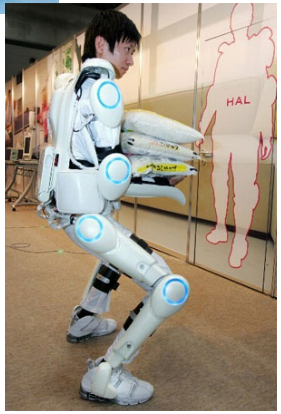
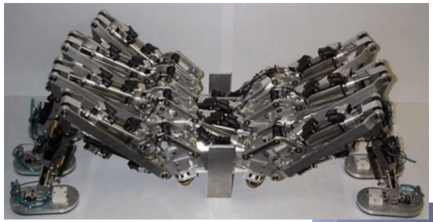
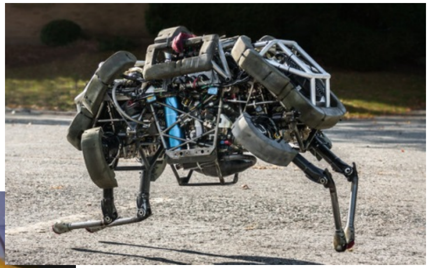
Robot design process









Professor Gurvinder S Virk
Technical Director

InnotecUK Limited
Email: gurvinder.virk@innotecuk.com

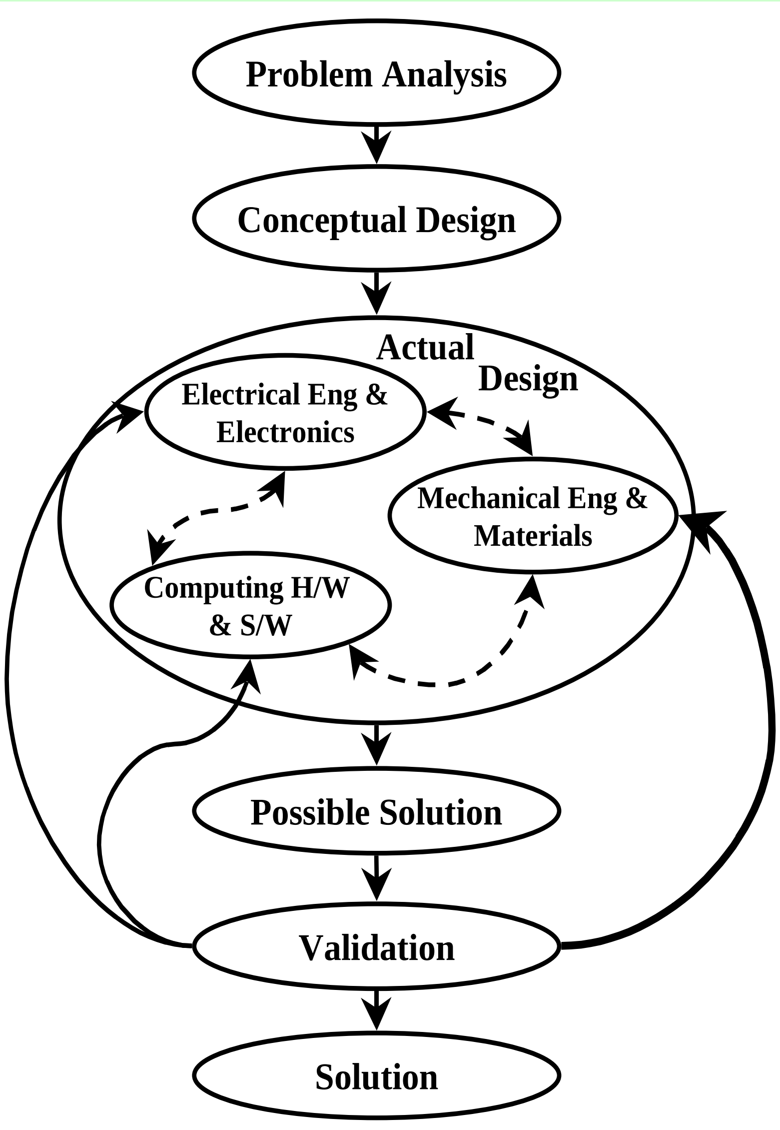
General robot design process

- Gathering information: What must robot do?
- Identifying specific details of the design which must be satisfied and operational environment (Remember SAFETY!)
- Identifying possible and alternative design concept solutions (can be assessed)
- Planning and designing an appropriate structure including detailed drawings
- Building and testing prototype
- Test and assess final robot

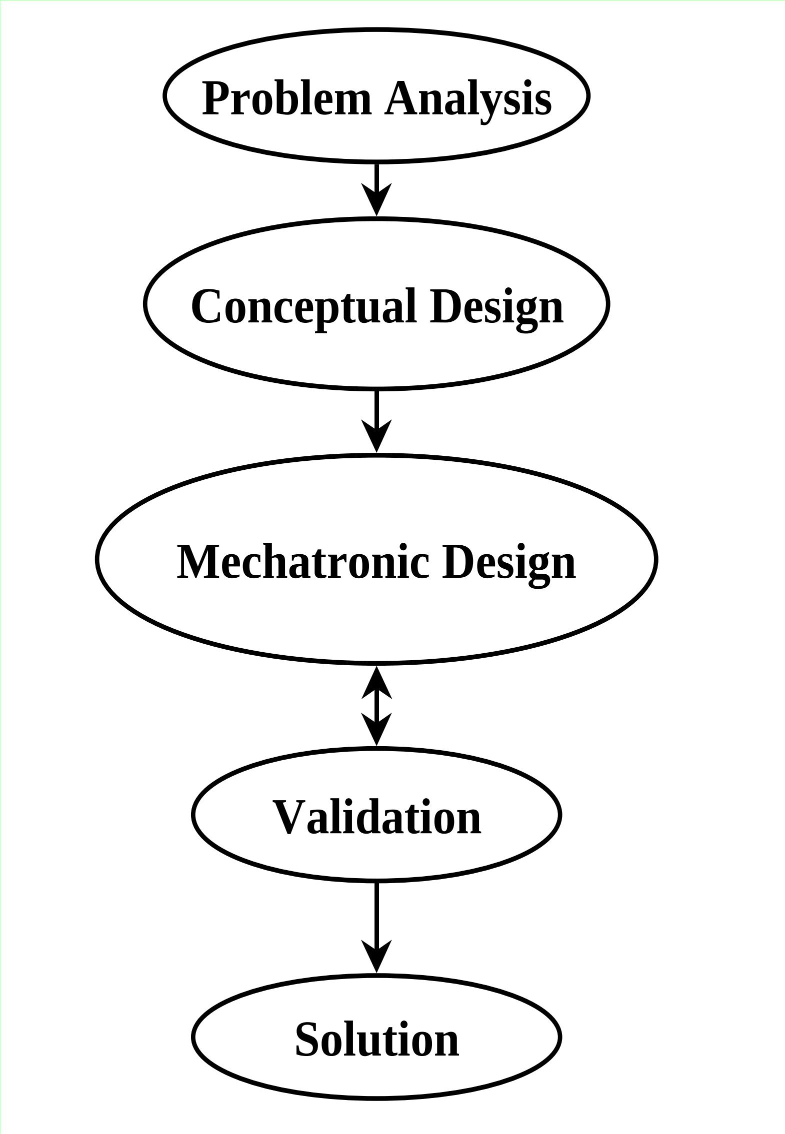
Electronics | Mechanics | Computing | ETC

Mechatronic approach for design

Traditional design approach



Ideal mechatronic approach



Modular decomposition of a robot

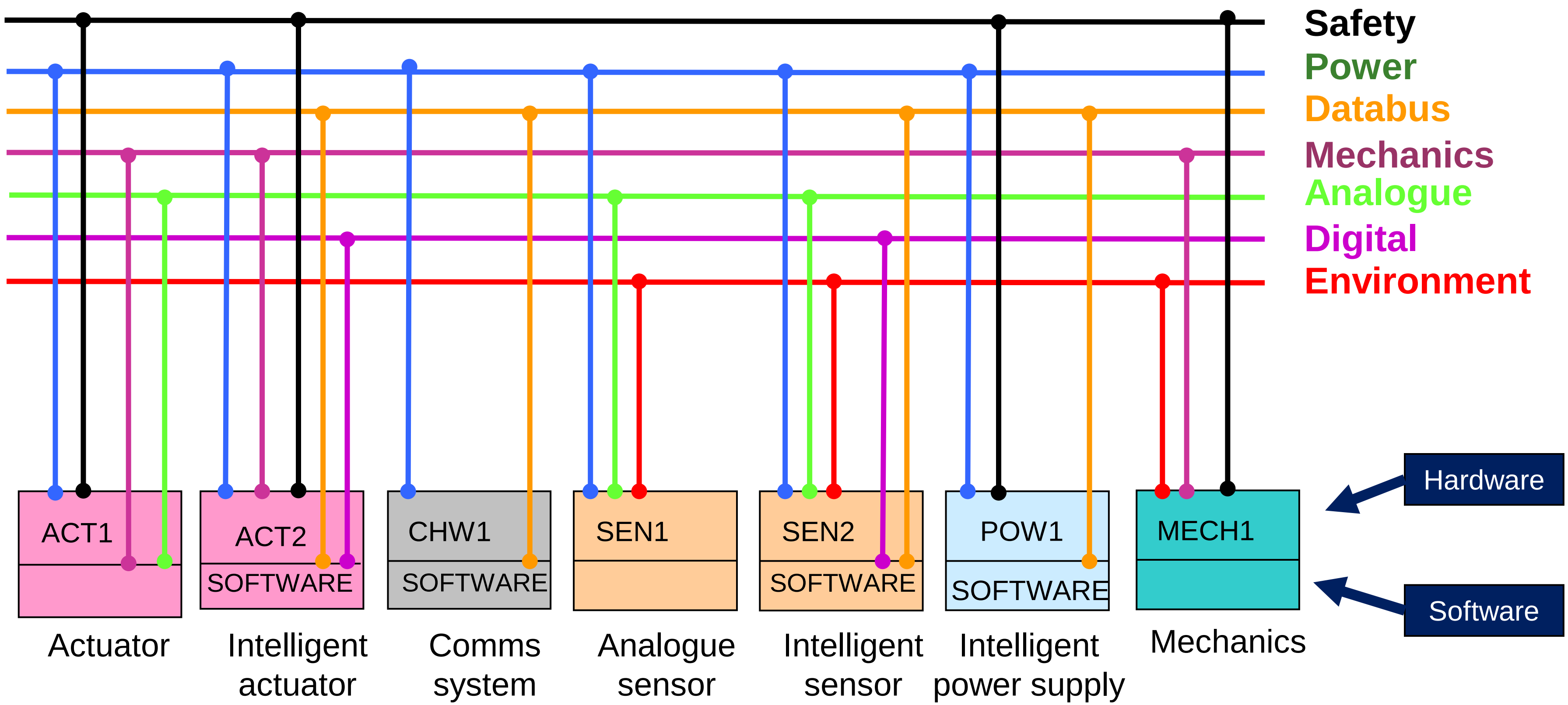
- **Basic modules**
  - **Input modules**
  - **Processing modules**
  - **Output modules**
  - **Infrastructure modules**
- **Super Modules**
- **Interfacing standards: 6+1 variables identified:**
  1. **Power**
  2. **Analogue**
  3. **Digital**
  4. **Databus**
  5. **Mechanics**
  6. **Environment**
  7. **Safety**

Developed by EC Network of Excellence on Climbing and walking robots (CLAWAR; see www.clawar.org)

ISO TC299/ WG6 Modularity for service robot

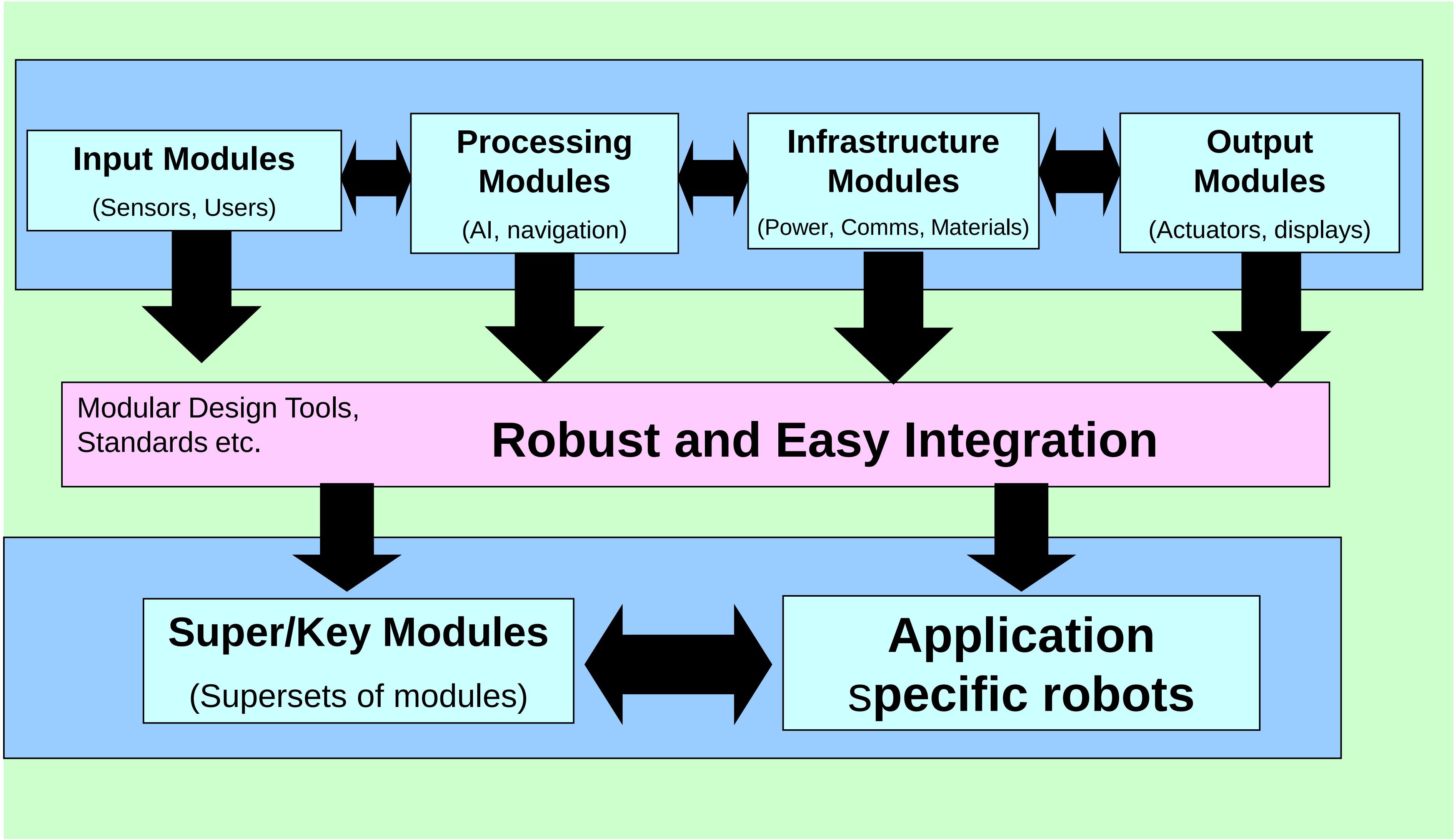
Modular robot components interfacing

Partitition robot components into modules which interface to other modules via “interaction variables”. Main interaction variables are identified as shown below by CLAWAR and ISO TC299/WG6 with some example robot modules



Interaction variables are: 1) Power; 2) Communications (global or direct point-to-point in analogue or digital forms), 3) Mechanical linkages, environmental aspects)

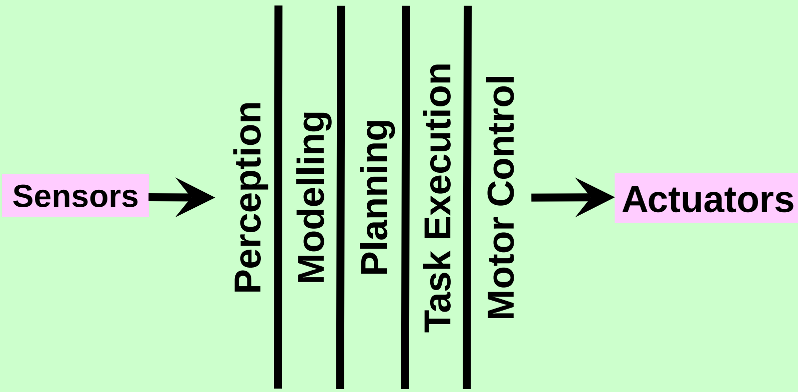
Modular robot design approach



Robot behaviour paradigms

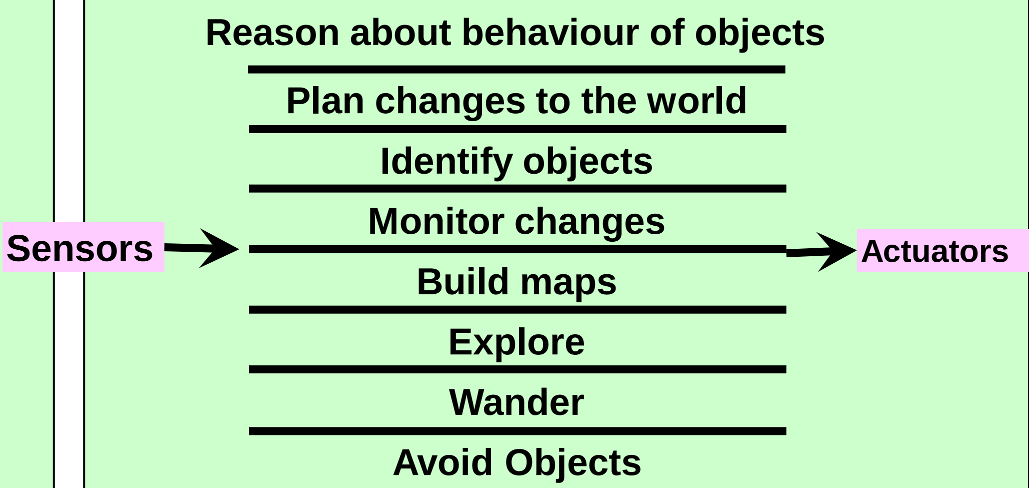
Hierarchical

- Used in early robotics
- Problems: Time of reaction are excessive



Reactive paradigm

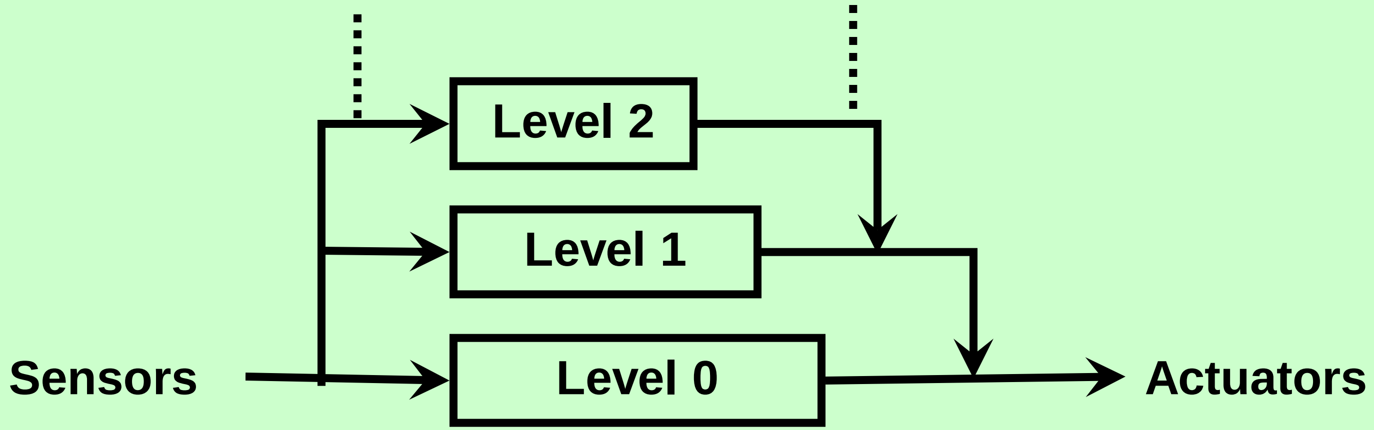
- Organises things to get a more direct route from sensors to actuators
- Schematically depicted by Brooks (1986):



- Problem: Conflicting orders to actuators

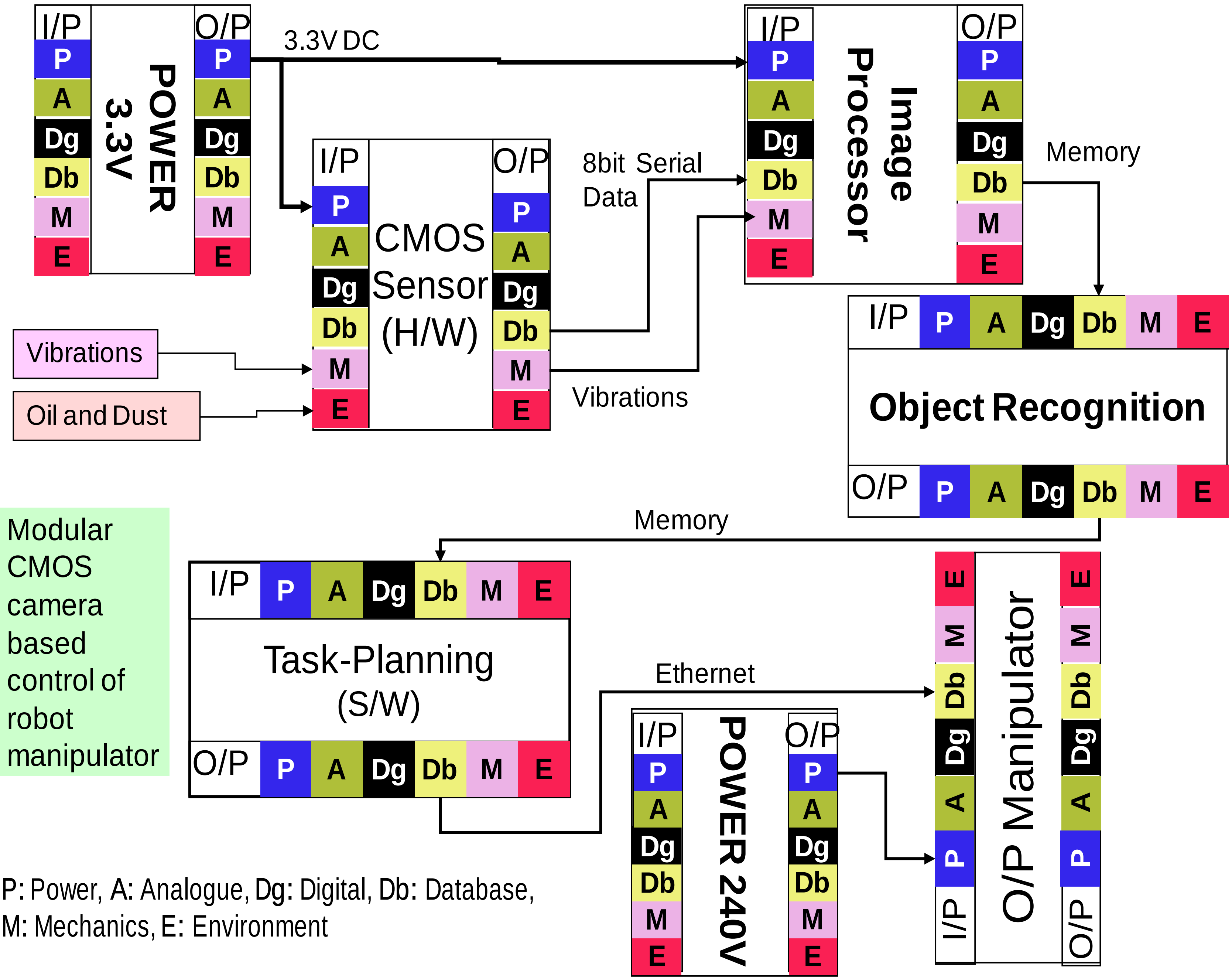
Brooks' Subsumption Architecture

- Components behaviours need to be divided into layers (modules) with inputs, outputs and a reset
- Arbitration scheme: a module at a higher level can
  - Suppress the input of a module at a lower level thereby preventing the module from seeing a value at its input
  - Inhibit the output of a module at a lower level thereby preventing that output from being propagated to other modules



  - Problem: Complex set-up of modules to avoid low-level reaction problems

Modular CMOS camera based control of robot manipulator



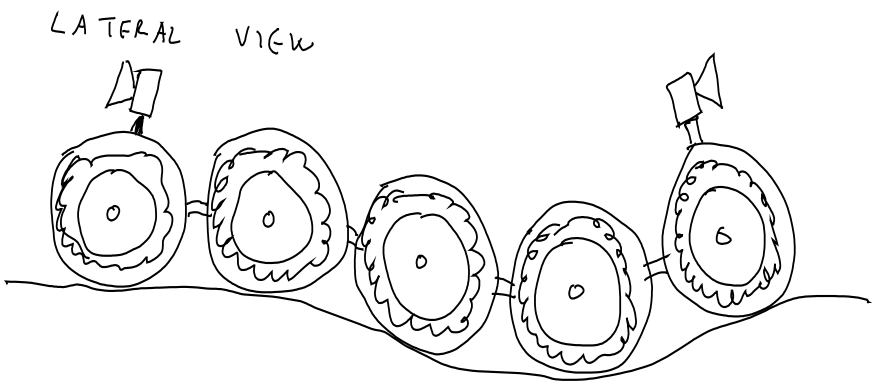
P: Power, A: Analogue, Dg: Digital, Db: Database, M: Mechanics, E: Environment

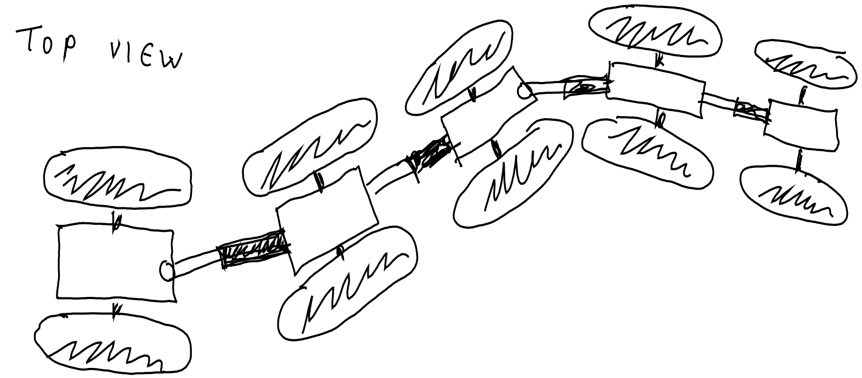
Design example: Search and rescue robot

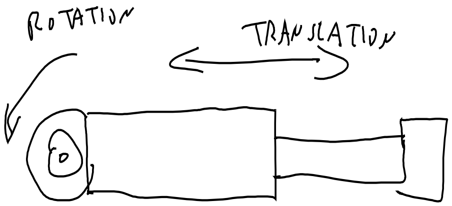
- **Aim**
  - Perform inspections in partially collapsed buildings to locate possible presence of survivors. The robot should be able to enter from any opening in the building and to navigate inside through small gaps in the environment
- **Operational environment**
  - Corridors and rooms blocked by various objects, uneven terrain, stairs
  - Low or no light conditions
  - Dust, mud and liquids on travel surface
- **Tasks/ Behaviours**
  1. Sense surrounding environment: Sensing 1
  2. Sense presence of survivors (safety issue): Sensing 2
  3. User Interface: Communicate environment/ survivors information to operator and receive user commands
  4. Travel through environment (locomotion behaviour): safety issue
  5. Monitor power level: Homing behaviour

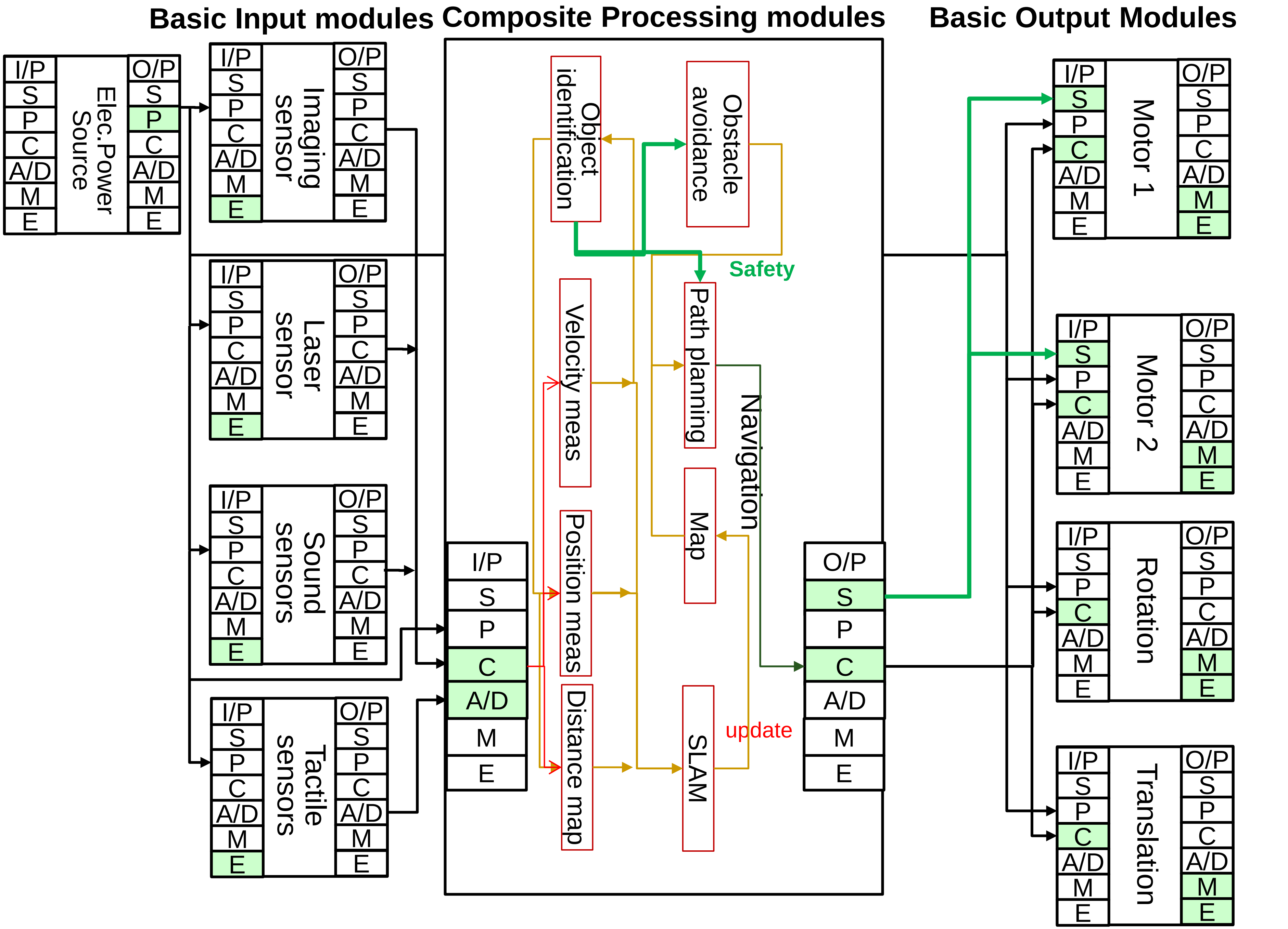
Locomotion behaviour

- **Mobility base made of 2 wheeled modules to give different locomotion behaviours:**
  - **4 wheeled motion: Only two module wheels are in contact with the ground, while the others are in air. Articulations are fixed. Used to traverse flat terrains**
  - **Snake motion: All the wheels are in contact with uneven ground, the rotational articulation are activated to adapt the robot with ground. Used to traverse and to climb over obstacles.**
  - **Peristaltic motion. All the wheels are in contact with the environment (eg. tunnels), the rotation/prismatic actuation between the modules are periodically actuated to allow peristaltic motion. This motion will increase traction capabilities of the system and will be used to travel / climb over difficult obstacles or for very slippery terrains.**









S: Safety, P: Power, C: Communications, A/D: Analogue/Digital, M: Mechanics, E: Environment

Input modules: Sensors

- **Sensors** measure distance, angle, location, identity, orientation, velocity, acceleration, force, torque, strain, contact, etc
- **Passive sensors** capture signals already in the environment
  - Camera (video, infrared), microphone, temperature
- **Active sensors** send energy into the environment
  - Sonar, laser range-finder
- **Proprioceptive sensors** measure the robot's state
  - Joint angles, joint force/torque, wheel revolutions, …
  - So sensing is both external and internal
- **Analogue / Digital sensors: Analogue need A/D, digital is quantised and/or in pulse form. µP can measure voltage (8bit, 12bit, 16bit, etc)**
- **HCI: User interface, force feedback, VR, etc**

Output modules: Actuators

- Actuators are devices for altering or generating a mechanical property, usually a force or torque or motion. Those which are designed to accurately generate any desired force, displacement, velocity etc. within a given range are called servo-actuators.
- Electromagnetic actuators (DC, Permanent magnet, Stepper, AC, Brushless, etc)
- Hydraulic actuated robots have the advantage of mechanical simplicity (few moving parts), as well as physical strength and high speed
- Pneumatic drives systems are normally reserved for small, limited sequence pick and place applications. Lack of stiffness (air compressibility) and control problems associated with stiction prevent their use if good accuracy is required.
- Others: Piezo, direct fuel, chemical, etc

- Other output modules are for user interfaces (displays, haptic devices, etc)

Decision making modules

- Provide the intelligence in the robot
- Vison could be included here but it could also be part of sensing but as there is lots of processing involved to get the needed information from the raw image(s) it can be see as part of “decision making” for features like “obstacle detection”, “object recognition”, etc.
- Similar for other sensing systems implemented

Infrastructure modules

- **Materials**
  - Size, shape, configuration and weight
  - How modules link up physically and how movement between the modules is achieved
- **Power supplies**
  - On –board and cater for all powering requirements of modules (batteries, generator, compressor, etc) or via appropriate distribution system
  - Main powering methods: electrical (ac, dc, voltage levels, single phase, three phase, etc), pneumatic (working pressure and flow rates), and hydraulic (pressure, medium and flow rates)
- **Communications**
  - Types of communications: Analogue, digital, data bus
  - Wired, wireless
  - Security and safety

Assignment: Service robot design

Perform a concept design of a service robot for one of the following applications;

1. A mobile robot able to take a pet dog for a walk outdoors
2. A floor cleaning robot for a public railway station
3. A mobile robot able to welcome and guide visitors to their hosts in an organisation

Define assumptions made using sound logical reasoning bearing in mind:

- Specific aims of robot (tasks, safety, performance needed, etc)
- Key behaviours needed and how these may be achieved using appropriate sensors, decision making and actuators
- Need for a modular block diagram of key behaviours of the robot designed

Work individually or in small groups and prepare your concept design as a short Powerpoint presentation (maximum 6 slides) by 16.00 today and send to Professor Virk (gurvinder.virk@innotecuk.com).

Powerpoint file should contain:

i. Names, organisations, and email addresses of all group members
ii. Design structured as follows
    a) Aim of robot and assumptions made about application and operational environment
    b) Main behaviours needed in your robot system. Specify any constraints
    c) How a few behaviours can be achieved using a modular supply chain approach
    d) Explain decisions made and pay attention to design assessment criteria presented in lectures
    e) Present a sketch of your design

Summary

- **Overview of robot design process**
- **Key robot components described and design process based on modularity introduced**
- **Assignment on robot concept design**

Thanks are expressed to all the colleagues (too many to mention individually) across the world who have helped with the formulation of this lecture on Robot design from material placed on the www