

Engineering of Mind

An Introduction to the Science of Intelligent Systems

John Wiley & Sons, 2001

James S. Albus

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?

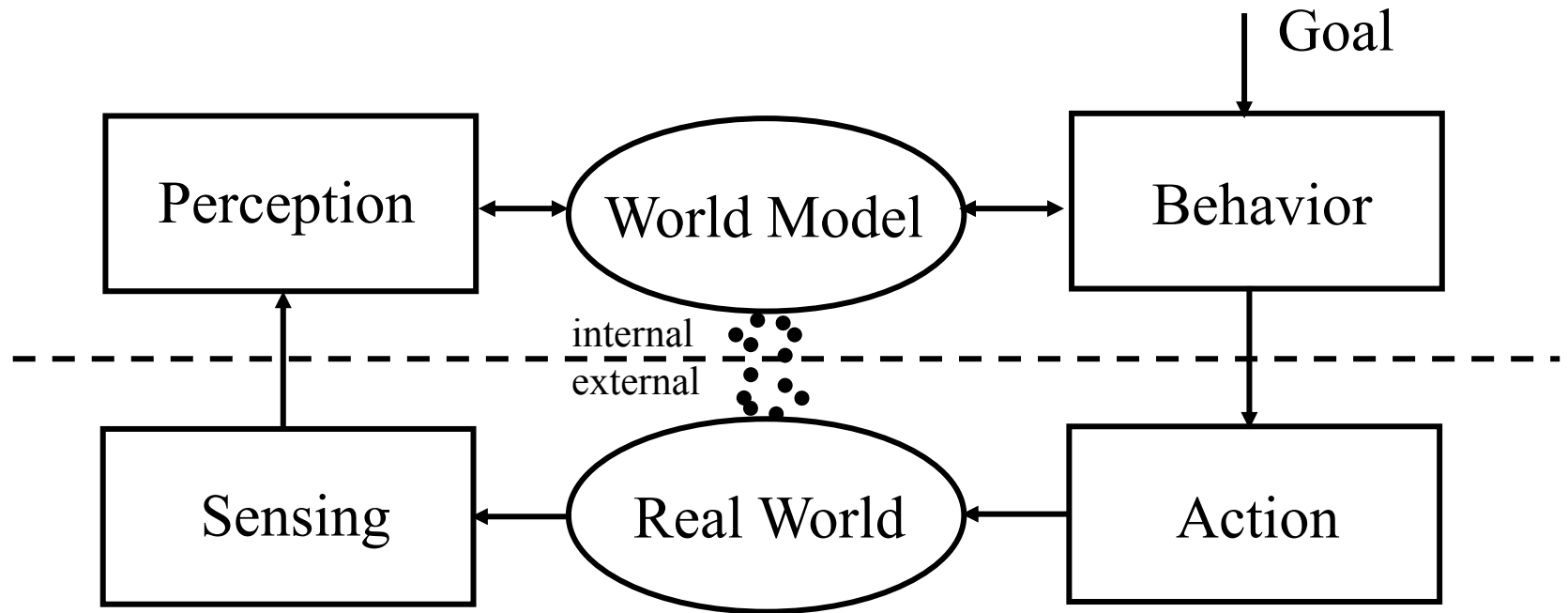
Technologies are understood in principle

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

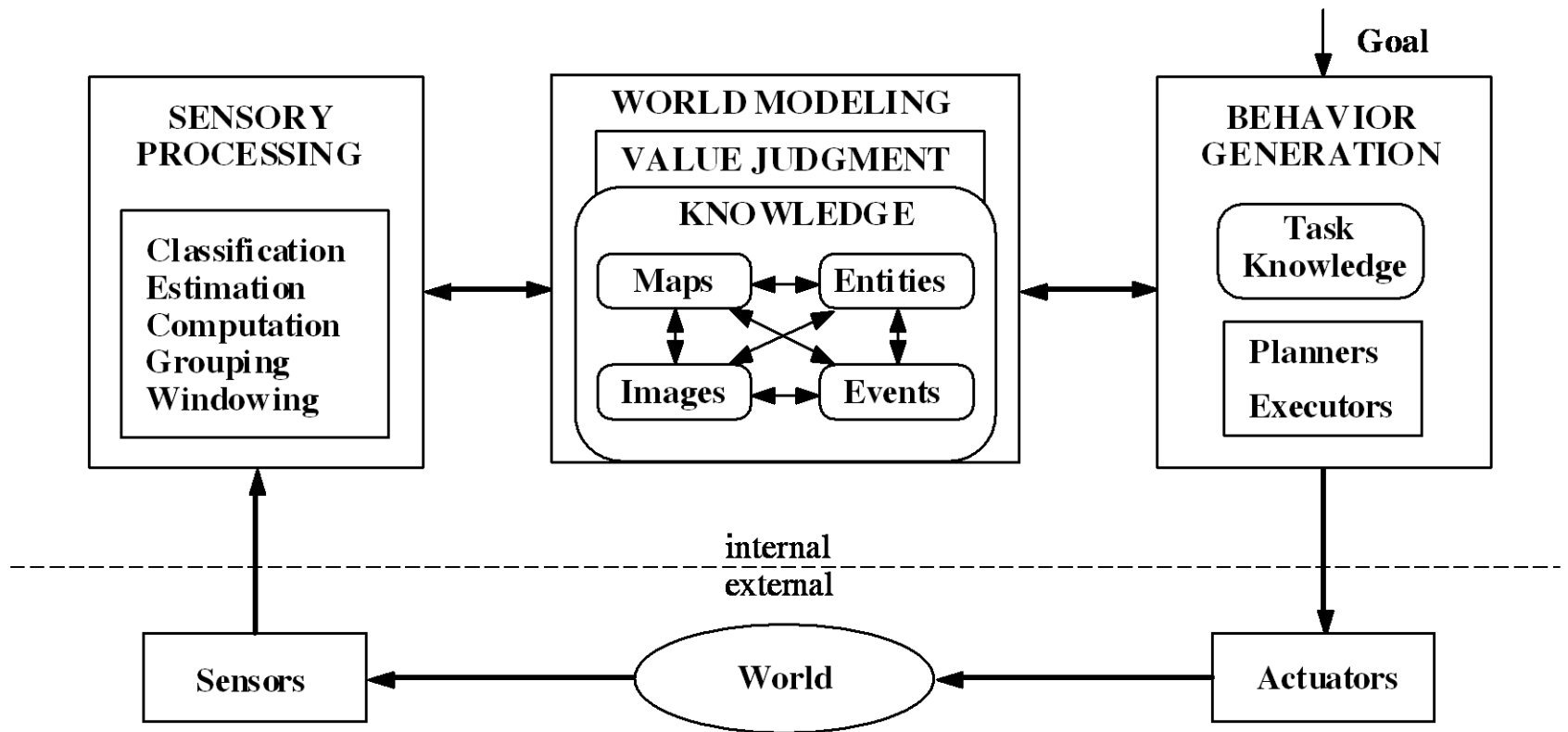


Perception establishes correspondence between internal world model and external real world

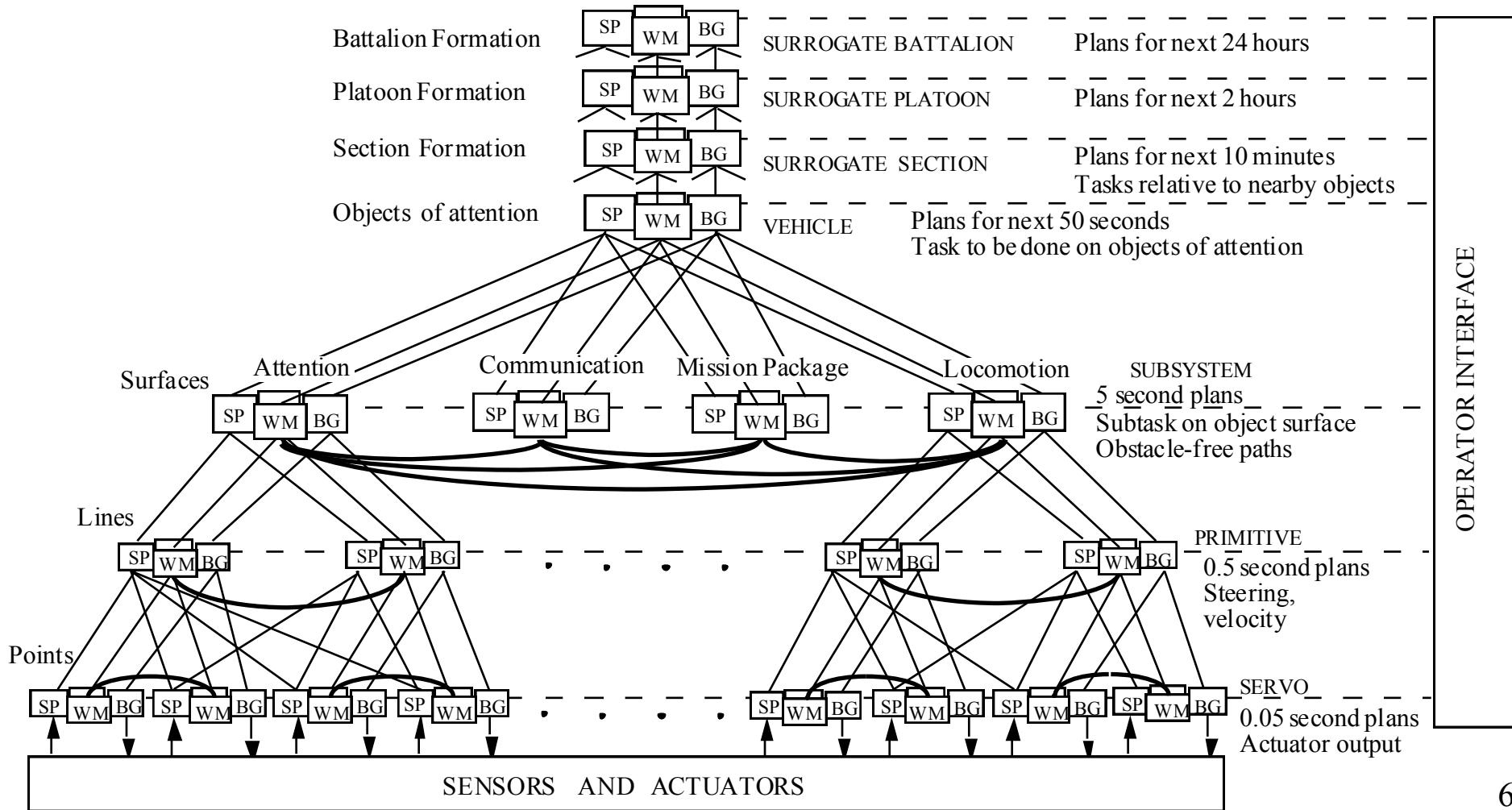
Behavior uses the world model to generate action to achieve goals

First Level of Detail

Technologies are understood in principle



A Reference Model Architecture for Unmanned Vehicles



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

10^{10} ops by 2005

10^{11} by 2010

10^{12} by 2015

10^{13} ops by 2020

10^{14} by 2025

10^{15} by 2030

Why now?

We now know how to deal with complexity

Hierarchical decomposition in time and space

Multi-resolutional 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

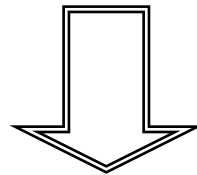
- **The mind is a product of the brain which is arguably the most complex structure in the universe**
 - more complex than the atom**
 - more complex than the genome**
 - more complex than the galaxies**
- **Mind is what separates humans from other species**
 - not physics or chemistry**
 - not biology 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**