Hybrid Intelligent Systems

Lecture 3

Logical approach to AI

Two approaches to AI

- Symbolic or Logical approach or sometimes simple AI
- Subsymbolic approach or computational intelligence

Logical approach

- Based on representation of knowledge or algorithms to solve of tasks as
  - sequence of steps for achievement of goal or
  - proof of statement
- Basically usage of symbolic information
- Most popular approach in beginning of AI (50-70th years)

First-Order Logic

- Propositional logic only deals with "facts", statements that may or may not be true of the world, e.g., "It is raining". But, one cannot have variables that stand for books or tables.
- In first-order logic, variables refer to things in the world and, furthermore, you can quantify over them: talk about all of them or some of them without having to name them explicitly.

What is a logic?

- A formal language
  - Syntax – what expressions are legal
  - Semantics – what legal expressions mean
  - Proof system – a way of manipulating syntactic expressions to get other syntactic expressions (which will tell us something new)
- Why proofs? Two kinds of inferences an agent might want to make:
  - Multiple percepts => conclusions about the world
  - Current state & operator => properties of next state

1-order logic (syntax)

Formal theory:

S=<B,F,A,R>,

where: B – alphabet,
F – formulas-facts;
A – formulas-axioms,
R – rules of inference.

1-order logic (syntax)

$F(x_1, x_2 \ \dots \ x_n)$ predicate (logical function),

x_i – variable of area,

n – arity of predicate.

$f(x_1, x_2 \ \dots \ x_m)$ – function determined on area for x_i, it may be argument of predicate as variable

1-order logic (syntax)

Formula consists of predicates, logical connective &, V, ¬, generality quantifier $\forall$ and existential quantifier $\exists$

And also implication: $F_1(x_1) \to F_2(x_2)$

From $F_1(x_1)$=*true* follow $F_2(x_2)$=*true*.

$\exists$

1-order logic (semantics)

$(\forall x)(F(x))$ For all value of *x* *F(x)* is *true*

$(\exists x)(F(x))$ Exist at least one value of *x* for which *F(x)* is *true*

Interpretation of 1-logic for knowledge representation (semantics)

- F(x) – property of object x;
- High(tower), green(tree), good(student)

- F(x,y) – relation between objects x and y
- Mother(Maria,John), study(John,"Kyung Hee")
- Under(cloude,earth), hot(weather,Korea)

Conjunction Normal Form (CNF)

- Formulas of 1-order logic are transformed to set of clauses (CNF)
- Without generality quantifiers (its have in mind)
- Without existential quantifiers (its are replaced by set of predicates-facts with concrete constants as arguments)
- Clauses not include conjunctions &

For CNF algorithms of proof exist.
First of them was “resolution” of Robinson

Logic of Horn is basis of logic programming and Prolog

Horn Clauses

- A clause is Horn if it has at most one positive literal
  - $\neg P_1 \vee \ldots \vee \neg P_n \vee Q$ (Rule)
  - Q (Fact)
  - $\neg P_1 \vee \ldots \vee \neg P_n$ (Consistency Constraint)
- We will not deal with Consistency Constraints
- Rule Notation
  - $P_1 \wedge \ldots \wedge P_n \rightarrow Q$ (Logic)
  - If $P_1 \ldots P_n$ Then Q (Rule-Based System)
  - Q :- $P_1, \ldots, P_n$ (Prolog)
- P_i are called antecedents (or body)
- Q is called the consequent (or head)

Example of program in Prolog (part)

```
/* description of objects */
      cube("Cube_1", 10).
      cylinder("Cyl_1", 10, 20).
/* description of location    */
      object("cube_1", "table").
      object("Cyl_1", "box").
/*  description of any actions (commands)  */
take(_):-      in_arm(_),   /*  checking of free of arm  */
      write("arm is not free")),
      nl,
      !.
take(X):- object(X,Y), /*recognition of location of X*/
      turn_to(Y),
      select_object(X,Coord_X,Coord_Y),
      position(Coord_X,Coord_Y),
      get,     /* set of arm  */
assert(in_arm(X)).  /*save what is in arm*/
```

```
put(X,Y):- in_arm(Z), /* recognition what is in arm*/
      Z<>X,
      write("arm is not free"),
      nl,
      !.
put(X,Y):- in_arm(X),
      turn_to(Y),
      center(Y, Coord_X,Coord_Y),
      position(Coord_X,Coord_Y),
      off,
      retract(in_arm(X)),
      !.
put(X,Y):- not(in_arm(_)),
      object(X,Y),
      write("Object "),
      write(X),
      write(" is already in "),
      write(Y),
      nl,
      !.
put(X,Y):- not(in_arm(_)),
      take(X),
      put(X,Y).
```

Disadvantages of 1-order logic for knowledge representation

- Monotonic reasoning
- Impossibility of using of uncertainty.
- Impossible of using of predicates as arguments of other predicates
- not enough powerful devices of description of structures

Another paradigms in logical approach based on logic

- Modal logics — different modalities (quantifiers)
- Fuzzy logic — measure of truth
- Description logic — concepts (atomic, complex), roles (relations); orientation on semantic networks and frames
- Rules — empiric rules of interpretation of rules
- Markov logic — + probabilistic (hybrid approach)

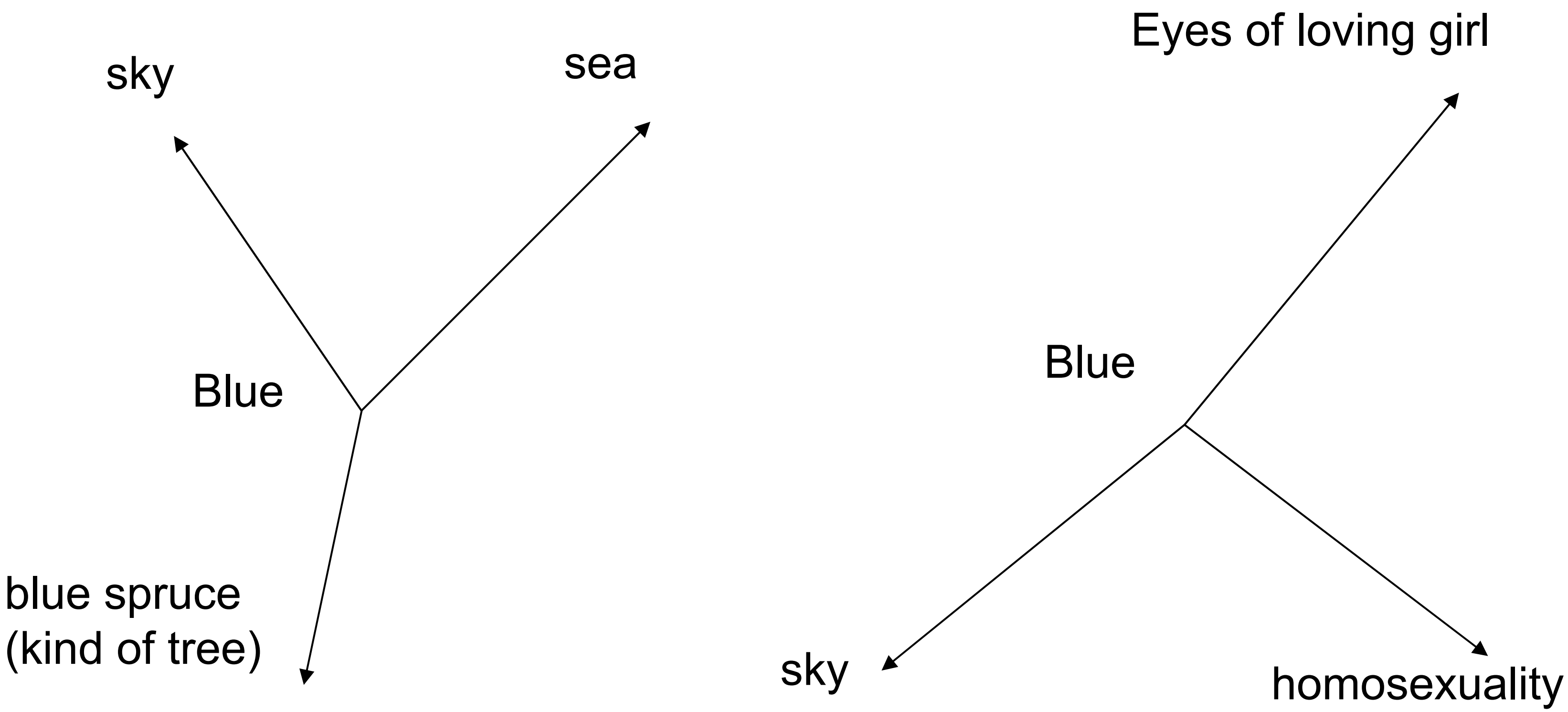
Reasons of necessary of uncertainty in AI

- Objective (features of whole environment)
  - Uncertainty of our world and limited capabilities of our senses
- Subjective (features of interaction with concrete environment)
  - Different experience of different persons and peoples, in particular, it maps on features of semantics of different languages

Single absolute truth is exist:

Absolute truths are not exist

Different representations of concepts by different persons



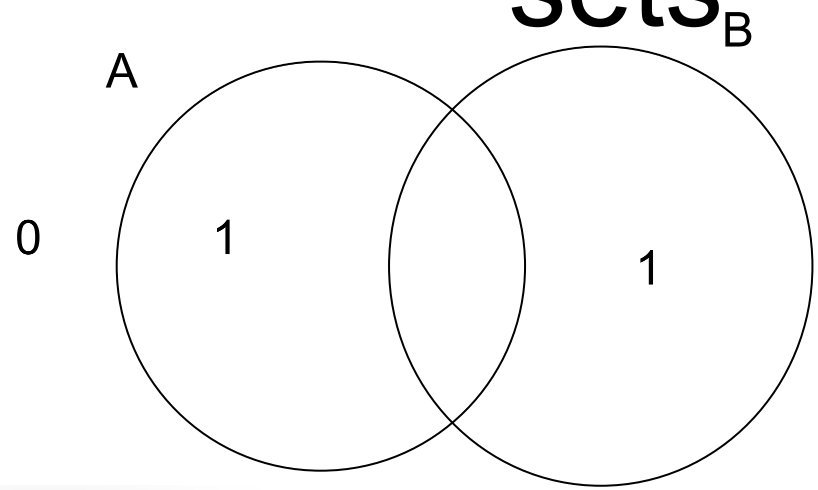
Different representations of concepts in different languages

- Blue
  - Pale blue one word in Russian
  - Dark blue one another word in Russian
- Pigmy has many single words for description of forest:
- Forest under rain
- Forest after rain
- Forest in hot season
- Forest in morning
- Forest in evening
- and so on

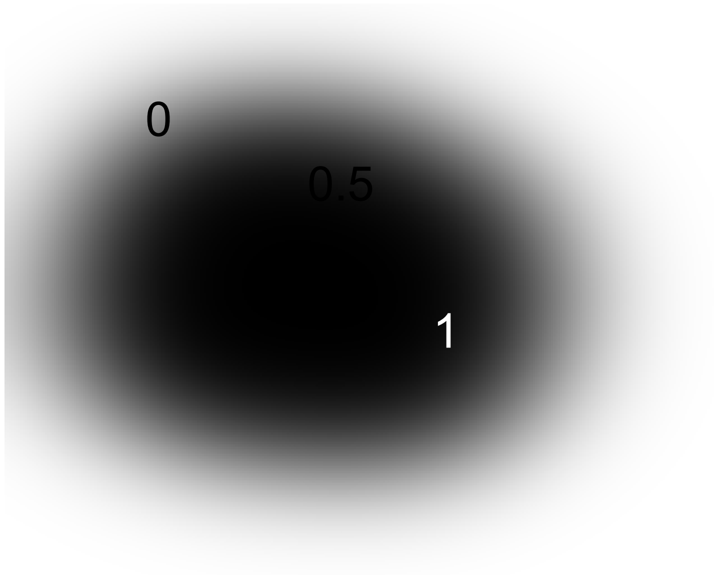
Fuzzy logic

- Based on concept “fuzzy set” of L. Zadeh
- In classical set theory any Jones may member of any set or not, but not at once
- In Fuzzy Set Theory Jones at once may be member of any set and no with any confidence
- Examples of sets: “young people”, “good people”, “high people” and so on

Fuzzy logic is based on fuzzy sets



In classical set theory
any element can to be
member of set or not.
Is(a, A) = 1 or 0, true or false



In fuzzy set theory
any element can to be
member of set with any uncertainty
or confidence
Is(a,A) = 0 or 1 or 0.5 or 0.126 or …
from interval (0,1)

This uncertainty is determined by

membership function $0 \le \mu_A(a) \le 1$

Main logical operations in fuzzy logic

- Conjunction - $\mu A\&B(x) = min(\mu A(x), \mu B(y))$
- Disjunction - $\mu A \wedge B(x) = max(\mu A(x), \mu B(y))$
- Negation – $\mu \neg A(x) = 1 - \mu A(x)$

Linguistic variable
Definition of linguistic variable

When we consider a variable, in general, it takes numbers as its value. If the variable takes linguistic terms, it is called “linguistic variable”.

Definition(Linguistic variable) The linguistic variable is defined by the following quintuple.

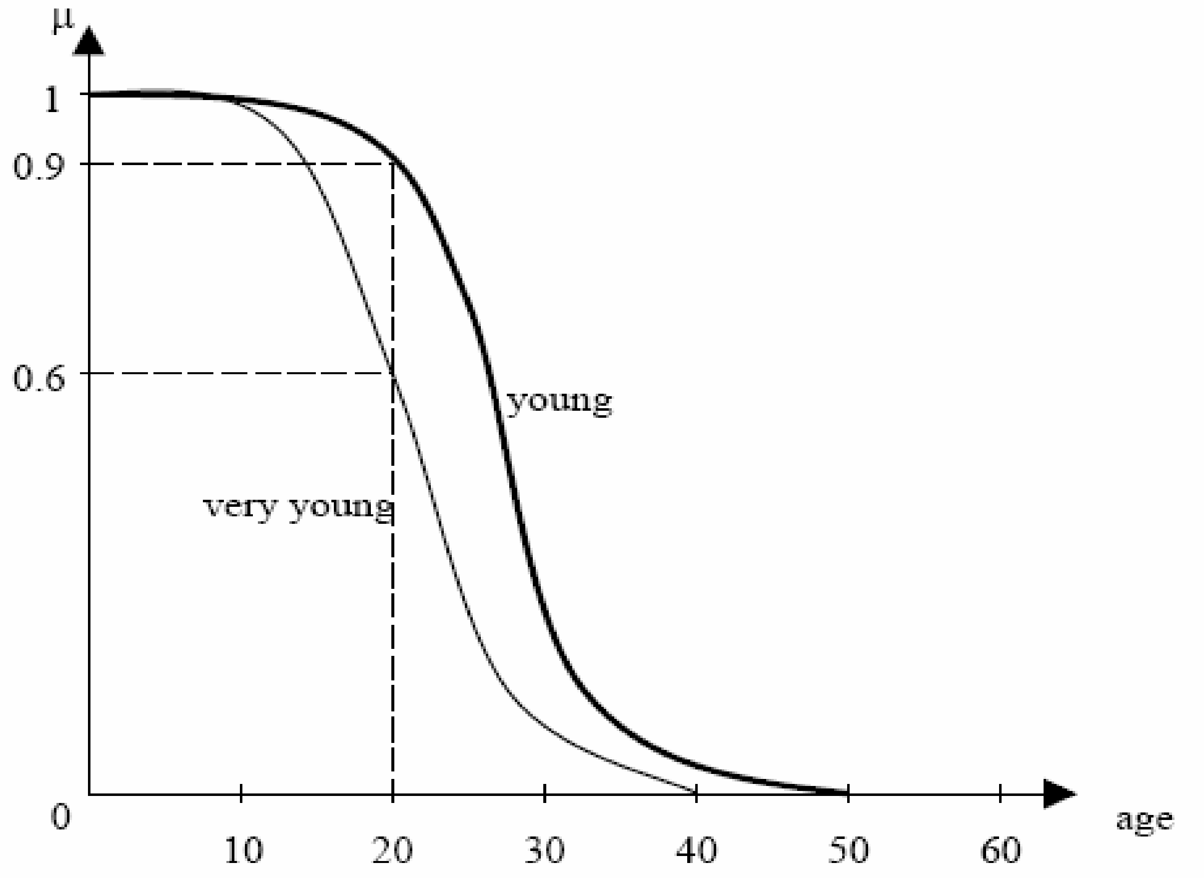
Linguistic variable = (*x*, T(*x*), U, G, M) *x*:

- x - name of variable
- T(*x*): set of linguistic terms which can be a value of the variable
- U: set of universe of discourse which defines the characteristics of the Variable
- G: syntactic grammar which produces terms in T(*x*)
- M: semantic rules which map terms in T(*x*) to fuzzy sets in U

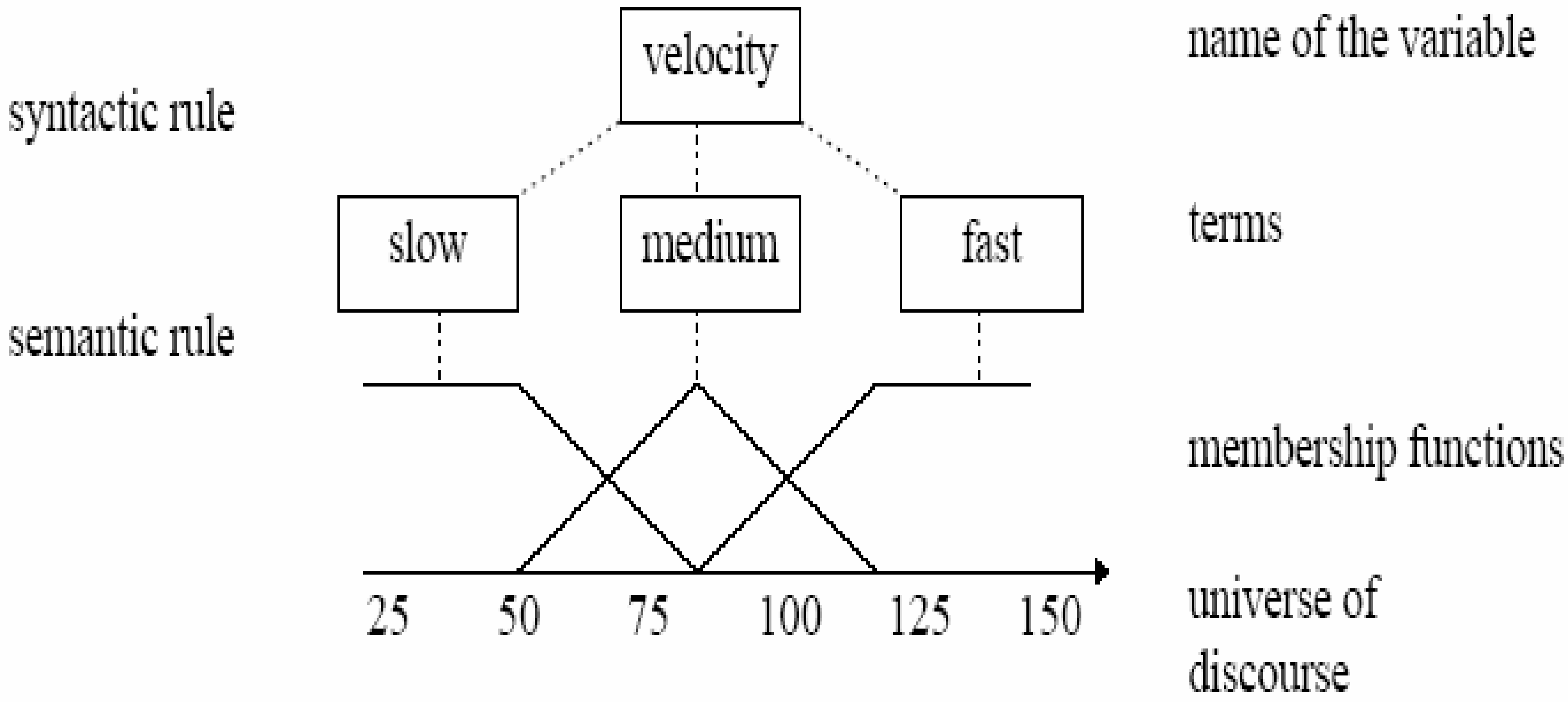
Example of linguistic variable

P = "20 is young."

Assume the terms "young" and "very young" are defined as shown in Fig



Example of linguistic variable



During inference it is needed to execute two operations:

1. Fuzzification
   Transformation from number to symbol value of linguistic variable and corresponding value of membership function
2. Defuzzification
   Transformation from symbol value to number

Features of fuzzy logic

- In fuzzy logic, exact reasoning is viewed as a limiting case of approximate reasoning
- In fuzzy logic, everything is a matter of degree
- In fuzzy logic, knowledge is interpreted a collection of elastic or, equivalently, fuzzy constraint on a collection of variables
- Inference is viewed as a process of propagation of elastic constraints
- Any logical system can be fuzzified

Examples of tasks solving by fuzzy models

- Control of clothes washer
- Making of decision in diagnostic systems (expert systems in medicine, for example)
- Making of decision in business planning
- May be used knowledge such as:
  - If *temperature* is *high* then *diagnose* is *grippe* with confidence 80%
  - If *speed* is *slow* then *increase transfer of fuel*

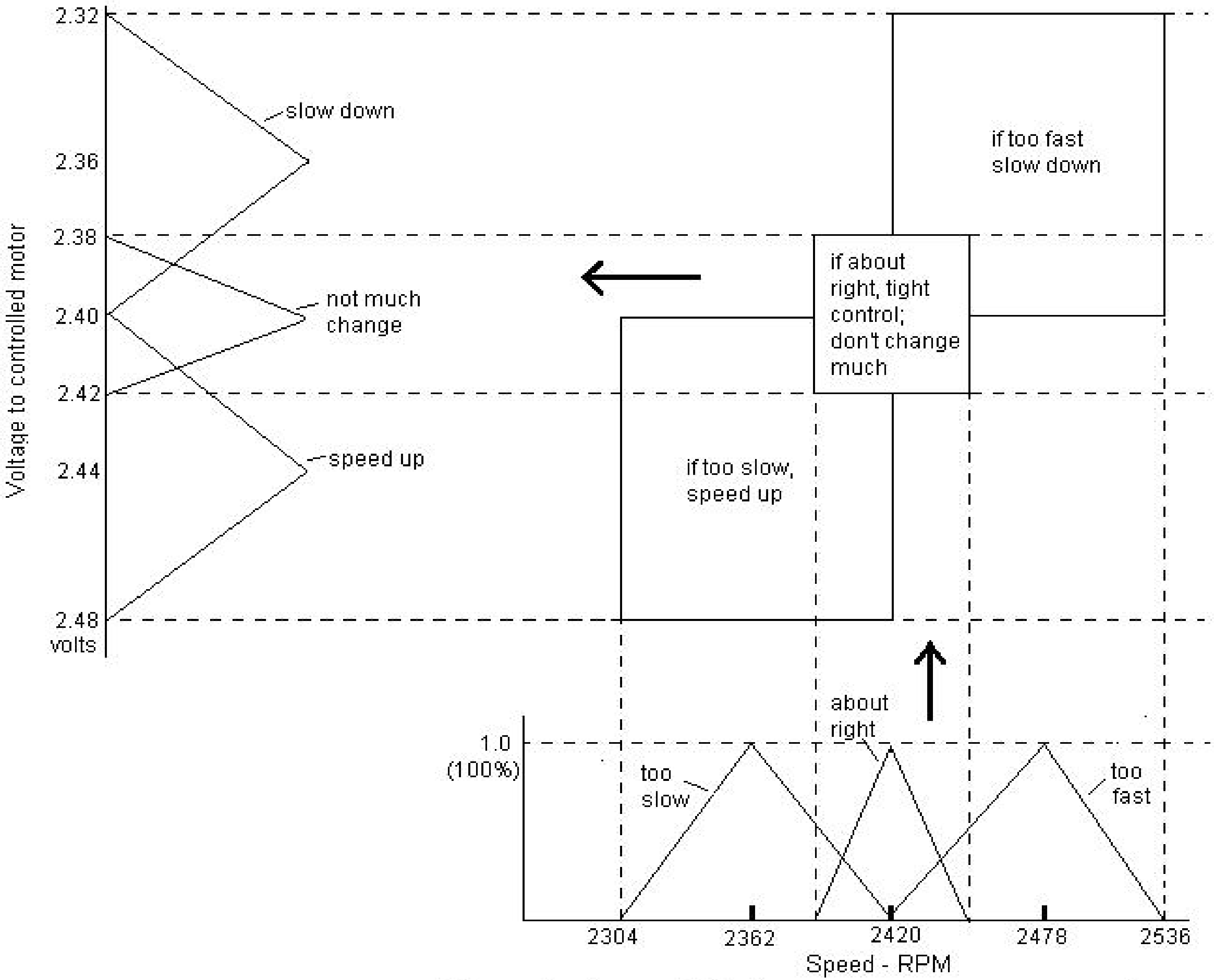
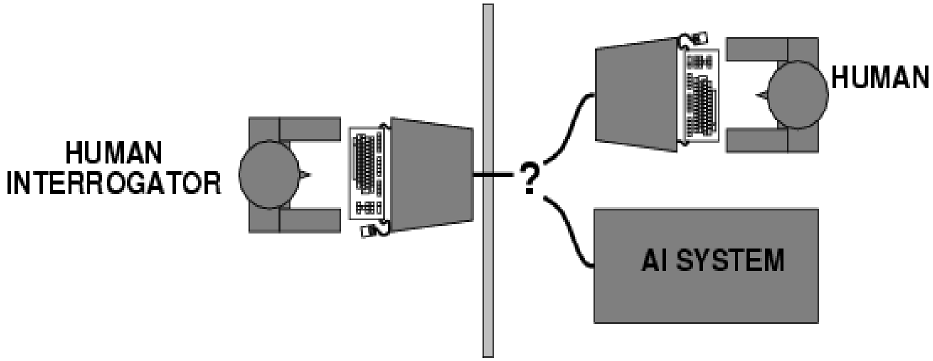


Figure 4 Cause-Effect

Acting humanly: Turing Test

- Turing (1950) "Computing machinery and intelligence":
- "Can machines think?" → "Can machines behave intelligently?"
- Operational test for intelligent behavior: the Imitation Game



- Anticipated all major arguments against AI in following 50 years
- Suggested major components of AI: knowledge, reasoning, language understanding, learning