given scenario, choose work cell type, justify reason, sketch the work cell diagram

Robot Work Cell

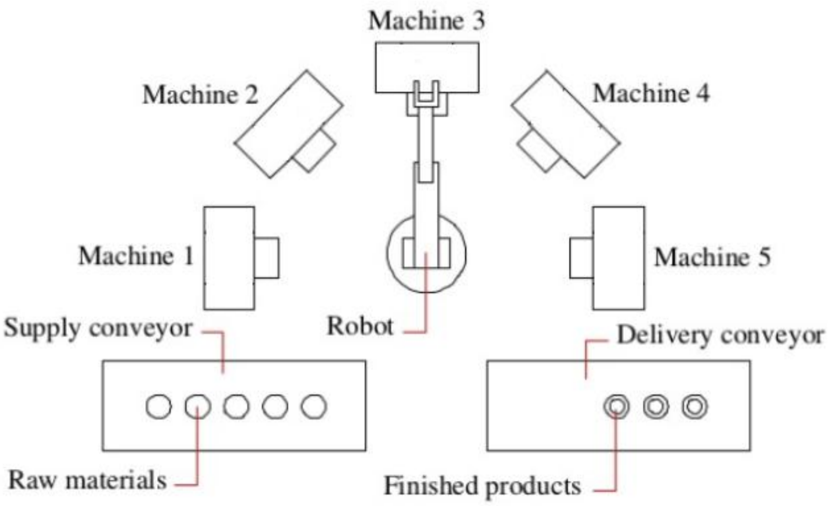
Most people know that using industrial robots for a manufacturing process can improve product quality, reduce labor and production costs, and decrease waste; but there is an additional benefit of using a robotic cell to enhance the overall flow and efficiency.

A **robot work cell** is a complete system that includes the robot, controller, and other peripherals such as a part positioner and safety environment. Robotic work cells are made to allow robots to operate at their full capacity and speed. There are regulations in place that limit the speed of a robot within the presence of a human worker and with the right barriers. However, in robotic work cell this limitation is removed. The layout of these work cells can be customized to specific application process in order to increase how quickly a part can be completed and moved down the production line. Operators can load and unload parts while another part is being completed within the same work cell area.

Generally, there are 3 types of robotic work cell: 1) Robot-centered work cell 2) In-line robot work cell 3) Mobile robot work cell.

1) Robot-centered work cell

1. The robot is positioned at the approximate centre of the work cell.
2. Other components and equipment are arranged in a partial circle around the robot.
3. This layout allows for high utilization of robot
4. Parts to be presented in known location and orientation (usage of conveyors, part-feeders, pallets)



End-of-Line Robotic Case Packer & Palletizer - Schneider Packaging
https://www.youtube.com/watch?v=zM_8pHBvYm0

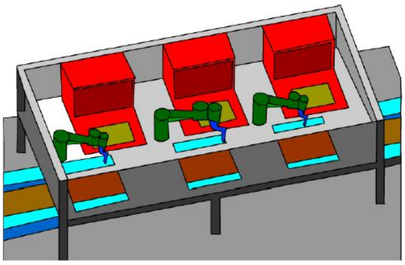
Combi RCE Robotic Random Case Erector installed by SWS Packaging
https://www.youtube.com/watch?v=9-W9gfCtZhE


Part-feeders

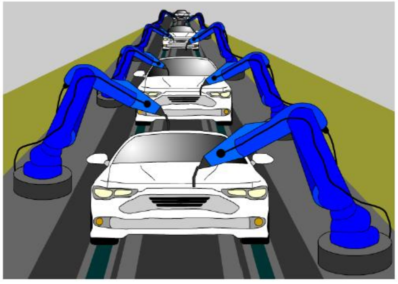

Pallets

2) In-line robot work cell

1. One or more robots are located along an in-line conveyor or other material transport system.
2. Work is organized so that parts are presented to the robots by the transport system.
3. Typical applications such as in welding lines used to spot-weld car body frames, usually utilizes multiple robots.



Inline robotic cell layout



Inline robotic cell layout for spot-weld

4. There are 3 types of **work part transport systems** used in **in-line robot work cell**:
   a) Intermittent Transfer
   b) Continuous Transfer
   c) Non-synchronous Transfer

a) Intermittent Transfer System

- The parts are moved in a start-and-stop motion from one station to another along the line. It is also called synchronous transfer since all parts are moved simultaneously to the next stop.
- The advantage of this system is that the parts are registered in a fixed location and orientation with respect to the robot during the robot's work cycle.

b) Continuous Transfer System

- Work parts are moved continuously along the line at constant speed. The robot(s) has to perform the tasks as the parts move along.
- The position and orientation of the parts with respect to any fixed location along the line are continuously changing.
- This results in a "tracking" problem, that is, the robot must maintain the relative position and orientation of its tool with respect to the work part.
- This tracking problem can be partly solved by the moving baseline tracking system i.e. by moving the robot parallel to the conveyor at the same speed, or by the stationary baseline tracking system i.e. by computing and adjusting the robot tool to maintain the position and orientation with respect to the moving part.

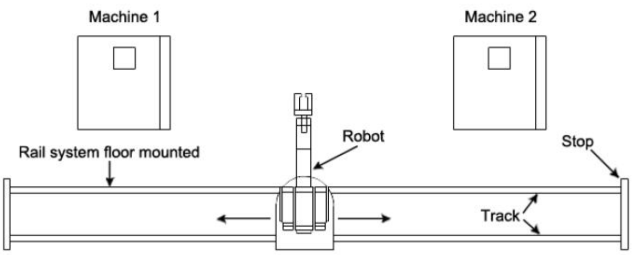
c) Non-synchronous Transfer System

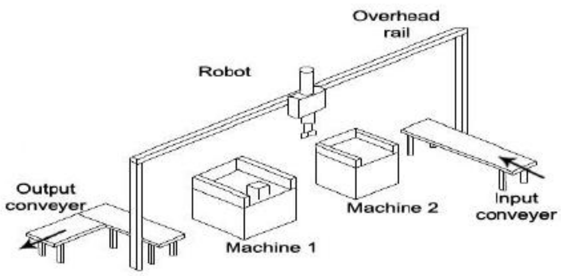
- This is a "power and free system". Each work part moves independently of other parts, in a stop-and-go manner.
- When a work station has finished working on a work part, that part then proceeds to the next work station. Hence, some parts are being processed on the line at the same time that others are being transported or located between stations. Here, the timing varies according to the cycle time requirements of each station.
- The design and operation of this type of transfer system is more complicated than the other two because each part must be provided with its own independently operated moving cart.
- However, the problem of designing and controlling the robot system used in the power-and-free method is less complicated than for the continuous transfer method.
- For the irregular timing of arrivals, sensors must be provided to indicate to the robot when to begin its work cycle. The more complex problem of part registration with respect to the robot that must be solved in the continuously moving conveyor systems are not encountered on either the intermittent transfer or the non-synchronous transfer.
- Non-synchronous transfer systems offer a greater flexibility than the other two systems.

Mercedes-Benz E-Class Production:
https://www.youtube.com/watch?v=LEgGqSybLTo

3) Mobile robot work cell

1. In this arrangement, the robot is provided with a means of transport, such as a mobile base, within the work cell to perform various tasks at different locations.
2. The transport mechanism can be floor mounted tracks or overhead railing system that allows the robot to be moved along linear paths.





Mobile robot work cell

3. Mobile robot work cells are suitable for installations where the robot must service more than one station (production machine) that has long processing cycles, and the stations cannot be arranged around the robot in a robot-centred cell arrangement.
4. One such reason could be due to the stations being geographically separated by distances greater than the robot's reach. The type of layout allows for time-sharing tasks that will lower the robot idle time.
5. One of the problems in designing this work cell is to find the optimum number of stations or machines for the robot to service.

Mobile Collaborative Robot - FANUC's New CR-7iA/L Uses AGV to Move Between Robotic Assembly Stations: https://www.youtube.com/watch?v=rQBnZuby05s

Mechanical systems in the operation of robot work cell produce mechanical motion. Rotary, linear and reciprocating motions are the three mechanical motions for automated application in a robot work cell.

Advantages of robot work cell

- Less floor space required.
- Increase the use of equipment and machinery
- Reduced work-in-process inventory
- Reduced raw material and finished goods inventory
- reduces downtime by increasing productivity with constant workflow

Safety Monitoring

- Emergency stopping requires an alert operator to be present to notice the emergency and take action to interrupt the cycle (however, safety emergencies do not always occur at convenient times, when the operator is present).

- Therefore, a more automatic and reliable means of protecting the cell equipment and people who might wander into the work zone, is imperative. This is safety monitoring.

- Safety monitoring (or hazard monitoring) is a work cell control function where various types of sensors are used for such purpose. For example, limit switches and proximity sensors can be used to monitor status and activities of the cell, to detect the unsafe or potentially unsafe conditions. Other type of sensors such as temperature sensors, pressure sensitive floor mats, light beams combined with photosensitive sensors, and machine vision can also be used to protect the cell equipment and people who might wander into the work zone.

  Robotics Risk Assessment: Recognizing Potential Hazards:
  https://www.youtube.com/watch?v=GtNKX4kpC18

won't come out

Robotic Sensors

Passive sensors

Passive sensors measure ambient environment energy entering the system. Examples of passive sensor: thermocouple, camera, Light Dependent Resistor (LDR).

- Advantage – their operation conditions are not limited by the battery and that they are inexpensive / Simplicity of the design, therefore, low cost and low power consumption
- Disadvantage – can only be used to detect energy when the naturally occurring energy is available

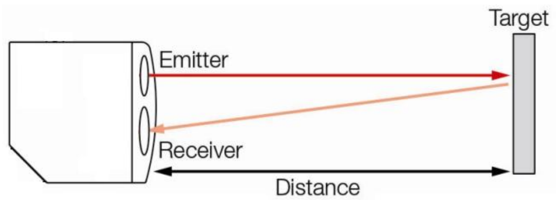
Active sensors

Active sensors emit energy into the environment, and then measure the environment response. Examples of active sensor: laser range finders, sonar sensor, synthetic aperture radar (SAR)

- Advantage – is their ability to obtain measurements at any time, regardless of the time of day, season or amount of natural illumination.
- Disadvantage – require the generation of a fairly large amount of energy to adequately illuminate the targets.

Proprioceptive sensors measure values internally to the system (robot), e.g. battery level, wheel position, joint angle, etc. Examples of proprioceptive sensors: encoders, potentiometers, gyroscopes, compasses,etc. Exteroceptive sensors are used for the observation of the environments and objects. Examples of exteroceptive: sonar sensors, IR sensitive sensors, ultrasonic distance sensors.

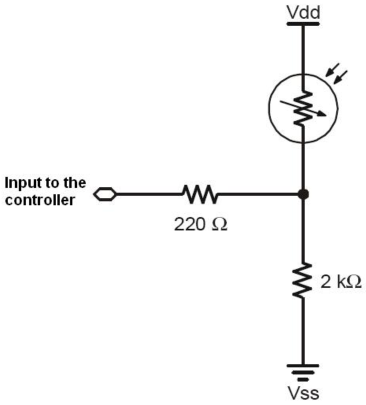
Ultrasonic sensor can be used for determining the proximity of objects (solid walls) while the robot is navigating. The ultrasonic sensor uses time of flight (TOF) method for distance measurement.In this method, the time taken for a pulse to travel from the transmitter to an observed object and back to the receiver is recorded and used to calculate distance by $d=0.5*c*t$, where d= distance between a sensor and an object, c=speed of light and t= time difference between the emission of a signal and its return to the sensor, after being reflected by an object



The ultrasonic sensor is attached in front of the robot. Whenever the robot is going on the desired path the ultrasonic sensor transmits the ultrasonic waves continuously from its sensor head. Whenever an obstacle comes ahead of it, the ultrasonic waves are reflected back from an object and that information is passed to the microcontroller of the robot. The microcontroller receives the data and performs the necessary movement of the robot to help the robot to avoid obstacle.

Photoresistor

A photoresistor is a light-dependent resistor (LDR) that covers the spectral sensitivity similar to that of the human eye. The active elements of these photoresistors are made of Cadmium Sulfide (CdS). Light enters into the semiconductor layer applied to a ceramic substrate and produces free charge carriers. A defined electrical resistance is produced that is inversely proportional to the illumination intensity. In other words, darkness causes more resistance, and brightness causes less resistance.



The resistance of a photoresistor decreases with light intensity. When the photoresistor is shaded, its resistance value is large, which in turn makes Vo smaller. If the I/O pin senses that voltage applied to it is above 1.6 V, it stores a 1 in its input register. On the other hand, when the photoresistor is not shaded, its resistance value is low. If it senses the applied voltage is less than 1.6 V, it stores a 0 in its input register. By comparing the value in the input register, the mobile robot can be programmed to recognize the difference between shade and no shade.

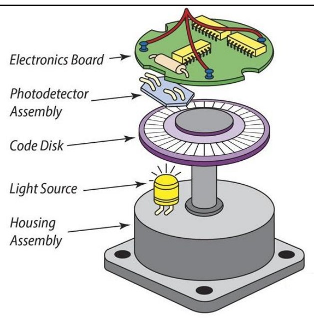
Servo motor

A servo motor is made up of a small DC motor, a gear transmission which reduces speed and increases strength, and a small circuit control that makes it possible to move the motor accurately.

A typical Servo motor has three wires known as power, ground, and control. Servo motor usually does not rotate freely. Its rotation span is approximate 200 to 250 degree, except for the Parallax continuous rotation servo which can rotate freely. Servo motor requires a driver circuit.

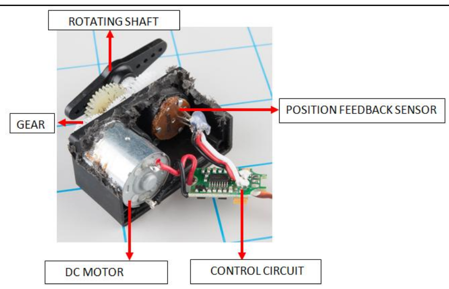
DC motor and shaft encoder could be an equivalent to servo motor, but without the gear arrangement part. Hence, it will have less torque than the servo motor. Servo motor has all the parts inside a single package and hence easy to use and compact as compared to the DC motors with encoders. Due to the absence of gear, DC motor with encoders is easier to repair and with no wear and tear problem. However, the servo motor will bring more accurate control.

DC motor



DC motor with shaft encoder

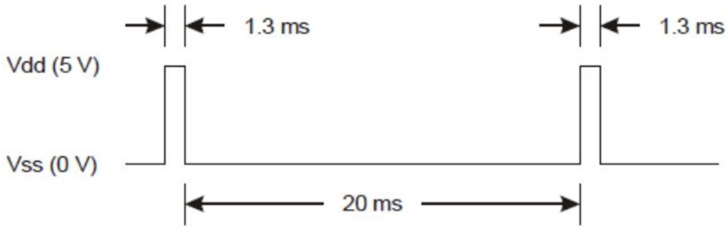
Servo motor



Internal parts of servo motor

The limitations of DC motors with encoders:
Inaccurate wheel diameter measurement or misaligned wheels…, the error of estimated position is generated by friction of ground surface…, some encoders which are installed externally are susceptible to dirt, oil and dust contaminates,…will lead to error accumulation over time

Full speed clockwise requires 1.3 ms high pulses. To do this, use servo_speed(-75)



Explain the following snippet code:

```
from cyberbot import *
bot(18).servo_speed(75)
bot(19).servo_speed(-75)
sleep(3000)
bot(18).servo_speed(-75)
bot(19).servo_speed(-75)
```

Architectures for Robot Control

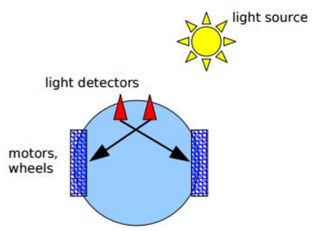
come out in set A

Mobile robot architecture can be classified according to the relationship between sensing, planning and acting components inside the architecture. Based on this, there are three types of architectures: reactive, deliberative, and hybrid (deliberative/reactive).

Reactive Control

- Reactive control or reactive planning involves using sensor data to react to obstacles in real time, making immediate adjustments to the robot's speed or trajectory to avoid collisions.
- Limitations to this approach are that such robots, because they only look up actions for any sensory input, do not usually keep much information around, have no memory, no internal representations of the world around them, and no ability to learn over time.
- Example of reactive control is a light-chasing robot:

```
(behavior chase-light
  :period (1 ms)
  :actions ((set left-motor (right-sensor-value))
            (set right-motor (left-sensor-value))))
```

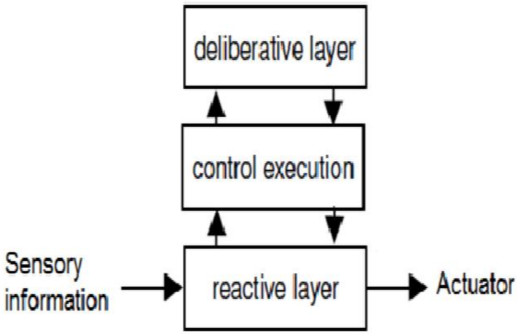


Deliberative Control

- Deliberative planning, on the other hand, involves using a pre-built map of the environment to plan a collision-free path to the robot's destination.
- This can take a long time. However, if there is time, this allows the robot to act strategically.
- The deliberative systems were also used in non-physical domains, such as playing chess.

Hybrid Control

- In hybrid control, the goal is to combine the speed of reactive control and the brains of deliberative control. In it, one part of the robot's "brain" plans, while another deals with immediate reaction, such as avoiding obstacles and staying on the road.
- By combining these two approaches, robots can balance the need for fast, reactive obstacle avoidance with the ability to plan ahead for more complex environments.



- The three-layer hybrid architecture is often known as hybrid architecture which uses higher level planning in order to guide the lower level of reactive components.
- The bottom layer is the reactive/behavior-based layer, in which sensors and actuators are closely coupled
- The upper layer provides the deliberative component such as planning and localisation.
- The control execution layer is responsible to supervise the interaction between the high level layer and low level layer / The control execution layer combines the speed of reactive control and the brains of deliberative control.

When we compare deliberative architectures with reactive architectures we observe that deliberative architectures work in a more predictable way, have a high dependency of a precise and complete model of the world, and they can generate optimized trajectories for the robot. On the other end, reactive architectures have a faster response to dynamic changes in the environment, can work without a model of the world, and are computationally much simpler. Finally, hybrid architectures try to present the best characteristics of the other two architectures.

Challenges involved in developing effective obstacle avoidance algorithms for robots.

- Obstacles can appear suddenly, and their size, shape, and location can vary widely.
- Robots must be able to make decisions in real time, taking into account their current speed and trajectory, as well as the proximity and movement of nearby obstacles.

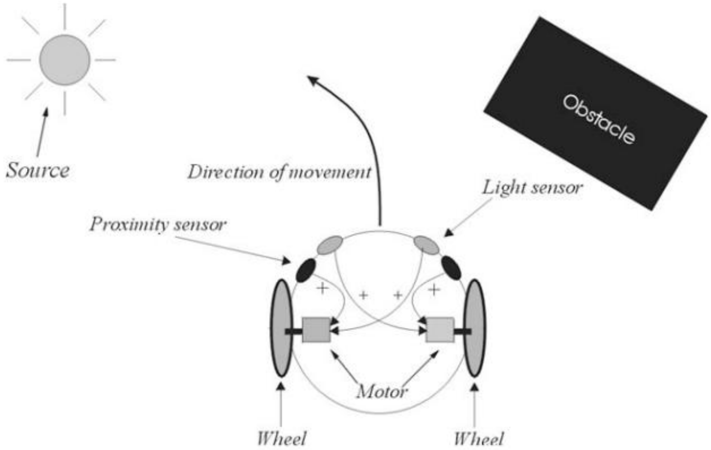
Pseudocode for a basic obstacle avoidance algorithm for a mobile robot

```
while True:
    sensor_data = read_sensor()
    min_distance = calculate_min_distance(sensor_data)
    if min_distance < safety_distance:
        obstacle_direction = calculate_obstacle_direction(sensor_data)
        turn_direction = -1 if obstacle_direction < 180 else 1
        turn_angle = turn_direction * max_turn_angle
        adjust_trajectory(turn_angle)
    move_forward(speed)
```

- Good paper for reading:
  Nakhaeinia, D., Tang, S.H., Noor, S.M. and Motlagh, O., 2011. A review of control architectures for autonomous navigation of mobile robots. *International Journal of Physical Sciences*, *6*(2), pp.169-174.

Braitenberg vehicle

A Braitenberg vehicle is a conceptual mobile robot in which simple sensors are connected directly to drive wheels.



The Braitenberg vehicle with two light sensors at the robot's front will be attracted to light and two proximity sensors beside the light sensors will turn the vehicle away from obstacles. After the Braitenberg vehicle has acquired the phototaxis competence, it can be taught to avoid obstacles as well. If the vehicle approaches the obstacle, the proximity sensor with a high proximity activation accelerates the motor on the sensor's side whereas this sensor slows down the motor on the opposite side. The presence of an obstacle leads to different motor speeds, which causes the vehicle to turn. The ability to move towards a light source is not lost by this. If not obstacle is detected and if the left half of the field of is brighter than the right half (by a certain threshold), then the robot should move left. If the right half of the field of is brighter than the left half (by a certain threshold), then the robot should move right. If both halves of the field of view are close to each other in brightness, then the Braitenberg should move straight ahead.

Brownouts typically happen when batteries are already running low, and the servos suddenly demand more power. The symptom is the programs will be restarted. When the program restarts the Boe-Bot will have different behaviour patterns meaning that the Boe-Bot will dance crazy or do other things it is not programmed to do.When the battery supply drops below the level normal level, the controller will reset. This can be detected using piezospeaker or buzzer each time the controller reset. The piezospeaker can create a tone that can indicate that a brownout has occurred. The FREQOUT command allows the piezospeaker to create a tone.

Human-Robot Interaction (HRI)

Human-Robot Interaction (HRI) is a field of study dedicated to understanding, designing, and evaluating robotic systems for use by or with humans. Interaction, by definition, requires communication between robots and humans.

According to Goodrich and Schultz (Goodrich and Schultz, 2007), the interaction between a human and robot are categorized into two. These include **remote interaction** and **proximate interaction**.

Remote Interaction

The human and the robot are not co-located and are separated spatially or even temporally (for example, the Mars Rovers are separated from earth both in space and time).

Proximate interaction

The humans and the robots are co-located (for example, service robots may be in the same room as humans).

Anthropomorphism

- Is the tendency to attribute human characteristics to inanimate objects, animals and others with a view to helping us rationalise their actions.
- Examples in cartoons (Disney being particularly prolific)



- You might be thinking that **anthropomorphism** sounds a lot like **personification**—and you're right. But here's the **difference**. With **anthropomorphism**, the object or animal is actually doing something human. With **personification**, the object or animal just seems like it's doing something human. You generally hear personification in poetry.
- For example: If you were to say: *My computer hates me*.

  Personification: Your computer does not actually hate you. We use this expression to mean that your computer isn't working at that particular moment.

  Anthropomorphism: Would be if your computer grew arms and legs, punched you in the neck, and stole your wallet…then it would ACTUALLY hate you.

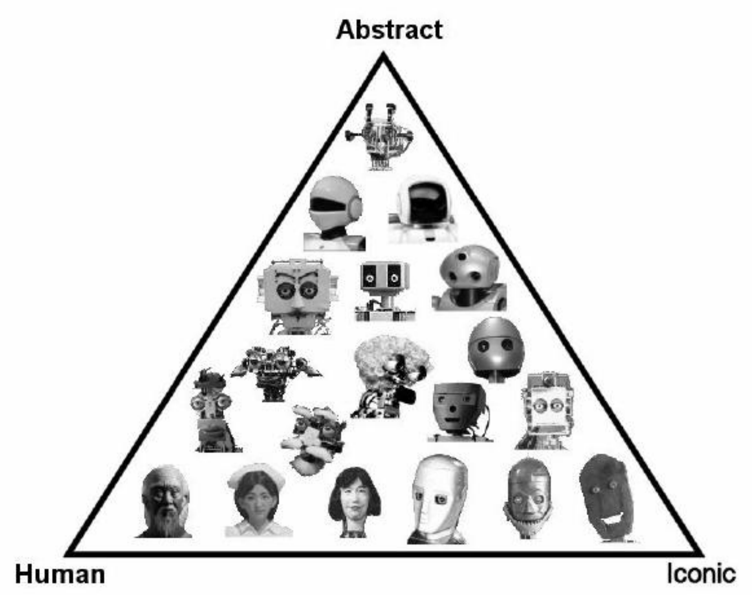


Figure 1: Anthropomorphism design space for robot heads. Notes: The diagram refers uniquely to the head construction and ignores body function and form. This is also by no means an exhaustive list. Examples were chosen to illustrate the proposed idea.

- Figure 1 provides an illustrative “map” of anthropomorphic features as applied to a design of existing robotic heads in the development of social relationships between a physical robot and people. The three extremities of the diagram (**human**, **iconic** and **abstract**) embrace the primary categorisations for robots employing anthropomorphism to some degree. “**Human**” correlates to an as-close-as-possible proximity replication of the human head. “**Iconic**” seeks a very minimum set of features as often found in comics that still succeeds in being expressive. The “**Abstract**” corner refers to more mechanistic functional design of the robot with minimal attention to humanlike aesthetics.

- In order to portray artificial emotional states, some utilise a strongly realistic humanlike construction (i.e. with synthetic skin and hair) for facial gestures. Building mannequin-like robotic heads, where the objective is to hide the “robotic” element as much as possible and blur the issue as to whether one is talking to a machine or a person, results in effectively unconstrained anthropomorphism. However, as Mori outlined with “The Uncanny Valley” (Mori, 1982), the closer the design and functionality of the robot comes to the human, the more susceptible it is to failure unless such a high degree of resolution is achieved that its distinction from a human becomes very difficult.

- You made the robot interact with you while working on your assignments.
  But how many of you:
  - Swore at your robot?
  - Complimented your robot?
  - Referred to your robot as he/she?
  - Gave your robot a name?

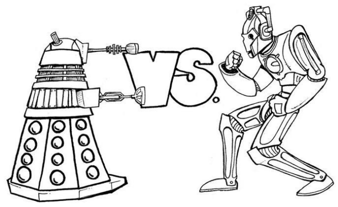
  Why?

- Good papers for reading:
  a) Duffy, B.R., 2003. Anthropomorphism and the social robot. *Robotics and autonomous systems*, *42*(3-4), pp.177-190.
  b) Złotowski, J., Proudfoot, D., Yogeeswaran, K. and Bartneck, C., 2015. Anthropomorphism: opportunities and challenges in human–robot interaction. *International Journal of Social Robotics*, *7*(3), pp.347-360.

won't come out

The "Uncanny Valley"

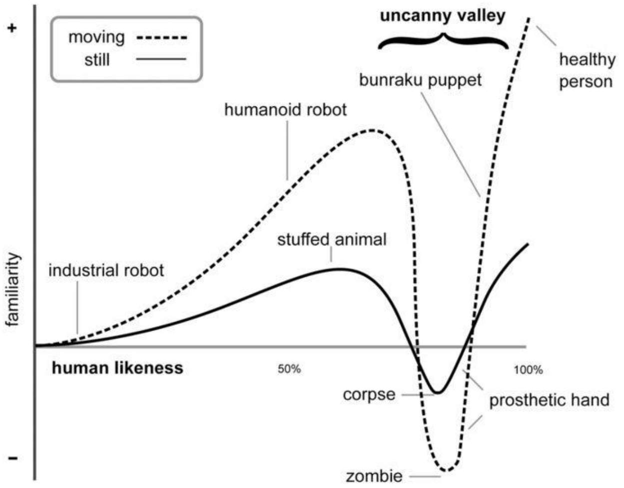
"These were robots in human form with distorted faces, and they gave my daughter nightmares. When I asked her why she was frightened of the Cybermen but not of the Daleks, she replied that the Cybermen looked like terrible human beings, whereas the Daleks were just Daleks."
— **Ann Lawrence**, writer for *The Morning Star* on *Doctor Who: The Tomb of the Cybermen*

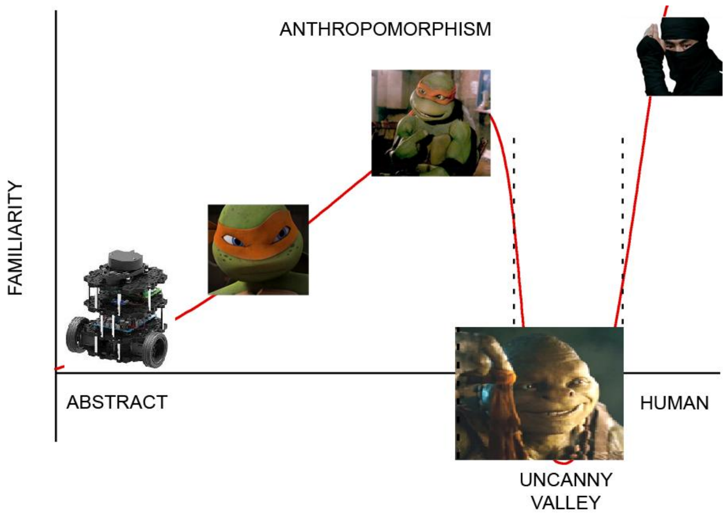


Dalek **Cyberman**

The term "uncanny valley" describes our strange revulsion toward things that appear nearly human, but **not quite right**. *The uncanny valley is a common unsettling feeling people experience when humanoid robots closely resemble humans in many respects but are not quite convincingly realistic*. This strange revulsion usually involves robots, but can also include computer animations and some medical conditions.

In 1970, Japanese roboticist Masahiro Mori proposed the "uncanny valley" hypothesis, which predicted a nonlinear relation between robots' perceived human likeness and their likeability as follows,





The uncanny valley is a psychological theory about the effect involving art and robots and human emotions. As something starts to look more human-like, there is a point at which people start to feel it looks wrong. At this point, they have negative feelings toward the object. These feelings keep getting worse as the object is made to look more human-like. The uncanny valley occurs because of mismatches between aspects of the robot's appearance and/or behaviour. At a certain point, as the object starts to get very close to looking human-like, how people feel towards it tend to reverse and they have more positive emotional feelings towards it.

The uncanny valley effect can be reduced by ensuring that a character's facial expressions match its emotive tones of speech, and that its body movements are responsive and reflect its hypothetical emotional state. Special attention must also be paid to facial elements such as the forehead, eyes, and mouth, which depict the complexities of emotion and thought.

To investigate the uncanny valley theory, a collection of video clips depicting robots of varying human similarity and at varying levels of sophistication are used in the experiment. Video clips but not still images are used because animated stimuli provide an even richer set of cues to evaluate the human likeness of given stimulus. These clips will be presented to participants. The clips and scales are randomized to prevent order effect. Participants will then be asked to rate these clips using human likeness, familiarity, and eeriness scales. From subjective ratings collected, statistical measures will be employed to determine whether the set of humanlike robots reflects an uncanny valley.