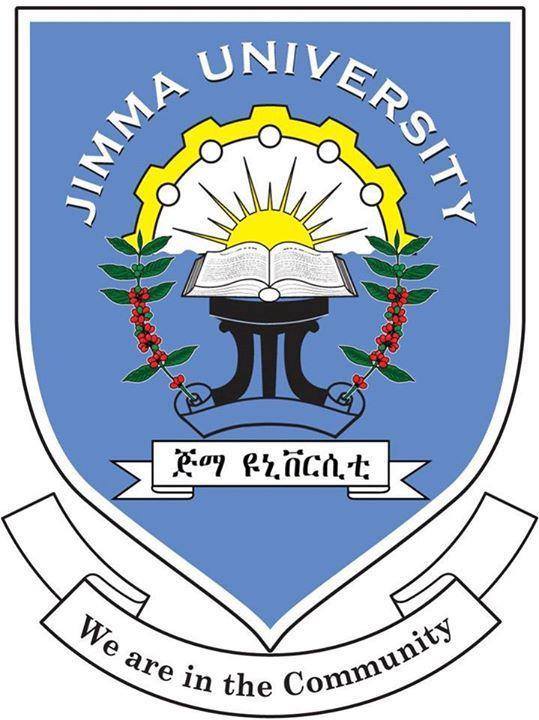
JIMMA UNIVERSITY



JIMMA UNIVERSITY INSTITUTE OF TECHNOLOGY

FACULTY OF COMPUTING AND INFORMATICS

PROGRAM: -DEPARTMENT OF COMPUTER SCIENCE

SECTION -2 GROUP-16

**Artificial Intelligence Assignment Report**

**on**

**Robots and Robot locomotion**

**Submitted By:**

**1) Sadesa Takele………………….Ru 2994/11**

**2) Misgana Chimdessa……………RU 2860/11**

**3) Abdulmuid Shafi………………..RU 3002/11**

**4 ) Banchigizie Beyene………………..RU 2791/11**

**May 10 2022**

**Submitted to: -MR Dessalegn**

**Faculty of Computing & Informatics, JIT, Jimma University, Jimma, Oromia, Ethiopia**

**CERTIFICATE**

This is to certify that the Assignment entitled Robots and Robot locomotion.

**Done By**

**Sadesa Takele**

**Misgana Chimdessa**

**Abdulmuid Shafi**

**Banchigize Beyene**

of 4th year I Semester BSC in the year 2022 in

partial fulfillment of the requirements for the award of Degree of

Bachelor of Science

# ACKNOWLEDGEMENT

Any task in the world cannot be accomplished on a sole basis. It directly or indirectly needs the support of their others. More than all, God is the top, continuance and higher supporter of every worker, developer, and designer or on whatever tasks. Thus, first of all we would like to give a secrete thank to our God who have been the first reason of us to reach on today and this level and who will take care of us on the left and future of our living life and our future working. Second, we would like to for thank our Teacher MR Dessalegn to give this chance. Third; we would like to give thank for our Group who help us by idea stand with us.

Contents

[ACKNOWLEDGEMENT 3](#_Toc103019018)

[Abstract 6](#_Toc103019019)

[1 CHAPTER ONE 7](#_Toc103019020)

[1.1 Introduction 7](#_Toc103019021)

[1.2 Robot Hardware 8](#_Toc103019022)

[1.2.1 Sensors 8](#_Toc103019023)

[1.2.2 Effectors 10](#_Toc103019024)

[1.3 ROBOTIC PERCEPTION 10](#_Toc103019025)

[1.3.1 Localization 10](#_Toc103019026)

[1.3.2 Mapping 11](#_Toc103019027)

[1.3.3 Other types of perception 11](#_Toc103019028)

[1.4 Planning to move 12](#_Toc103019029)

[1.4.1 Configuration space 12](#_Toc103019030)

[1.4.2 Cell decomposition methods 12](#_Toc103019031)

[1.4.3 Skeletonization methods 13](#_Toc103019032)

[1.5 PLANNING UNCERTAIN MOVEMENTS 13](#_Toc103019033)

[1.5.1 Robust methods 13](#_Toc103019034)

[2 CHAPTER TWO 14](#_Toc103019035)

[2.1. Introduction 14](#_Toc103019036)

[2.2 Legged Locomotion 14](#_Toc103019037)

[2.2.1 Stability 14](#_Toc103019038)

[2.2.2 Leg configuration 15](#_Toc103019039)

[2.2.3 One leg 16](#_Toc103019040)

[2.2.4 Two legs 16](#_Toc103019041)

[2.2.5 Four legs 17](#_Toc103019042)

[2.2.6 Six legs 17](#_Toc103019043)

[2.3 Wheeled Locomotion 17](#_Toc103019044)

[2.3.1 Wheel types 18](#_Toc103019045)

[2.4 Issues of wheeled locomotion 19](#_Toc103019046)

[2.4.1 Stability 19](#_Toc103019047)

[2.4.2 Maneuverability 19](#_Toc103019048)

[2.4.3 Controllability 19](#_Toc103019049)

[2.5 Examples of wheel configurations 19](#_Toc103019050)

[2.6 Other concepts 20](#_Toc103019051)

[2.6.1Tracked slip/skid locomotion 20](#_Toc103019052)

[2.6.2 Walking wheels 20](#_Toc103019053)

[3 Conclusion 20](#_Toc103019054)

[References 21](#_Toc103019055)

# 

# Abstract

A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks:

Robot locomotion is the collective name for the various method that robots use to transport themselves from place to place. The mechanism that makes a robot capable of moving in its environment is called as robot locomotion

# 1 CHAPTER ONE

**Robotics**

## 1.1 Introduction

Robots are physical agents that perform tasks by manipulating the physical world. 'To do so, they are equipped with effectors such as legs, wheels, joints, artd grippers. Effectors have a single purpose: to assert physical forces on the environment.' Robots are also equipped with sensors, which allow them to perceive their enviromment. Present day robotics employs a diverse set of sensors, including cameras and ultrasound to measure the environment, and gyroscopes and accelerometers to measure the robot's own motion.

Most of today's robots fall into one of three primary categories.

**Manipulators**, or robot arms, are physically anchored to their workplace, for example in a factory assembly line or on the International Space Station. Manipulator motion usually involves an entire chain d controllable joints, enabling such robots to place their effectors in any position within the workplace. Manipulators are by far the most common type of industrial robots, with over a million units installed worldwide. Some mobile manipulators are used in hospitals to assist surgeons. Few car manufacturers could survive without robotic manipulators, and some manipulators have even been used to generate original artwork.

The second category is the **mobile robot**. Mobile robots move about their environment using wheels, legs, or similar mechanisms. They have been put to use delivering food in hospitals, moving containers at loading docks, and similar tasks. Earlier we encountered an example of a mobile robot: the NAVLAB unmanned land vehicle (ULV) capable of driverless autonomous highway navigation. Other types of mobile robots include unmanned air vehicles (UAV), commonly used for surveillance, crop-spraying, and military operations, autonomous underwater vehicles (AUV), used in deep sea exploration, and planetary rovers, such as the Sojourner robot

The third type is a hybrid: a mobile robot equipped with manipulators. These include the humanoid robot, whose physical design mimics the human torso.

Hybrids can apply their effectors further afield than anchored manipulators can, but their task is made harder because they don't have the rigidity that the anchor provides. Real robots usually must cope with environments that are partially observable, stochastic, dynamic, and continuous. Some, but not all, robot environments are sequential and multiagent as well. Partial observability and stochasticity are the result of dealing with a large, complex world.

Real robots usually must cope with environments that are partially observable, stochastic, dynamic, and continuous. Some, but not all, robot environments are sequential and multiagent as well. Partial observability and stochasticity are the result of dealing with a large, complex world.

The robot cannot see around corners, and motion commands are subject to uncertainty due to gears slipping, friction, etc. Also, the real world stubbornly refuses to operate faster than real time. In a simulated environment, it is possible to use simple algorithms such as the Q-learning algorithm to learn in a few CPU hours from millions of trials. In a real environment, it might take years to run these trials. Furthermore, real crashes really hurt, unlike simulated ones. Practical robotic systems need to embody prior knowledge about the robot, its physical environment, and the tasks that the robot will perform so that the robot can learn quickly and perform safely.

## 1.2 Robot Hardware

### 1.2.1 Sensors

Sensors are the perceptual interface between robots and their environments. Passive sensors, such as cameras, are true observers of the environment: they capture signals that are generated by other sources in the environment. Active sensors, such as sonar, send energy into the environment. They rely on the fact that this energy is reflected back to the sensor. Active sensors tend to provide more information than passive sensors, but at the expense of increased power consumption and with a danger of interference when multiple active sensors are used at the same time. Whether active or passive, sensors can be divided into three types, depending on whether they record distances to objects, entire images of the environment, or properties of the robot itself.

Many mobile robots make use of range finders, which are sensors that measure the distance to nearby objects. One common type is the sonar sensor, also known as an ultrasonic transducer. Sonar sensors emit directional sound waves, which are reflected by objects, with some of the sound making it back into the sensor. The time: and intensity of this returning signal thus carry information about the distance to nearby objects. Underwater sonar sensors are the technology of choice for AUVs. On land, sonar sensor; are mainly used for near-range collision avoidance, due to their limited angular resolution.

Some range sensors measure very short or very long distances. Close-range sensors include tactile sensors such as whiskers, bump panels, and touch-sensitive skin. At the other end of the spectrum is the Global Positioning System (GPS), which measures the distance to satellites that emit pulsed signals. At present, there are two dozen satellites in orbit, each transmitting signal on two different frequencies. GPS receivers can recover the distance to these satellites by analyzing phase shifts. By triangulating signals from multiple satellites, GPS receivers can determine their absolute location on Earth to within a few meters. Differential GPS involves a second ground receiver with known location, providing millimeter accuracy under ideal conditions. Unfortunately, GPS does not work indoors or underwater.

The second important class of sensors is imaging sensors the cameras that provide us with images of the environment and, using the computer vision techniques, models and features of the environment. Stereo vision is particularly important in robotics, because it can capture depth information; although its future is somewhat uncertain as new active technologies for range imaging are being developed successfully.

The third important class is proprioceptive sensors, which inform the robot of its own state. To measure the exact configuration of a robotic joint, motors are often equipped with shaft decoders that count the revolution of motors in small increments. On robot arms, shaft decoders can provide accurate information over any period of time. On mobile robots, shaft decoders that report wheel revolutions can be used for odometry the measurement of distance travelled. Unfortunately, wheels tend to drift and slip, so odometry is accurate only over short distances. External forces, such as the current for AUVs and the wind for UAVs, increase positional uncertainty. Inertial sensors, such as gyroscopes, can help but cannot by themselves prevent the inevitable accumulation of position uncertainty.

Other important aspects of robot state are measured by force and torque sensors. These are indispensable when robots handle fragile objects or objects whose exact shape and location is unknown. Imagine a one-ton robotic manipulator screwing in a light bulb. It would be all too easy to apply too much force and break the bulb. Force sensors allow the robot to sense how hard it is gripping the bulb, and torque sensors allow it to sense how hard it is turning. Good sensors can measure forces in three translational and three rotational directions.

### 1.2.2 Effectors

Effectors are the means by which robots move and change the shape of their bodies. To understand the design of effectors, it will help first to talk about motion and shape in the abstract, using the concept of a degree of freedom (DOF). We count one degree of freedom for each independent direction in which a robot, or one of its effectors, can move

Sensors and effectors alone do not make a robot. A complete robot also needs a source of power to drive its effectors. The electric motor is the most popular mechanism for both manipulator actuation and locomotion, but pneumatic actuation using compressed gas and hydraulic actuation using pressurized fluids also have their application niches. Most robots also have some means of digital communication such as a wireless network. Finally, there has to be a body frame to hang all the bits and pieces on and a soldering iron for emergencies.

## 1.3 ROBOTIC PERCEPTION

Perception is the process by which robots map sensor measurements into internal representations of the environment. Perception is difficult because in general the sensors, are noisy, and the environment is partially observable, unpredictable, and often dynamic. As a rule of thumb, good internal representations have three properties: they contain enough information for the robot to make the right decisions, they are structured so that they can be updated efficiently, and they are natural in the sense that internal variables correspond to natural state variables in the physical world

### 1.3.1 Localization

Localization is a generic example of robot perception. It is the problem of determining where things are. Localization is one of the most pervasive perception problems in robotics, because knowledge about where things are is at the core of any successful physical interaction. For example, robot manipulators must know the location of objects they manipulate. Navigating robots must know where they are in order to find their way to goal locations.

The localization problem comes in three flavors of increasing difficulty. If the initial pose of the object to be localized is known, localization is a tracking problem. Tracking problems are characterized by bounded uncertainty. More difficult is the global localization problem, in which the initial location of the object is entirely unknown. Global localization problems turn into tracking problems once the object of interest has been localized, but they also involve phases where the robot has to manage very broad uncertainties. Finally, we can be mean to our robot and "kidnap" the object it is attempting to localize. Localization under such devious conditions is known as the kidnapping problem. Kidnapping is often used to test the robustness of a localization technique under extreme conditions.

### 1.3.2 Mapping

In robotics, one often seeks to localize many objects. The classical example of such a problem is that of robotic mapping. Imagine a robot that is not given a map of its environment. Rather, it has to construct such a map by itself. Clearly, humankind has developed amazing skills in mapping places as big as our entire planet. So, a natural problem in robotics is to devise algorithms that enable robots to do the same.

### 1.3.3 Other types of perception

Not all of robot perception is about localization and mapping. Robots also perceive the temperature, odors, acoustic signals, and so on. Many of these quantities can be estimated probabilistically, just as in localization and mapping. All that is required for such estimators are conditional probability distributions that characterize the evolution of state variables over time, and other distributions that describe the relation of measurements to state variables.

However, not all working perception systems in robotics rely on probabilistic representations. In fact, while the internal state in all our examples had a clear physical interpretation, this does not necessarily have to be the case.

The trend in robotics is clearly towards representations with well-defined semantics. Probabilistic techniques outperform other approaches in many hard-perceptual problems such as localization and mapping.

## 1.4 Planning to move

In robotics, decisions ultimately involve motion of effectors. The point-to-point motion problem is to deliver the robot or its end-effector to a designated target location. A greater challenge is the compliant motion problem, in which a robot moves while being in physical contact with an obstacle. An example of compliant motion is a robot manipulator that screws in a light bulb, or a robot that pushes a box across a table top.

We begin by finding a suitable representation in which motion planning problems can be described and solved. turns out that the configuration space the space of robot states defined by location, orientation, and joint angles is a better place to work than the original 3D space. The path planning problem is to find a path from one configuration to another in configuration space. in robotics, the primary characteristic of path planning is that it involves continuous spaces. The literature on robot path planning distinguishes a range of different techniques specifically aimed at finding paths in high-dimensional continuous spaces. The major families of approaches are known as cell decomposition and skeletonization.

### 1.4.1 Configuration space

The first step towards a solution to the robot motion problem is to devise an appropriate problem representation. It turns out to be easier to plan with a configuration space representation. Instead of representing the state of the robot by the Cartesian coordinates of its elements, we represent the state by a configuration of the robot's joints.

The second problem with configuration space representations arises from the obstacles that may exist in the robot's workspace.

### 1.4.2 Cell decomposition methods

Our first approach to path planning uses cell decomposition that is, it decomposes the free space into a finite number of contiguous regions, called cells. These regions have the important property that the path planning problem within a single region can be solved by simple means (e.g., moving along a straight line). The path planning problem then becomes a discrete graph search problem, very much like the search problems.

### 1.4.3 Skeletonization methods

The second major family of path-planning algorithms is based on the idea of skeletonization. These algorithms reduce the robot's free space to a one-dimensional representation, for which the planning problem is easier. This lower-dimensional representation is called a skeleton of the configuration space.

## 1.5 PLANNING UNCERTAIN MOVEMENTS

None of the robot motion planning algorithms discussed thus far addresses a key characteristic of robotics problems: uncertain. In robotics, uncertainty arises from partial observability of the environment and from the stochastic (or unmodeled) effects of the robot's actions. Errors can also arise from the use of approximation algorithms such as particle filtering, which does not provide the robot with an exact belief state even if the stochastic nature of the environment is modeled perfectly. Ignoring uncertainty in this way works when the uncertainty is small.

Unfortunately, ignoring the uncertainty does not always work. In some problems the robot's uncertainty is simply too large. If the robot only faces uncertainty in its state transition, but its state is fully observable, the problem is best modeled as a Markov Decision process, or MDP. The solution of an MDP is an optimal policy, which tells the robot what to do in every possible state. In this way, it can handle all sorts of motion errors, whereas a single-path solution from a deterministic planner would be much less robust in robotics, policies are usually called navigation functions

### 1.5.1 Robust methods

Uncertainty can also be handled using so-called robust methods rather than probabilistic methods. A robust method is one that assumes a bounded amount of uncertainty in each aspect of a problem, but does not assign probabilities to values within the allowed interval. A robust solution is one that works no matter what actual values occur, provided they are within the assumed interval. An extreme form of robust method is the conformant planning.

# 2 CHAPTER TWO

**ROBOT LOCOMOTION**

## 2.1. Introduction

A mobile robot needs locomotion mechanisms to make it enable to move through its environment. There are several mechanisms to accomplish this aim; for example, one, four, and six-legged locomotion and many configurations of wheeled locomotion. The focus of this elaboration is legged and wheeled locomotion.

Legged robot locomotion mechanisms are often inspired by biological systems, which are very successful in moving through a wide area of harsh environments. for example, the six-legged walking of a stick insect, which is often a paradigm for six legged robots. But it is very difficult to copy these mechanisms for several reasons. The main problems are the mechanical complexity of legs, stability and power consumption. Wheels are a human invention and a very popular locomotion concept in man made vehicles. Most mobile robots are legged or wheeled.

## 2.2 Legged Locomotion

A legged robot is well suited for rough terrain; it is able to climb steps, to cross gaps which are as large as its stride and to walk on extremely rough terrain where, due to ground irregularities, the use of wheels would not be feasible. To make a legged robot mobile each leg must have at least two degrees of freedom (DOF). For each DOF one joint is needed, which is usually powered by one servo. Because of this a four-legged robot needs at least eight servos to travel around.

## 2.2.1 Stability

Stability is of course a very important issue of a robot, because it should not overturn. Stability can be divided into the static and dynamic stability criterion.

Static stability means that the robot is stable, with no need of motion at every moment of time. Static stability is given, when the Centre of mass is completely within the support polygon and the polygon’s area is greater than zero, therefore static stability requires at least three points of ground contact.

To achieve statically stable walking a robot must have a minimum number of four legs, because during walking at least one leg.

is in the air. Statically stable walking means that all robots’ motion can be stopped at every moment in the gait cycle without overturning. Most robots which are able to walk static stable have six legs, because walking static stable with four legs means that just one leg can be lifted at the same time (lifting more legs will reduce the support polygon to a line), so walking becomes slowly.

Most two-legged walking machines are dynamically stable for several reasons. Human like robots have relatively small footprints, because of this the support polygon is almost a line (in the double support phase, when both foots are connected with the ground) which is even reduced to a single point (in the single support phase, when just one foot has ground contact) during walking. Therefore, the robot must actively balance itself to prevent overturning.

## 2.2.2 Leg configuration

To move a leg forward at least two degrees of freedom are required, one for lifting and one for swinging. Most legs have three degrees of freedom; this makes the robot able to travel in rougher terrain and to do more complex maneuvers

If the robot has more than one leg there is the issue of leg coordination for locomotion. The total number of possible gaits in which a robot can travel depends on the number on legs it has. The gait is a periodic sequence of lift and release events for each leg. If a robot has k legs the number of possible events N is, accordant to [1],

N=(2k-1)!

In case of a bipedal walking machine (k=2) the number of possible events is

N=(2k-1)! = (2\*2-1)! = 3! = 6

So, there are six possible different events, these are

1. Lift left leg

2. Release left leg

3. Lift right leg

4. Release right leg

5. Lift both legs together

6. Release both legs together

In case of k=6 legs there are already 39916800 possible events, in face of that, controlling a six-legged robot is because of the large number of possible events more complex than controlling a two-legged robot.

## 2.2.3 One leg

One leg is of course the minimum number of legs which a legged robot can have. A smaller number of legs reduces body mass of the robot and no leg coordination is needed. One-legged locomotion requires just a single point of ground contact; this makes the robot amenable to travel the roughest terrain. As an example, the robot is able to overcome an obstacle like a gap that is larger than its stride by talking a running start. A multi legged robot that cannot run is just able to cross gaps that are as large as its reach. But the single point of ground contact offers the main problem for single legged robots – stability. Static stability is impossible even when the robot is stationary, because the support polygon is reduced to a single point. So singled legged robots must be dynamically stable, that means that the robot has to actively balance itself either by changing its Centre of gravity or by imparting corrective forces. One of the first successful one-legged robots was the one leg hopper.

## 2.2.4 Two legs

Two legged robots are already able to walk, run, jump, dance and travel up and down stairs, but stability is still a problem for bipedal robots, because they have to be dynamically stable. There is no general algorithm to solve the problem of dynamic stability for bipedal robots; often used approaches are based on the zero-moment point (ZMP). Examples of robots using this approach are QRIO and Asimo.

The rudiment idea of this approach is to maintain balance by planning footprint positioning. The ZMP is the point where the robot has to base on to keep its balance. When the robot should move forward it has first to compute the ZMP and after that it has to step the appropriate leg exactly to the computed position.

One benefit of a two-legged locomotion is that the total weight of the robot is reduced due to fewer legs (a six-legged robot has much more leg mass and because of this more body mass), but this advantage creates another problem. Each leg must have sufficient capacity to support the full weight of the robot, in case of four or six legged robots the weight of the robot’s body is distributed to more legs. An important feature of bipedal robots is their anthropomorphic shape, they can be built in human like dimensions, which makes them predestinated for research in human robot interaction.

## 2.2.5 Four legs

Most four-legged robots use dynamic stable walking (like nearly all four-legged animals), because static stable walking requires at least three points of ground contact. This means that just one leg can be lifted at the same time and so walking becomes slowly; in case of dynamic stability the number of ground contact points can vary from zero, when the robot is jumping, to the total number of legs, when the robot is stationary. One possible dynamic stable gait of Titan VIII is a trot gait, where the two diagonal legs are lifted at the same time.

## 2.2.6 Six legs

Six-legged locomotion is the most popular legged locomotion concept because of the ability of static stable walking. The most used static stable gait is the tripod gait, where each times the two exterior legs on the one side and the inner leg of the other side are moved together. Due to the possibility of static stable gaits the control complexity is reduced on the one hand, because there is no issue of stability control in general, but on the other hand most six legged robots legs have three degrees of freedom and six legs have to be controlled, so leg coordination becomes more complex Six legged robots are often inspired by nature, two examples of such robots are Lauron and Genghis.

## 2.3 Wheeled Locomotion

The most popular locomotion mechanism in man made vehicles is wheeled locomotion; so it is not surprising that it is often used in mobile robotics. Reasons for this are the easy mechanical implementation of the wheel, there is no need of balance control if the vehicle has at least three or in some case two wheels and wheeled locomotion is relatively power efficient, even at high speed. The problems of wheeled robots are different from the problems of legged robots, as mentioned before, stability is not such a profoundly problem like it is in legged locomotion, but there are some others. The focus of research in wheeled robotics is on traction and stability in rough terrain, maneuverability and control.

### 2.3.1 Wheel types

In general, there are four major classes of wheels

the standard wheel with two degrees of freedom, these are rotation around the wheel axle and around the contact;

the castor wheel with two degrees of freedom, rotation around the wheel axle and the offset steering joint

the Swedish 45° and Swedish 90° or omni wheel, which has three degrees of freedom: rotation around the contact point, around the wheel axle and around the rollers.

the Ball or spherical wheel, this wheel is omnidirectional, but it is technical difficult to implement.

The main advantages of the standard and the castor wheel are the easy implementation, the high load capacity and the high tolerance to ground irregularities. But these wheels are not inherently omnidirectional, to make a vehicle using these wheels steerable, the steerable wheel(s) (depends on the wheel configuration of the vehicle) must be steered first along a vertical axis and the moved around a horizontal axis. So especially in case of heavy vehicles and when it is not moving during steering this steering method cause’s high friction and scrubbing during steering as the wheel is actively twisted around its vertical axis, this increases the power consumption and reduces the positioning accuracy of the vehicle.

The Swedish wheel functions as a normal wheel, but it has little passive rollers around the circumference. These rollers provide low resistance in another direction as well, depending on the angle in which the rollers are arranged, so the wheel is able to roll smoothly in any direction. The wheels’ primary axis serves as the only actively powered joint, but it is possible to design with these wheels’ holonomic omnidirectional robots; how this can be done is shown later.

The spherical wheel is a real omnidirectional wheel. There are several implementations of spherical wheels. One of this is the ball wheel mechanism which was developed by West and Asada in 1997.

In the ball wheel design power from a motor is transmitted through gears to an active roller ring and then to the ball via friction between the rollers and the ball. Due to the rollers, fixed at the roller ring and the chassis, the ball is able to roll passively in any direction.

When designing a wheeled robot, the developer has the choice of several different wheel arrangements and wheel types. The combination of wheel type and arrangement is strongly linked and governs the stability, maneuverability and controllability of the robot.

## 2.4 Issues of wheeled locomotion

### 2.4.1 Stability

As mentioned before the minimum number of wheels required for static stability is two. A robot with a two wheeled differential drive can achieve stability if the Centre of mass is below the wheel axle or if there is a third point of contact striking the floor. But these are some special cases; under normal circumstances a wheeled robot needs at least three wheels with ground contact to achieve static stability, additionally the Centre of gravity has to be completely within the support polygon, formed by the three wheels with ground contact.

### 2.4.2 Maneuverability

Maneuverability is a very important issue for a wheeled robot to solve its tasks. When a robot is able to move in any direction of the ground plane (x y) it is omnidirectional. This level of movement requires usually actively powered wheels that can move in more than one direction like Swedish or spherical wheels

### 2.4.3 Controllability

The advantage of omnidirectional designs is the high maneuverability of the robot, but this advantage makes it more difficult to control the robot.

## 2.5 Examples of wheel configurations

some different examples of wheel configurations

The synchro drive that is often used for indoor robots.

This mechanism consists of three steerable wheels arranged in a triangle. All wheels are driven and connected by a single belt which is actuated by one motor, thereby this single motor sets the speed of all wheels together.

## 2.6 Other concepts

Wheeled and legged locomotion are the most used and investigated locomotion mechanisms for mobile robots. But there are some other concepts, two of them are tracked slip/skid locomotion and a combination of wheeled and legged locomotion.

### 2.6.1Tracked slip/skid locomotion

Wheeled locomotion offers some disadvantages, especially in case of omnidirectional vehicles using spherical or Swedish wheels, in rough, loose terrain, due to the increasing rolling friction which causes power inefficiencies. In tracked slip/skid locomotion vehicles using tracks like a tank, one example of a robot using this concept is the Nanokhod robot which probably will go to mars. A tracked vehicle is steered by moving the tracks with different speed in the same direction or in opposite direction.

The use of tracks offers a much larger area of ground contact, so the vehicles traction on loose surface is much better than the traction of wheels, furthermore the vehicle is able to drive through rougher terrain than wheeled vehicles are (it is for example able to cross larger gaps).

### 2.6.2 Walking wheels

Legged robots are able to climb stairs and travel through rough terrain, but they offer some inefficiencies on flat surface and controlling the robots is difficult. Wheeled robots are very energy efficient on hard surface, even at high speed, but most of them are surely not able to climb stairs. One idea is a hybrid solution which combines the advantages of legged and wheeled locomotion

# 3 Conclusion

* Robots are equipped with sensors for perceiving their environment and effectors with which they can assert physical forces on their environment. Most robots are either manipulators anchored at fixed locations or mobile robots that can move.
* Robotic perception concerns itself with estimating decision-relevant quantities from sensor data. To do so, we need an internal representation and a method for updating this internal representation over time. Common examples of hard perceptual problems include localization and mapping.
* Probabilistic filtering algorithms such as Kalman filters and particle filters are useful for robot perception. These techniques maintain the belief state, i.e., a posterior distribution over state variables.
* The planning of robot motion is usually done in configuration space, where each point specifies the location and orientation of the robot and its joint angles.
* When developing a robot, it is the designer’s task to analyze the terrain in which the robot will travel and what the robot has to do there. According to this analysis the robot’s locomotion mechanism can be chosen
* Furthermore, there is, especially in legged locomotion, a large requirement of research, to make robots faster, more energy efficient, stable and maneuverable.

# References

* Artificial Intelligence A Modern Approach Second Edition
* S. Roland, Introduction to autonomous mobile robots. 12-45, 2004
* M. Vukobratovic, B. Borovac, Zero Moment Point – Thirty-five years of its life, International Journal of Humanoid Robotics vol. 1, pp. 157–173, 2004
* E. Cuevas, D. Zaldivar, R. Rojas, Walking trajectory control of a biped robot, Technical report, Freie Universität Berlin, 2004
* E. Cuevas, D. Zaldivar, R. Rojas, Walking trajectory control of a biped robot, Technical report, Freie Universität Berlin, 2004 http://www.ai.mit.edu/projects/leglab/robots/Spring\_Flamingo/Spring\_Flamingo.html
* <http://www.sony.net/Products/aibo/>
* M. Wada, H.H. Asada, Design and control of a variable footprint mechanism for holonomicomnidirectional vehicles and its application to wheelchairs, Robotics and Automation, Volume: 15, pp. 978-989
* <http://asl.epfl.ch/index.html?content=research/systems/Shrimp/shrimp.php>
* http://asimo.honda.com/