Engineering of Mind

An Introduction to the Science of Intelligent Systems

John Wiley & Sons, 2001

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Outline

What is Mind?
Could it be engineered?
What if it could?
What is Mind?

- Imagination
- Thought
- Reason
- Emotion
- Feeling
- Perception
- Knowledge
- Communication
- Intelligence
- Intuition
- Awareness
- Consciousness

Mind is a set of processes that run in the Brain

Mind is what the brain does
All Processes of Mind have Computational Equivalents

Imagination = visualization, modeling, & simulation
Thought = analysis of what is imagined
Reason = logic applied to thinking
Emotion = value judgment, evaluation of good and bad
Feeling = experience of sensory input
Perception = transformation of sensation into knowledge
Knowledge = organized information
Communication = transfer of knowledge
Intelligence = ability to acquire and use knowledge
Intuition = built in knowledge
Awareness = knowledge of the world situation
Consciousness = include self in world model
Can Mind Be Engineered?

Technologies are understood in principle

- sensing, perception, representation, decision, control,
- system architecture for integration

Progress is rapid

- brain research, cognitive science, computer science,
- AI and robotics, signal processing, image understanding,
- decision theory, modeling & simulation, control theory,
- computational power
The Basic Structure

Perception establishes correspondence between internal world model and external real world

Behavior uses the world model to generate action to achieve goals
First Level of Detail

Technologies are understood in principle

- SENSORY PROCESSING: Classification, Estimation, Computation, Grouping, Windowing
- WORLD MODELING: Value Judgment, Knowledge, Maps, Entities, Images, Events
- BEHAVIOR GENERATION: Task Knowledge, Planners, Executors

Goal

Sensors ↔ World ↔ Actuators

internal external
A Reference Model
Architecture for Unmanned Vehicles

Battalion Formation
Platoon Formation
Section Formation
Objects of attention

Surfaces
Lines
Points

Attention
Communication
Mission Package
Locomotion

SUBSYSTEM
5 second plans
Subtask on object surface
Obstacle-free paths

PRIMITIVE
0.5 second plans
Steering, velocity

SERVO
0.05 second plans
Actuator output

OPERATOR INTERFACE

SURROGATE BATTALION
Plans for next 24 hours

SURROGATE PLATOON
Plans for next 2 hours

SURROGATE SECTION
Plans for next 10 minutes
Tasks relative to nearby objects

VEHICLE
Plans for next 50 seconds
Task to be done on objects of attention

SENSORS AND ACTUATORS

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New Perception of What is Possible

Autonomous ground vehicles with human level performance are achievable within two decades

Useable autonomous driving could be deployed by:
  2008 for convoy, leader-follower, mule
  2010 for smoke, point-man, indirect fires, scout

Human level performance could be achieved by:
  2012 for driving (on-road and off-road)
  2015 for tactical behaviors

Performance superior to humans by 2025
Why now? Why not before?

Not for lack of trying
Or for lack of hype

But for lack of:
• computing power
• knowledge about intelligent systems
• systems engineering methodology
Why now?

Computational power will soon be available

Computing power of human brain \( \sim 10^{13} \) - \( 10^{16} \) ops

Today’s supercomputer \( \sim 10^{13} \) ops

A single $1000$ PC will have

\[ \begin{align*}
10^{10} \text{ ops by 2005} & \quad 10^{11} \text{ by 2010} & \quad 10^{12} \text{ by 2015} \\
10^{13} \text{ ops by 2020} & \quad 10^{14} \text{ by 2025} & \quad 10^{15} \text{ by 2030}
\end{align*} \]
Why now?

We now know how to deal with complexity
  Hierarchical decomposition in time and space
  Multi-resolitional representations
  Multiple representations
    Iconic: Signals, Images, Maps
    Symbolic: Entities, Events
    Relationships: Pointers, Classes
  4D/RCS architecture validated by Demo III

We now know how to acquire and use knowledge
  Model-based perception
  Model-based behavior

We now know how to formalize decision making
  Value-driven decision theory
A Critical Point in History

• A Scientific Theory of Intelligence is emerging neurosciences, computer sciences mathematics, signal processing modeling, simulation, control theory artificial intelligence, robotics

• Engineering of Mind will soon be feasible theory & computing power are near money from military and industry is flowing
A Critical Point in History

What remains to be done . . .

A major engineering effort in sensors, perception, world modeling, and behavior generation

Will be done!

Economics of productivity growth will drive the technology in:

- manufacturing, construction, transportation,
- e-commerce, communications, entertainment,
- health care, environmental preservation,
- military systems, computer development
What If We Do Engineer Mind?

What would be the impact on:

Science?
Economic Prosperity?
Military Power?
Human Well Being?
Impact on Science

• The mind is a product of the brain which is arguably the most complex structure in the universe
  more complex than the atom
  more complex than the genome
  more complex than the galaxies

• Mind is what separates humans from other species
  not physics or chemistry
  not biology or physiology

• Mind is the essence of who we are
Impact on Economic Prosperity

Agriculture age – Muscle power
Industrial age – Machine power
Computer age – Brain power

Output = Productivity x Input
Manufacturing, Communications, Transportation, Commerce
Construction, Utilities, Education, Mining, Drilling
Medical care, Elder care, Agriculture, Entertainment
Impact on Military Strength

Intelligent weapons systems will:
- outperform manned systems
- cost less to train
- cost less to maintain readiness
- keep soldiers out of harm’s way

Intelligent weapons will revolutionize warfare
Impact on Human Well Being

Intelligent systems will create wealth to:
- pay for health care
- pay for education
- pay for housing, transportation, food
- pay for social security
- pay for clean environment
- eliminate poverty
What are the Risks?

- Mass unemployment
  - loss of income
  - idleness & boredom

- Loss of control over destiny

- Overpowered by superior intelligence
Analysis of the Risks

- Mass unemployment?
  historical evidence is negative
- Loss of income?
  productivity creates wealth, jobs, & ownership
- Idleness & boredom?
  the rich are seldom idle or bored
- Loss of control over destiny?
  freedom to pursue interests
- Overpowered by superior intelligence?
  might bring world peace and economic justice
Summary and Conclusions

• Engineering of Mind is feasible
• Truly intelligent systems are imminent
• The impact will be immense