CAP 379
Artificial Intelligence
Lab

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Lab 01
Prolog Fundamentals
Propositional Calculus

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What is Prolog?

- **Definition**:
  - Prolog stands for "Programming in Logic."
  - It is a logic programming language based on formal logic.
- **Features**:
  - Declarative paradigm.
  - Designed for symbolic computation and reasoning.
- **Use Cases**:
  - Artificial Intelligence.
  - Knowledge-based systems.
  - Natural Language Processing.

Prolog's Unique Approach

- **How Prolog Differs**:
  - **Imperative Languages** (e.g., Python, C): Focus on *how* to do tasks.
  - **Prolog**: Focuses on *what* is true or logically consistent.
- **Components**:
  - **Facts**: Represent truths.
  - **Rules**: Define relationships and infer new truths.
  - **Queries**: Ask questions about the facts and rules.

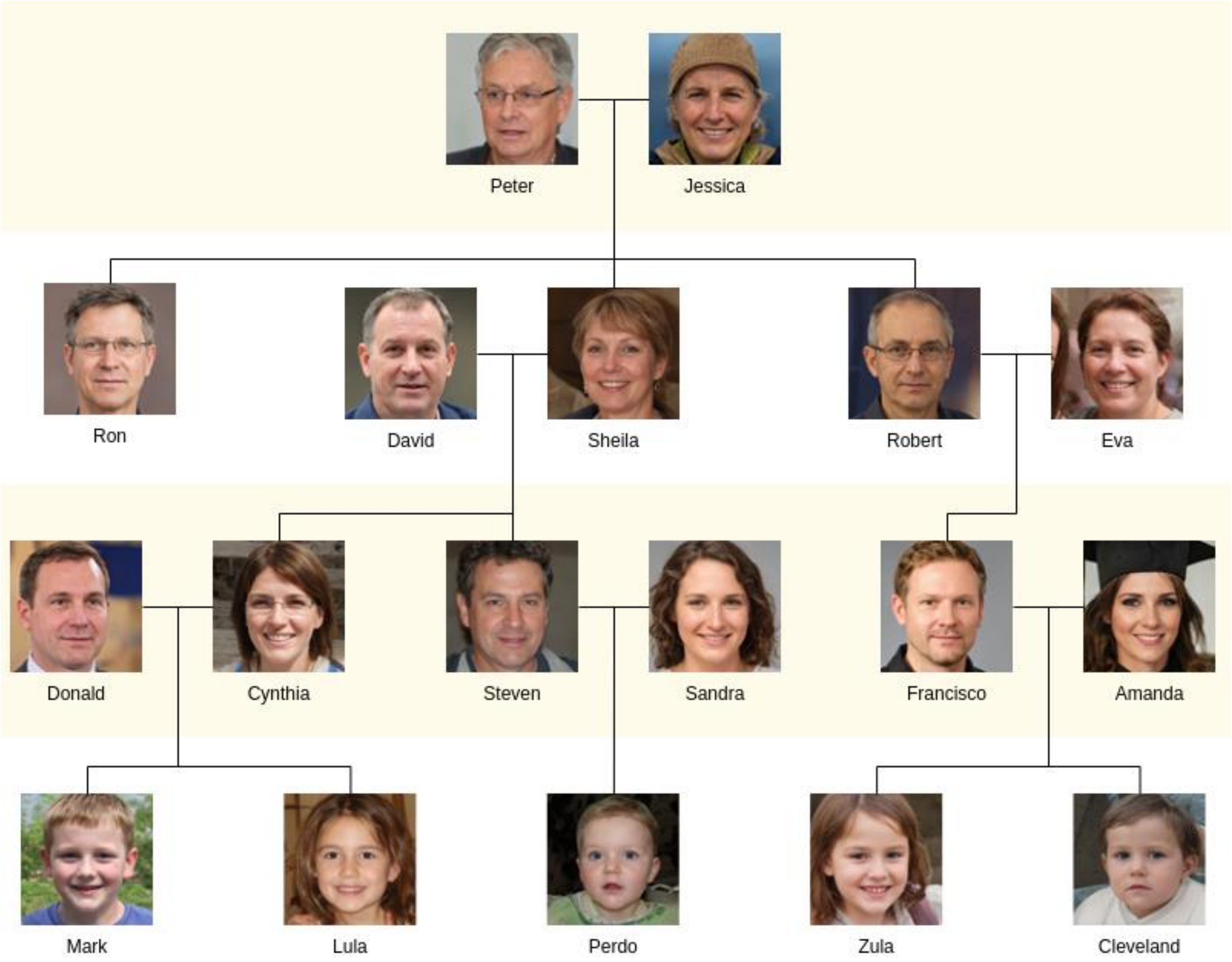
Applications of Prolog

- **AI and Expert Systems**:
  - Building knowledge bases.
  - Implementing reasoning engines.
- **Natural Language Processing**:
  - Syntax analysis.
  - Semantic understanding.
- **Problem Solving**:
  - Solving puzzles, games, and logical problems.
- **Database Systems**:
  - Querying structured information using logic.

Setting Up Prolog

- **Environment Setup**:
  - Recommended Software: SWI-Prolog, GNU Prolog.
- Installation:
  - Download from the official website.
  - Follow the installation instructions.
- **Prolog Console**:
  - `?-` indicates the Prolog prompt.

Propositional Calculus: Family Tree Example in Prolog



Propositional Calculus

- Proposition
  - It is Raining
  - 2+2=6
- Propositional Symbols: P, Q, R, S, ...
- Truth Symbols: true, false

Logical Connectives

- **Negation** (¬): The negation of a proposition P is denoted as ¬P, meaning "not P".
  - Example: ¬P (if P is true, ¬P is false).
- **Conjunction** (∧): Represents "and". P∧Q is true if both P and Q are true.
  - Example: P∧Q (both P and Q must be true).
- **Disjunction** (∨): Represents "or". P∨Q is true if at least one of P or Q is true.
  - Example: P∨Q (either P or Q or both are true).
- **Implication** (→): Represents "if... then...". P→Q is false only when P is true and Q is false.
  - Example: "If it rains, then the ground will be wet" (P→Q).
- **Biconditional** (↔): Represents "if and only if". P↔Q is true when both P and Q are either both true or both false.
  - Example: "You will get an A if and only if you study" (P↔Q).

Propositional Calculus Sentences

- Every propositional and truth symbol is a sentence.
- Negation ($\neg P$), conjunction ($P \wedge Q$), disjunction ($P \vee Q$), implication ($P \rightarrow Q$), and equivalence ($P \vee Q \equiv R$) are all valid sentences.
- Sentences are also called well-formed formulas (WFFs).
- Examples of components:
  - $P \wedge Q$: Conjuncts are P and Q.
  - $P \rightarrow Q$: Premise is P, conclusion is Q.
- Parentheses and brackets control the order of evaluation (e.g., $(P \vee Q) \equiv R$ vs $P \vee (Q \equiv R)$).

Truth Assignment Rules

- **Negation (¬P)**: True if P is false, false if P is true.
- **Conjunction (P ∧ Q)**: True if both P and Q are true; otherwise, false.
- **Disjunction (P ∨ Q)**: False only when both P and Q are false; otherwise, true.
- **Implication (P → Q)**: False only when P is true and Q is false; otherwise, true.
- **Equivalence (P ≡ Q)**: True if both expressions have the same truth value in all interpretations.

Logical Identities

- **Examples of Logical Identities**:
  - $\neg(\neg P) \equiv P$ (Double negation)
  - $P \rightarrow Q \equiv \neg P \vee Q$ (implication is equivalent to "not P or Q").
  - $P \rightarrow Q \equiv \neg Q \rightarrow \neg P$ (contrapositive law)
  - $(\neg P \rightarrow Q) \equiv (P \vee Q)$ (Contrapositive law)
  - de Morgan's Laws: $\neg (P \vee Q) \equiv (\neg P \wedge \neg Q)$, $\neg (P \wedge Q) \equiv (\neg P \vee \neg Q)$
  - Commutative: $(P \wedge Q) \equiv (Q \wedge P)$
  - Associative: $((P \wedge Q) \wedge R) \equiv (P \wedge (Q \wedge R))$
  - Distributive: $P \vee (Q \wedge R) \equiv (P \vee Q) \wedge (P \vee R)$

Focuses on *what* is true or logically consistent.

Consistency: A set of propositions is **consistent** if there is at least one interpretation where all the propositions are true

Rules

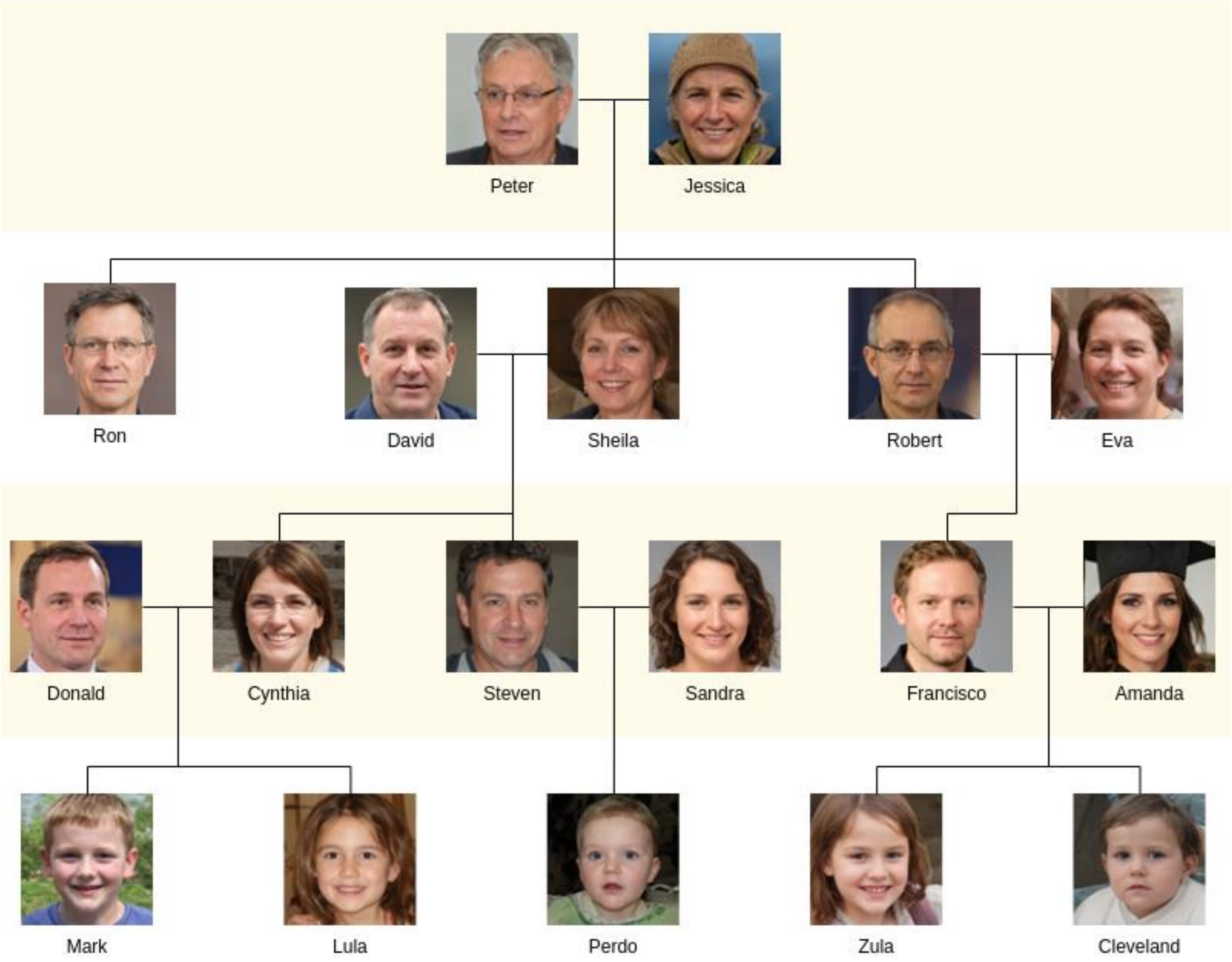
- **Rules of Inference**: Including rules like
  - **Modus Ponens:** From $P \rightarrow Q$ and P, infer Q (if $P \rightarrow Q$ and P then Q) and
  - **Modus Tollens:** $P \rightarrow Q$ and $\neg Q$, infer $\neg P$. (if $P \rightarrow Q$ and $\neg Q$ then $\neg P$).
  - **Disjunctive Syllogism**: From $P \vee Q$ and $\neg P$, infer Q.
  - **Hypothetical Syllogism**: From $P \rightarrow Q$ and $Q \rightarrow R$, infer $P \rightarrow R$.

Validity of Arguments

- An **argument** in propositional logic consists of premises and a conclusion.
- The argument is **valid** if, whenever all the premises are true, the conclusion must be true.

Back to Example

Filename: family-tree_propositional_logic.pl



Propositional Logic Steps

- **Step 1: Define Facts**
  - Use atomic propositions to represent parent-child relationships.
  - Explicitly enumerate all relationships (e.g., parent, sibling, grandparent, cousin).

Propositional Logic Steps

- **Step 2: Encode Relationships**
- **Parent-Child Relationships**: Each parent-child relationship is defined as a separate proposition:
  - `parent_peter_ron`, `parent_peter_david`, `parent_peter_sheila`, etc.
- **Sibling Relationships**:
  - Siblings are defined explicitly for all pairs:
    - `sibling_ron_david`, `sibling_ron_sheila`, etc.
- **Grandparent Relationships**:
  - Grandparents are defined explicitly by extending parent-child facts:
    - `grandparent_peter_mark`, `grandparent_jessica_lula`.
- **Cousins**:
  - Cousins are defined explicitly for all valid pairs:
    - `cousin_mark_lula`, `cousin_zula_cleveland`.

Propositional Logic Steps

- **Step 3: Query Relationships**
  - To find relationships, query explicitly defined propositions.

Step 1: Facts

- Parent-Child Relationships
  - parent_peter_ron.
  - parent_steven_perdo

Step 2: Define Rules

- Derived Relationships
  - Sibling Relationships
    - sibling_ron_david.
  - Grandparent Relationships
    - grandparent_jessica_mark.
  - Cousin Relationships
    - cousin_mark_lula.
    - cousin_mark_perdo.

Step 3: Queries

- Who are Peter’s children?
    - parent_peter_X.
- Are Mark and Lula cousins?
    - cousin_mark_lula.
- Who are Peter’s grandchildren?
    - grandparent_peter_X.

Limitations of Propositional Logic

- **Redundancy**:
  - Every relationship must be explicitly defined (e.g., all sibling and cousin relationships).
- **Scalability**:
  - Adding a new member to the family tree requires updating multiple facts and derived relationships.
- **Lack of Generalization**:
  - Cannot infer relationships dynamically (e.g., "Who are all of Peter's descendants?").
- **Relational Complexity**:
  - Cannot handle indirect or recursive relationships easily.