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DEPARTMENT OF INFORMATICS ENGINEERING

U.PORTO
FC FACULDADE DE CIÊNCIAS
UNIVERSIDADE DO PORTO

DEPARTMENT OF COMPUTER SCIENCE

Functional and Logic Programming

Bachelor in Informatics and Computing Engineering
2024/2025 – 1st Semester

Introduction to Logic Programming

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Agenda

- Logic Programming
- Prolog
- Applications
- Extensions

Logic Programming

- Logic Programming is a *Declarative* style of programming
  - The programmer describes **what** he wants the result to be
  - You already knew at least one example:
    - SQL

- Contrasts with *Imperative Programming*
  - The programmer specifies **how** the computer should obtain the result
  - Most of what you have worked with, so far

How vs What

Imperative

```
var clients;
forall (client in clients)
{
    if(client.age > 18)
        print client.name;
}
```

Declarative

```
SELECT name
    FROM Clients
    WHERE age > 18;
```

Logic Programming

- The idea behind logic programming is that, when given a problem, instead of designing and writing an algorithm to solve it, we simply specify the problem, and the computer solves the problem
  - In reality, we have to be mindful about how the solver works

Advantages

- There are several reasons to use Logic Programming
  - Rapid prototyping
  - Usually small code footprint
  - Flexible and intuitive (once you get to know it)
  - Intrinsic explainability of results
- Also provides with better reasoning skills (from learning a different ‘way of thinking about problems’)

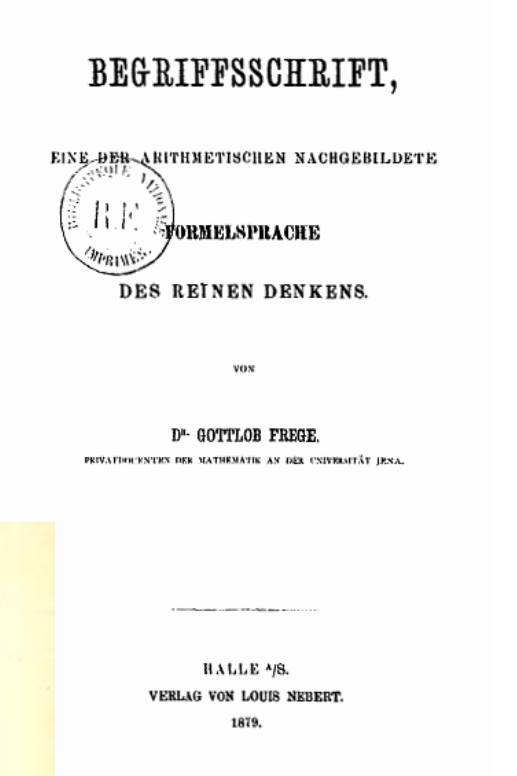
Logic programming is usually easier to learn than traditional programming
Yet, expert computer programmers often have
more trouble with logic programming than novice learners

Prolog

- Prolog is the most well-known Logic Programming language
  - Programs are descriptions of knowledge / relations
    - In the form of first-order logic predicates
  - A computation starts as a query, the program tries to prove the query
  - Not purely declarative (a compromise needed to make the language efficient, practical and useful)

History of Prolog

- Origins in logic
  - Aristotle's works on logic (*Organon*, 40BC)
  - 1879: *Begriffsschrift*, by Gottlob Frege
    - Foundation of first-order logic, introduces quantifier notation, and solves problems such as multiple generality
  - 1910-1913: *Principia Mathematica*, by Alfred N. Whitehead and Bertrand Russell
    - Foundations of mathematics, attempting to derive mathematical truths from axioms and inference rules in symbolic logic


BEGRIFFSSCHRIFT,

EINE DER ARITHMETISCHEN NACHGEBILDETE

FORMELSPRACHE

DES REINEN DENKENS.

VON

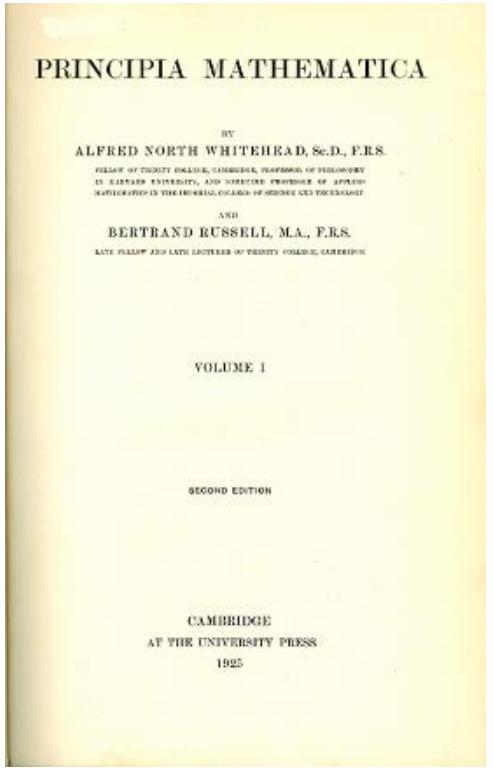
Dr. GOTTLOB FREGE,

PRIVATDOCENTEN DER MATHEMATIK AN DER UNIVERSITÄT JENA.

HALLE a/S.

VERLAG VON LOUIS NEBERT.

1879.


PRINCIPIA MATHEMATICA

BY

ALFRED NORTH WHITEHEAD, Sc.D., F.R.S.

AND

BERTRAND RUSSELL, M.A., F.R.S.

VOLUME I

SECOND EDITION

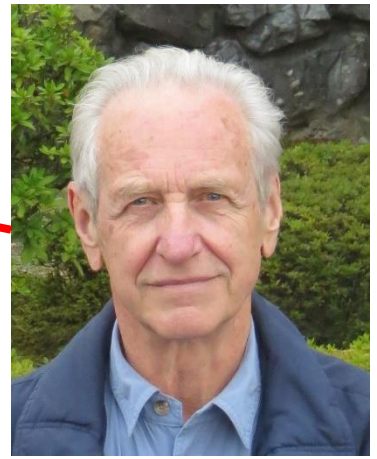
CAMBRIDGE

AT THE UNIVERSITY PRESS

1925

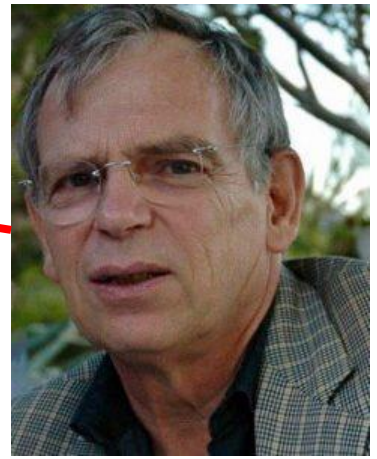
History of Prolog

Key People



Robert Kowalski

- Automated theorem-proving in first-order logic
- Question-answering system using natural language (French)



Alain Colmerauer

Philippe Roussel

Robert Pasero

Jean Trudel

Abridged Timeline

- 1960s: Early developments on automated theorem-proving in first-order logic and natural language processing
- 1972: Prolog (*Programmation en Logique*) is born
- 1970s: Advances in Prolog systems (Compiler, DCGs, ...)
- 1980s: Prolog gains popularity, especially in Europe and Japan
  - 1982: Fifth Generation Computer Systems Project
- 1990s: ISO Prolog (1995), parallel and concurrent systems
- 2000s: Several extensions and optimizations

According to an old joke, Logic Programming
was invented in Edinburgh in 1974 and implemented in Marseille in 1972

Contextual Timeline

IBM System/360

Pascal

C
Prolog

C++

IBM PC

1965

1970

1972

1973

1976

1980

1981

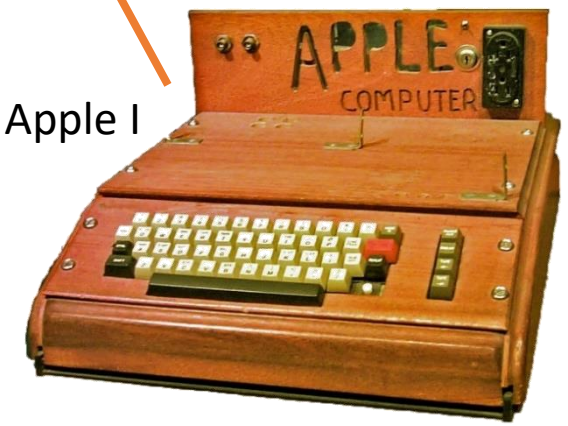
1990

1995

FORTRAN (1957)
LISP (1958)
COBOL (1959)
BASIC (1964)

Xerox Alto

Apple I



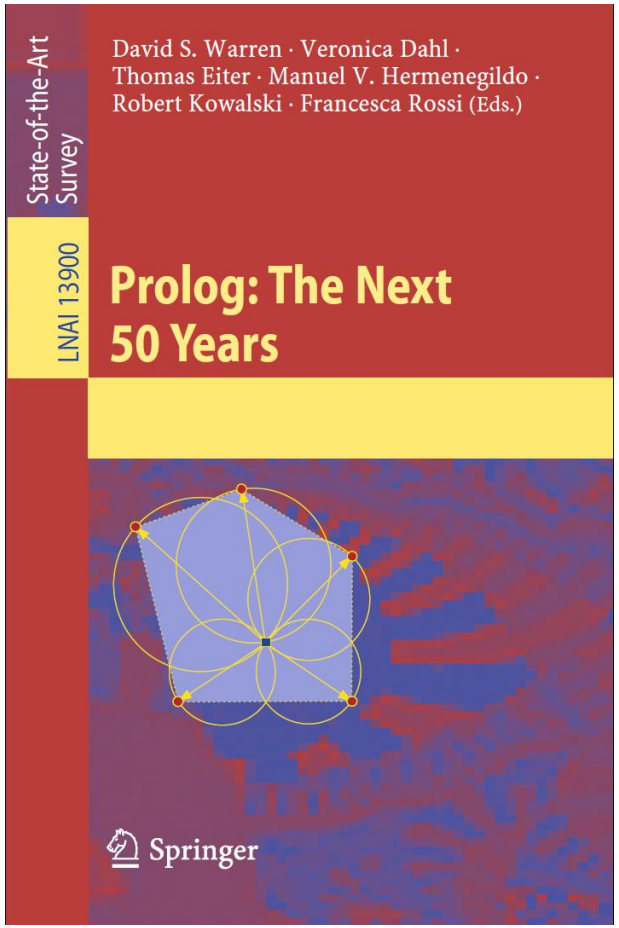
Python
Haskell

Java

History of Prolog

50 Years of Prolog

- In 2022, Prolog celebrated 50 years



- Several initiatives took place
  - Prolog Day Symposium
  - Alain Colmerauer Prize
  - Prolog: The Next 50 Years
  - Fifty Years of Prolog and Beyond
  - Prolog Education

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*Fifty Years of Prolog and Beyond**

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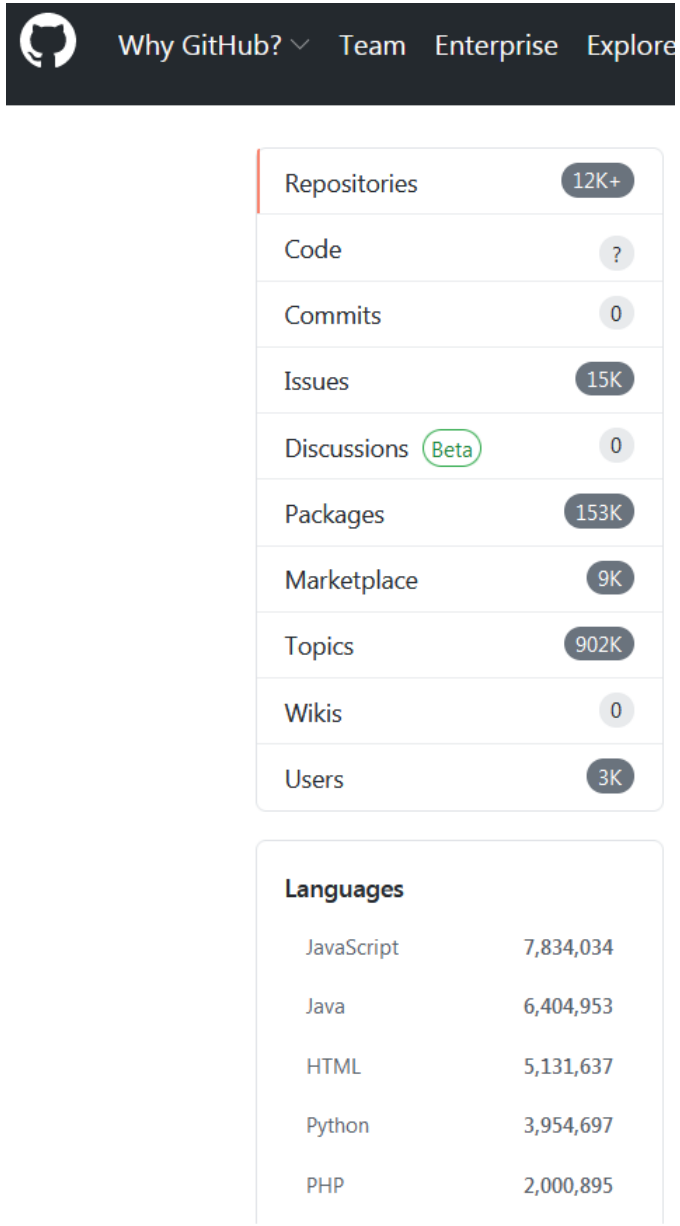
Abstract

Both logic programming in general and Prolog in particular have a long and fascinating history, intermingled with that of many disciplines they inherited from or catalyzed. A large body of research has been gathered over the last 50 years, supported by many Prolog implementations. Many implementations are still actively developed, while new ones keep appearing. Often, the



Applications

- Prolog is not the most widely-used or popular programming language in the world, but...
- Used in several projects and areas:
  - NASA Clarissa
  - IBM Watson
  - First Erlang interpreter
  - New Zealand's main stock broking system
  - ...

See https://www.quora.com/What-is-Prolog-used-for-today

Applications

- For many years, Prolog was one of the foremost languages used in Artificial Intelligence, especially in some noticeable application areas, such as:
  - Natural Language Processing
  - Expert Systems
  - Knowledge-Based Systems
  - Business Rules and Workflow
  - Computational Law
  - Planning and Scheduling
  - ...

Extensions

- There are several extensions to Logic Programming, such as
  - Abductive Logic Programming (ALP)
  - Inductive Logic Programming (ILP)
  - Concurrent Logic Programming
  - Constraint (Logic) Programming

"Constraint programming represents one of the closest approaches computer science has yet made to the Holy Grail of programming: the user states the problem, the computer solves it."

Eugene Freuder, 1997
('In Pursuit of the Holy Grail', Constraints: An International Journal, 2, 57-61)

Additional Readings & Resources

- Origins of Prolog
  - Robert A. Kowalski (1988). The Early Years of Logic Programming. Communications of the ACM, 31(1), pp. 38-43 (DOI: 10.1145/35043.35046)
  - Alain Colmerauer and Philippe Roussel (1996). The Birth of Prolog. In History of Programming Languages, pp. 331-367 (DOI: 10.1145/234286.1057820)
- ALP – The Association for Logic Programming
- ICLP - International Conference on Logic Programming
  - 2024 edition: https://www.iclp24.utdallas.edu/
- TPLP - Theory and Practice of Logic Programming. Cambridge University Press (http://journals.cambridge.org/tlp)

Additional Readings & Resources

- Prolog Applications
  - Fumio Mizoguchi (1991). Prolog and its Applications: A Japanese Perspective. Springer (ISBN: 978-0-412-37770-9)
  - Alex M. Andrew (2005). The commercial use of PROLOG. Kybernetes, 34(5), pp. 599-601 (DOI: 10.1108/03684920510595300)
  - Manny Rayner, Beth Ann Hockey, Jean-Michel Renders, Nikos Chatzichrisafis and Kim Farrell (2005). Spoken Language Processing in the Clarissa Procedure Browser. Natural Language Engineering 1(1), 28 pages (ICSI Technical Report TR-05-005)
  - Joseph Armstrong (2003). Making reliable distributed systems in the presence of software errors. PhD thesis. Royal Institute of Technology, Stockholm, Sweden.
  - Alessandro Dal Palù and Paolo Torroni (2010). 25 Years of Applications of Logic Programming in Italy. A 25-Year Perspective on Logic Programming, pp. 300-328
  - Awesome Prolog – Curated list of Prolog resources (by Klaudio Sinani)

Q & A