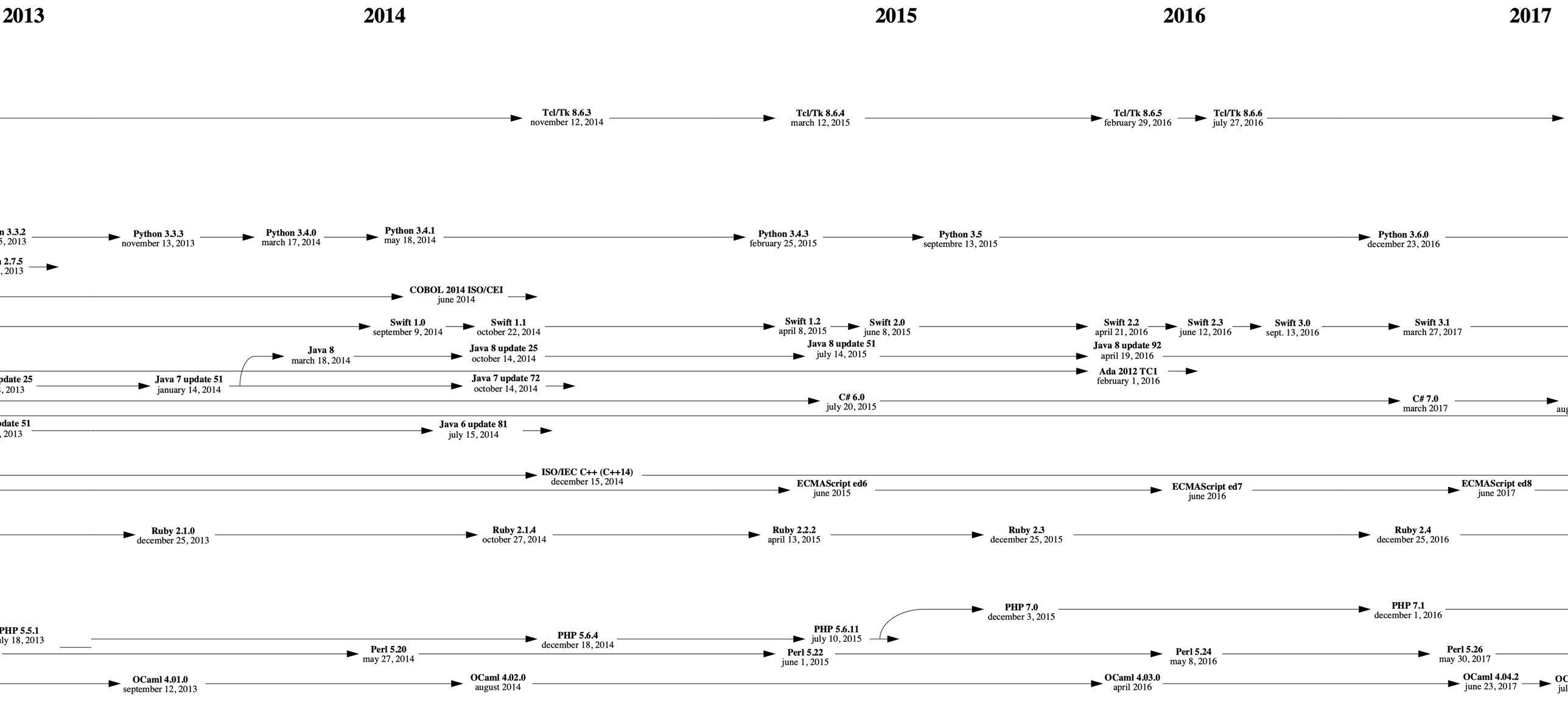
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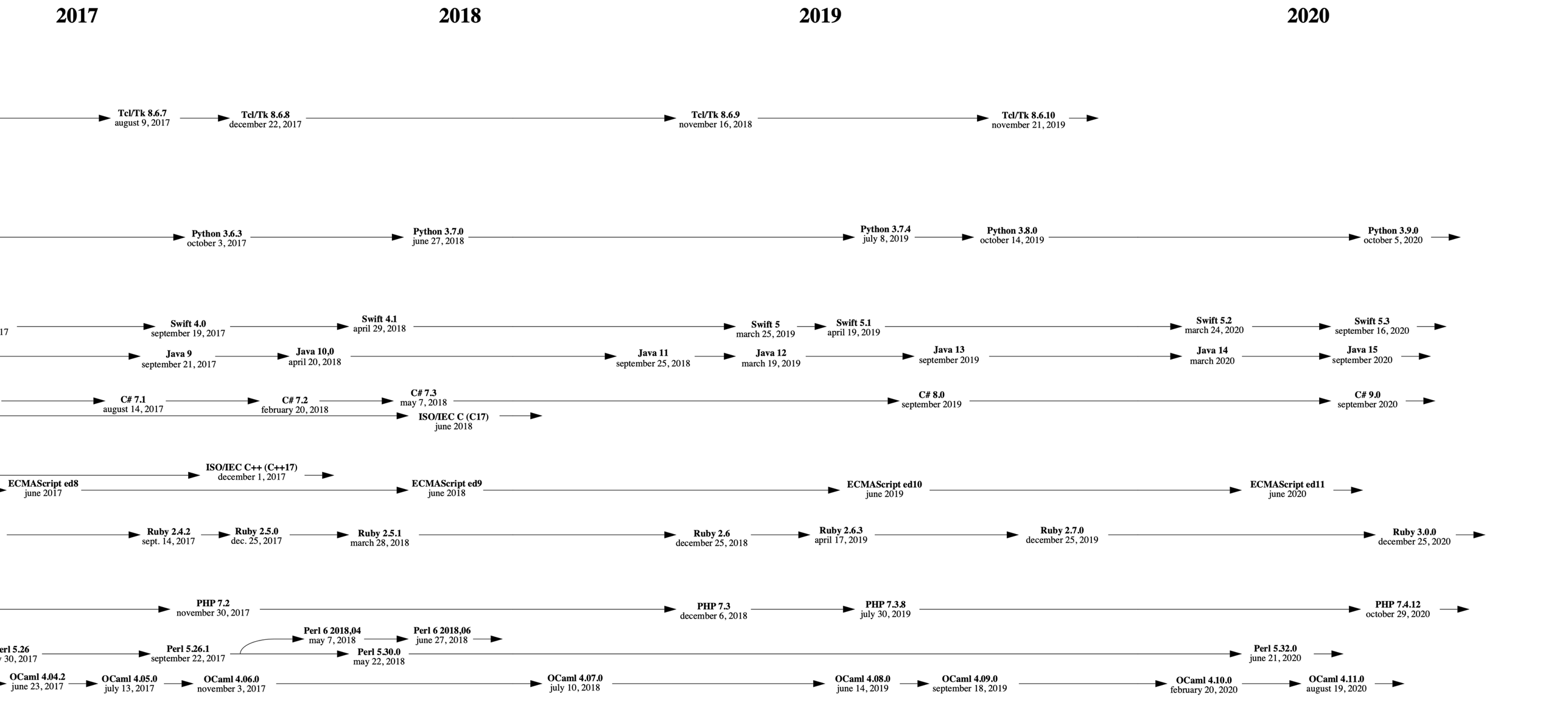
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Paradigma de programação

- Imperativo (How)
  - Procedimentos
  - Objetos (classes)
  - Variáveis de estado e campos de objetos
- Declarativo (What)
  - Funções
  - Predicados (logic)
  - Sinais (reactive)
  - Eventos
  - Variáveis (no sentido matemático)