New Approaches to Robotics

RODNEY A. BROOKS

Presented by **Sai Gowthami Bojja**

Introduction

Goal of AI: Construction of useful intelligent systems &
Understanding of human intelligence

Traditional Approach follows Modularize perception, world modeling, planning, and execution

New Approach builds intelligent control systems where many individual modules each directly generate some part of the behavior of the robot

Arbitration/Mediation Scheme - controls which behavior-producing module has control of which part of the robot at any given time

The two Central ideas

Situatedness

Robots are situated in the world

- Do not deal with abstract descriptions
- Environment directly influences the behavior of the system

E.g. Airline reservation system

Embodiment

Robots have bodies and experience the world directly

- Actions are part of a dynamic with the world
- Actions have immediate feedback on the robot's own sensations

E.g. A current generation industrial spray-painting robot

New Approach to robotics claims on how intelligence should be organized that are radically different from the approach assumed by traditional AI

Traditional approaches

Not experimental

No control experiment and very little quantitative data extraction or analysis

The intellectual pact between computer vision, robotics, and AI concerns the assumptions that can be made in building demonstration systems

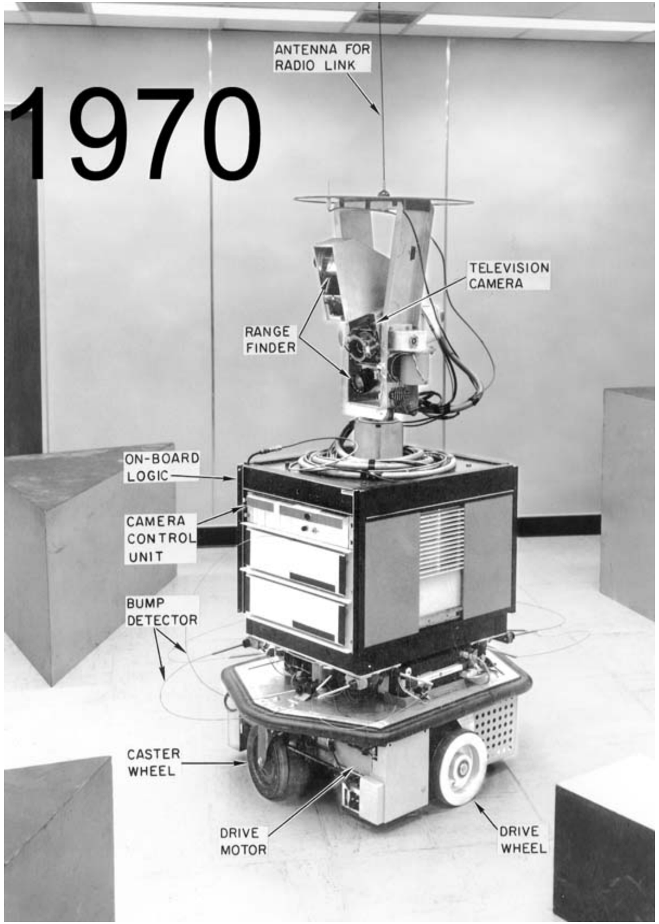
Establishes conventions for what the components of an eventual fully situated and embodied system can assume about each other.

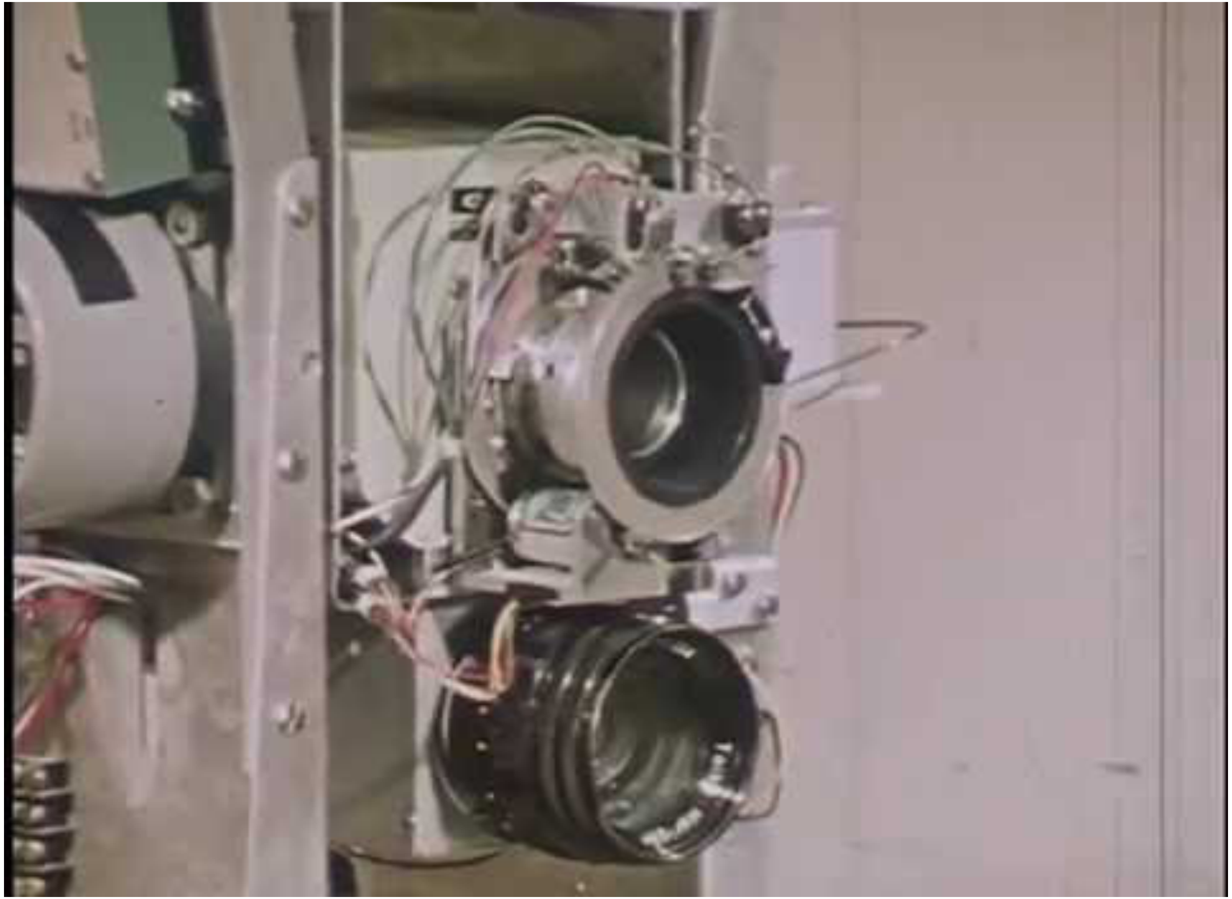
shakey

Developed at Stanford Research institute

Navigates from room to room, trying to satisfy a goal given to it on a teletype

A planning program called STRIPS is operated on those symbolic descriptions of the world to generate a sequence of actions for Shakey





copy-demo

A programmed camera system and a robot manipulator arm at MIT

Interprets an structure with white wooden blocks on a black background and builds a copy of the structure from additional blocks

Supports that a complete 3D description of the world could be extracted from a visual image

Cube Stacking Experiments

Legitimized all others work whose programs worked in a make-believe world of blocks

Make-Believe world of blocks: If one program could be built which understood such a world completely and could also manipulate that world, then it seemed that programs which assumed that abstraction could in fact be connected to the real world without great difficulty

Role of Computer Vision

Given a 2D image, infer the objects that produced it, including their shapes, positions, colors, and sizes

This lead to an emphasis on recovery of 3D shape, from monocular and stereo images

Role of AI

To take descriptions of the world and manipulate them based on a database of knowledge about how the world works in order to solve problems, make plans, and produce explanations

Role of Robotics

To deal with the physical interactions with the world

As robotics adopted complete 3D world model, many subproblems became standardized

- Collision-free path
- Understand forward kinematics and dynamics

New approach

“ The key idea of the new approach is to advance both robotics and AI by considering the problems of building an autonomous agent that physically is an autonomous mobile robot and that carries out some useful tasks in an environment that has not been specially structured or engineered for it ”

- Brooks

Key realizations

Agre and Chapman

The representations an agent uses of objects in the world need not rely on naming those objects with symbols that the agent possesses, but rather can be defined through interactions of the agent with the world

Rosenschein and Kaelbling

A formal symbolic specification of the agent's design can be compiled away, yielding efficient robot programs

Brooks

Internal world models that are complete representations of the external environment, besides being impossible to obtain, are not at all necessary for agents to act in a competent manner

Many of the actions of an agent are quite separable - intelligence can emerge from independent subcomponents interacting in the world

Pengi

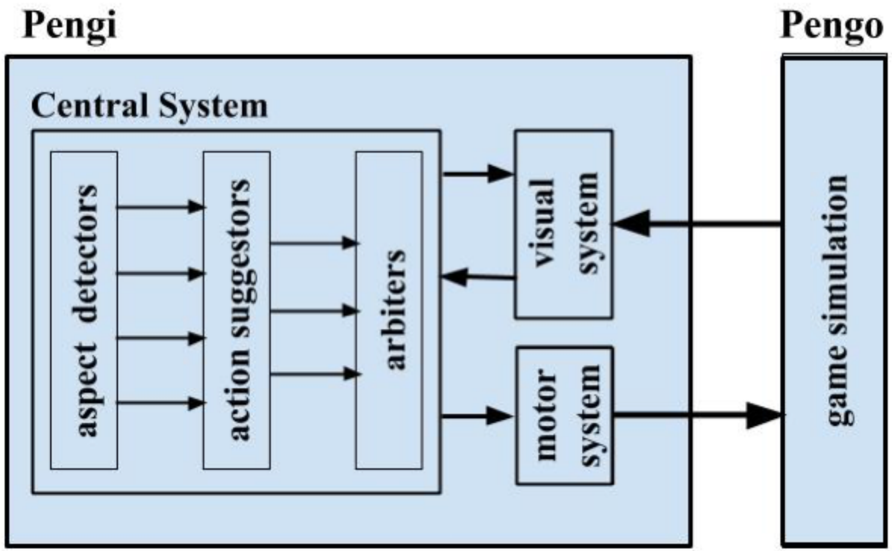
By Agre and Chapman

Video game program with one protagonist and many opponents

Components of architecture:

Visual Routine Processor(VRP) provides input to the system

A network of standard logic gates characterized into Aspect Detectors, Action Suggestors, and Arbiters



Pengi

VRP implements a version of **Ullman's visual routines theory** where markers from a set of six are placed on certain icons and follow them. The placement of these markers was the only state in the system

Projection operators let the player predict the consequences of actions. E.g. Launching a projectile

In the mind of the designer, output signals designate such things as "the protagonist is moving"

The next part of the network takes Boolean combinations of such signals to suggest actions, and the third stage uses a fixed priority scheme (that is, it never learns) to select the next action

The use of these types of deictic representations was a key move away from the traditional AI approach of dealing only with named individuals in the world and lead to very different requirements on the sort of reasoning that was necessary to perform well in the world

flakey

Used by Rosenschein and Kaelbling

Architecture was split into a perception subnetwork and an action subnetwork

The networks were constructed of standard logic gates and delay elements

Provably correct, real-time programs were generated by formally specifying the relationships between sensors and effectors and the world, and by using off-line symbolic computation

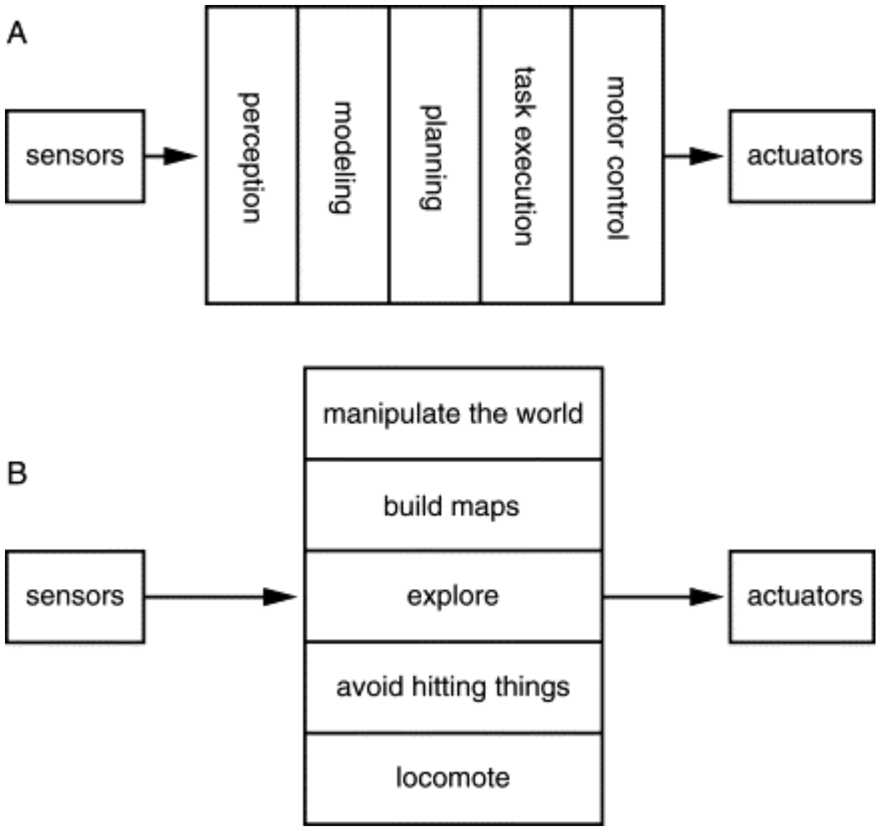
Subsumption architecture

Changed the modularity from the traditional AI approach

Vertical decomposition into task achieving behaviors rather than information processing modules

Used on robots which learn to coordinate many conflicting internal behaviors

The implementation substrate consists of networks of message-passing augmented finite state machines (AFSMs)



AFSMs

The messages(simple numbers (typically 8 bits)) are sent over predefined "wires" from a specific transmitting to a specific receiving AFSM

An AFSM has additional registers which hold the most recent incoming message on any particular wire

The registers can have their values fed into a local combinatorial circuit to produce new values for registers or to provide an output message

The network of AFSMs is totally asynchronous

Individual AFSMs can have fixed duration monostables which provide for dealing with the flow of time in the outside world

A **monostable multivibrator** is an electronic circuit that generates an output pulse

When triggered, a pulse of pre-defined duration is produced

layering

The behavioral competence of the system is improved by adding more behavior-specific network to the existing network. This process is called **layering**

Each of the layers is a behavior-producing piece of network in its own right, although it may implicitly rely on the presence of earlier pieces of network

E.g. An explore layer does not need to explicitly avoid obstacles, as the designer knows that the existing avoid layer will take care of it

A fixed priority arbitration scheme is used to handle conflicts

AREAS OF WORK

One of the shortcomings in earlier approaches was that reasoning was so slow that systems that were built could not respond to a dynamic real world

A key feature of the new approaches to robotics is that the programs are built with short connections between sensors and actuators, making it plausible to respond quickly to changes in the world

The first demonstration of the subsumption architecture was on the robot **Allen**

Non-reactive higher level layer would select a goal and then proceed in that direction and Lower level reactive layer avoids obstacles(using sonar readings)

Thus combines non-reactive capabilities with reactive ones

AREAS OF WORK

Retina bus(a cable that transmitted partially processed images from one site to another within the system) was implemented

Visual field is segmented into : Moving and Non - Moving parts
Floor and Non - Floor parts

Location, but not identity of the segmented regions, was used to implement **image-coordinate-based navigation**

Robustness was achieved by having redundant techniques operating in parallel and rapidly switching between them

AREAS OF WORK

Using **redundancy over many images** lead to trying to get complete depth maps over a full field of view from a single pair of stereo images

Traditional computer vision research tries to extract the maximal amount of information from a single image, or pair of images

Ballard:

Active vision system - one with control over its cameras, can work naturally in object-centered coordinates

Passive vision system - one which has no control over its cameras, is doomed to work in viewer-centered coordinates

AREAS OF WORK

Rochester

Exploited behavior-based or animate vision

Dickmanns and **Graefe**

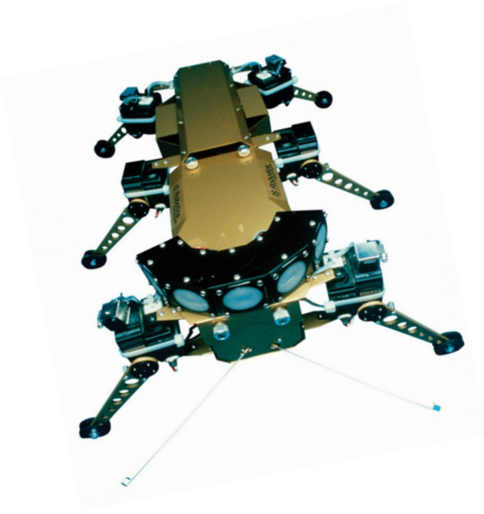
Used redundancy from multiple images, and multiple feature windows to track relevant features between images, while virtually ignoring the rest of the image

Raibert

Decomposed the problem into independently controlling the hopping height of a leg, its forward velocity, and the body attitude

The motion of the robot's body emerges from the interactions of these loops and the world

genghis



A six - legged robot programmed by Brooks using subsumption

Layers of behaviors implemented:

- To stand up
- To walk without feedback
- To adjust for rough terrain and obstacles by means of force feedback
- To modulate for this accommodation based on pitch and roll inclinometers

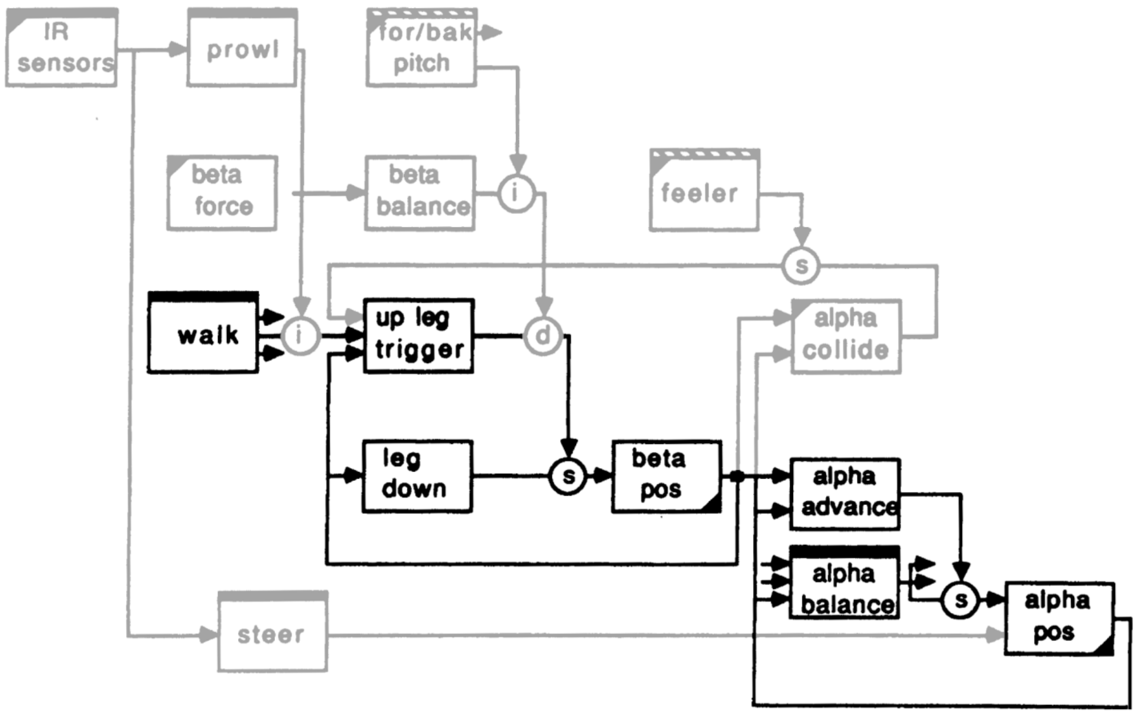
The trajectory for the body is not specified explicitly, nor is there any hierarchical control

The robot successfully navigates rough terrain with very little computation

Subsumption network to control ghengis

57 augmented finite state machines, with "wires" connecting them that pass small integers as messages

The network was built incrementally starting in the lower right comer, and new layers were added, roughly toward the upper left corner



AREAS OF WORK

Connell

Used a collection of 17 AFSMs to control an arm with two degrees of freedom mounted on a mobile base

When parked in front of a soda can, whether at floor level or on a table top, the arm was able to reliably find it and pick it up, despite other clutter in front of and under the can, using its local sensors to direct its search

A traditional AI planner produces plans for a robot manipulator to assemble the components of some artifact, and a behavior-based system executes the plan steps.

The key idea is to robust primitives to give the higher level planner, which can do more than carry out simple motions, thus making the planning problem easier.

AREAS OF WORK

Representation is a cornerstone topic in traditional AI

Mataric

Recently introduced active representations into the subsumption architecture

In experiments with **Toto,** a sonar-based office environment navigating robot, landmarks were broadcast to the representational substrate as they were encountered

A previously unallocated subnetwork would become the representation for that landmark and then take care of noting topological neighborhood relationships, setting up expectation as the robot moved through previously encountered space, spreading activation energy for path planning to multiple goals, and directing the robot's motion during goal-seeking behavior when in the vicinity of the landmark

AREAS OF WORK

Representations and the ways in which they are used are inseparable - all happens in the same computational units within the network

Nehmzow and Smithers

Experimented with including representations of landmarks

Robots operated in a simpler world of plywood enclosures

They used self-organizing networks to represent knowledge of the world, and appropriate influence on the current action of the robot

Edinburgh group

Done a number of experiments with reactivity of robots, and with group dynamics among robots using a Lego-based rapid prototyping system that they have developed.

AREAS OF WORK

Early behavior-based approaches used a fixed priority scheme to decide which behavior could control a particular actuator at which time

An alternative voting scheme was produced to enable a robot to take advantage of the outputs of many behaviors simultaneously

A scheme for selectively activating and de-activating complete behaviors was developed based on spreading activation within the network itself(Further developed and used for ToTo)

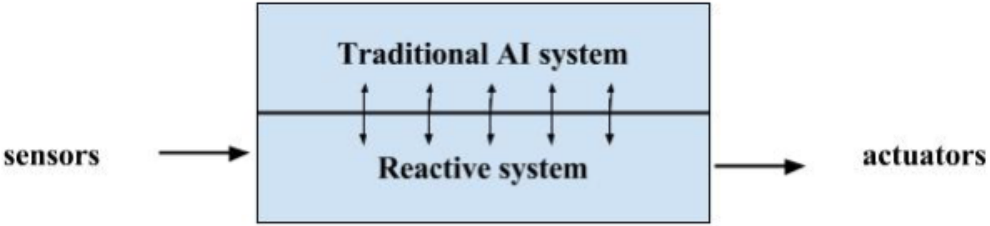
Work at IBM and Teleos Research using Q-1earning to modify the behavior of robots

AREAS OF WORK

Most researchers adopted the philosophies of the behavior-based approaches as the bottom of two-level systems

The idea is to let a reactive behavior-based system take care of the real time issues involved with interacting with the world

Traditional AI system sits on top, making longer term executive decisions that affect the policies executed by the lower level



A number of projects involve combining a reactive system, linking sensors, and actuators with a traditional AI system that does symbolic reasoning in order to tune the parameters of the situated component.

evaluation

Traditional Approach

Worked in a somewhat perfect domain

Much of the work is in developing algorithms that guarantee certain classes of results in the modeled world

Verifications are occasionally done with real robots

Research contributions do not have to be tested in situated systems

New Approach

Emphasis is on understanding and exploiting the dynamics of interactions with the world

Effects are extremely important on the overall behavior of a robot

Extremely important on the overall behavior of a robot

must be non-specific to the particular location in which the robot will be tested

Questions ?