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Eight-Legged Robot using Theo Jansen Mechanism

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Abstract

Purpose: Important developments have been occurred in the history of science and technology. Among them, the concept and application of robots with each passing year are a larger place. Different types of mechanisms are used in construction of robot according to modern application. In this Theo Jansen mechanism is implement in robot.

These kinetic sculptures are designed to be a fusion of art and engineering. Inspired from nature and bearing an uncanny resemblance to the movement of animals, these mechanisms are built using an array of triangles and connecting links that convert the rotation of an axle into the stepping motion of eight limbs.

Design: First, models the Theo Jansen mechanism using 3D computer model by intelligent inspiration of biological principles. Then, based on this model, it develops the prototype of the legs of robot through acrylic cutting.

Findings: A motion mechanism is used and only two motors are used for driving the system through microcontroller.

Originality: The modelled legged robot is original in terms of the developed motion mechanism.

Introduction

Nature's Inspirations for Legged Locomotion Systems:

Many animals in nature have adopted legs for various environmental conditions. Centipedes, spiders, cockroaches, cats, camels, kangaroos, and human are among those, either with different number of legs or with different kind of walking. It is understandable that people turned their attention to those walking animals, after it was recognized that the human invented wheeled and tracked systems did not satisfy all the needs. In this sense, legged systems have a peculiarity of imitating the nature.

This imitation is obvious in structural similarity between legged robots and imitated animals; however, for today the imitation is not limited to structural design. Today researchers are trying to understand the underlying biological principles of walking in animals, namely the operational and control structures. In biological sciences and robotics applications the most important item is the plan and coordination of leg movements. Movement is a fundamental distinguishing feature of animal life. The locomotion over a surface by means of limbs or legs can be defined as walking whatever are the number of limbs or legs that are used different ways of walking have been achieved by the evolutionary process in nature.

The plan of walking, namely the "gait pattern", determines the sequence of stepping of legs with their stance and swing durations in each step. Mahajan steal (1997) gives the following definition for gait: "The gait of an articulated living creature, or a walking machine, is the corporate motion of the legs, which can be defined as the time and location of the placing and lifting of each foot,

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coordinated with the motion of the body, in order to move the body from one place to another." Animal gaits can be divided into two main groups as statically stable and dynamically stable.

It introduces more flexibility and terrain adaptability at the cost of low speed and increased control complexity. In order to develop dynamic model and control algorithm of legged robots, it is important to have good models describing the kinematic behaviour of the complex multi-legged robotic mechanism as walking machines are increasingly gaining importance in space for planetary exploration, where the terrain is rugged thus reducing the expensive and dangerous extra vehicular Activities by Astronauts. Walking machines find wide range of applications like in military logistic support where there are no highways

Legged locomotion is a proper solution for movements on loose-rough-uneven terrains. This advantage of legged locomotion is mostly due to the fact that legged systems use isolated footholds. Wheeled and tracked systems follow the surface in a continuous manner; therefore, their performance is limited by the worst parts on the terrain. A legged system, on the other hand, can choose the best places for foot placement. These footholds are isolated from the remaining parts; hence the performance of the legged system is limited by the best footholds. Besides using isolated footholds, the legged system can provide active suspension, which does not exist in wheeled or tracked systems. This means that the system can have control on the force distribution through the foothold points. In this way an efficient utilization of the footholds provides further improvement of the vehicle-ground interaction. A legged system is well adaptive to uneven terrains, namely the legs can be arranged (lengthened and shortened according to the level changes, and they can jump over obstacles or holes. Therefore, the body can be moved in a desired orientation,

The legged locomotion is disadvantageous considering the system control and energy consumption. Legged mechanisms have complicated kinematics and dynamics, and a lot of actuators have to be controlled in continuous coordination; therefore, control of legged systems is more difficult in comparison to wheeled and tracked systems. Since they are comparatively novel development, there are no well-established technologies for legged systems

This Project work is concerned with a mechanism that lent itself for a mechanical walking machine, describing the new mechanism. Qualitatively and mathematically. The method of solving both the kinematics of the various links in the linkage and also provided a method of investigating the forces within the mechanism as it moves.

There has been much research into walking as a means of locomotion. Many designs of machine using a variety of means of obtaining foot motion have been developed over the years. If a new class of mechanism is worth considering, it needs to be located in the context of the other solutions attempted. The advantages of a new method must be demonstrated not only in relation to alternative designs for walking machines, but also in relation to other forms of overland locomotion, especially wheels and tracks.

OBJECTIVE OF THE WORK

The primary goal of this thesis is to create a suitable theoretical framework to justify the design choices for a new type of walking machine.

There is another aim. Another aim is to use this design opportunity to develop methods to automate complex parameter related designs. These methods, once developed, could be later extended to optimize other aspects of the design.

WALKING MECHANISM AND MACHINES

Although it seems that the earliest walking machines were manufactured in the 1960's, in fact small toys, automata, have been manufactured in Europe since the 18th century, including bipedal walkers that became the inspiration of modern passive dynamic bipeds, such as the Cornell Biped etc.

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Subsequent to this early period, research into walking machines has been extremely active. Machines have been constructed on many scales, from some the size of insects, to some the size of small trucks. There are many sites on the internet which have extensive lists of walking machines The number and creativity of different methods of inspiring from all animals do so easily is staggering. Many possible walking mechanisms, from enormous two footed drag line excavators, to twelve-legged steam powered experimental prototypes have been attempted.

Classification

The Walking machines are classified into groups according to the number of legs they have. Animals too are classified on this basis, like bipeds (humans and birds), quadrupeds (mammals and reptiles), hexapods (insects), octopods (arachnids) or polypods (caterpillars, centipedes and millipedes).

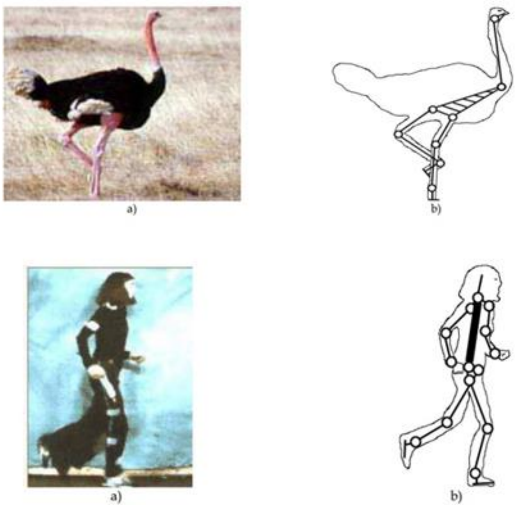

Fig 2.1.1

The number of legs has a major impact on the physics of walking. To maintain a structure's position in a three-dimensional space requires three points of support. If a machine has fewer than three legs, it is said to be dynamically balancing. In other words, the walker must have some mechanism to vary the position of its centre of gravity in relation to its foot position, to prevent it falling over. Machines with three or more legs continuously in contact with the ground are said to be statically balanced, they may maintain their centre of gravity at any constant position, providing the vertical projection of this centroid is within the polygon constructed by connecting the foot points on the support plane. This polygon is known as the "support polygon" and would be triangular for a tripod or some form of quadrilateral for a quadraped.

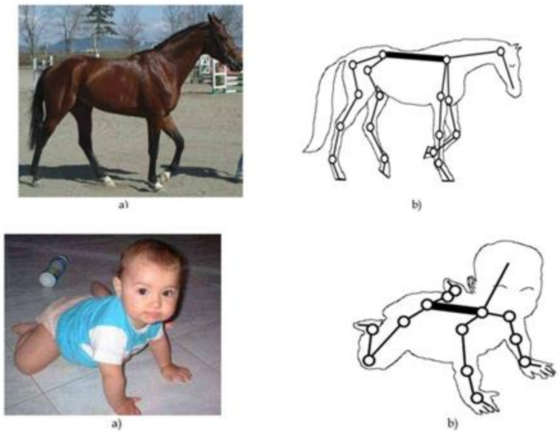

Fig 2.1.2

2.1.1 BIPEDS

The Honda robot (Figure) and the Centaurob (Figure) are examples of this configuration. Bipeds are usually anthropomorphic. They attempt to mimic the human mode of locomotion. In most gaits that humans use to move, the foot of one leg is always on the ground. The other leg is lifted, and in the process of moving to a suitable position for the next footfall. So, walking in humans equates to the balancing of a weight on a single column which is unconstrained in any dimension except its height. To maintain stability, the walking human or machine must ensure that their centre of gravity lies vertically above their footprint. As the legs and feet are usually arranged to lie side by side, the walker must move their centroid laterally by the size of the transverse pitch between the feet. This is the

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approach taken by humans and other natural bipeds, and also by the Honda robot.

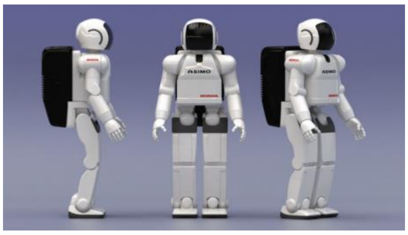

Fig 2.1.1.1

Another approach, as typified by the Centaurob, is to make the feet so large that their footprint is large enough to enclose a fixed centroid. Hence the annular shape of the feet on this machine. This is also the method used by walking drag lines. Some reduced lateral movement of the centroid may be required even with large feet.

Fig 2.1.1.2

Both of these approaches to maintaining stability have limitations. Active balancing requires a system to move the body, and sensors to detect position or imminent falling over and some type of response system to make corrections, in short, a control system. This control system makes any dynamically balanced walker complicated to design and implement. In large footed bipedal walkers, the size of the feet may limit where the machine can place them. Such a machine would also be relatively unstable, as the centroid location must be kept within a small range of positions, to ensure that it is always within the footprint. Any small changes in centroid position may make the walker topple over. This type of walker is only capable of walking on very flat surfaces, as any inclination or wobble in the foot can shift the centroid outside the footprint.

Fig 2.1.1.3

Most recently much attention has been given to passive, dynamic walkers. In this type of machine, as typified by the Cornell biped (Figure 6), the legs are not powered, and the biped is dynamically balanced. The main advantages of this configuration are low power consumption, humanoid appearance and negligible foot impact forces. Although this robot has knees, it would be incapable of negotiating everyday obstacles such as stairs.

2.1.2 QUADRAPEDS

Quadrupeds may also be dynamically or statically balanced. The balancing condition depends on the duty cycle of the leg mechanism. If each individual leg can be moved fast enough, the quadruped may maintain three legs supporting the body at all times, as shown in the walking truck (Figure). This type of gait will be statically balanced and a balance control system can be dispensed with. The disadvantage is that the leg mechanism must have fast action, in order to move the foot to the new foot placement position in 25% of the step time. This may be difficult to implement.
quadrupeds may also have gaits where only two legs support the body. These gaits all require balance control to ensure stability.

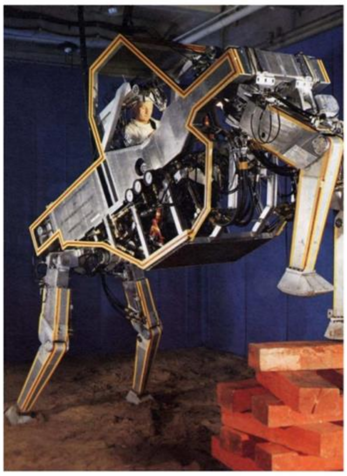

Fig 2.1.2

2.1.3 HEXAPEDS

Six legs are the minimum required to ensure static balancing with leg mechanisms with a symmetrical duty cycle, that is, where the return part of the cycle is the same duration as the walking part. Three legs can be in the walking phase of their cycle, while the additional three legs are moving along their return trajectory. This configuration has the twin advantages that it requires no balance control system, and the leg mechanism's movement can be more easily achieved due to the relative similarity between walking and return phases.

Fig 2.1.3

The triangular shape of the support polygon for each tripod means that a rigid legged walker will be completely fixed in space once the legs are in contact with the ground. There would be no rocking, and the orientation of the walker body can be determined completely from knowledge of the terrain, which may vary from planar. Rough terrain can be tolerated with a symmetric gait. Hexapods are a common and popular configuration amongst research groups, as the elimination of balance control simplifies the design of the machine significantly. The main problem with hexapods walkers is the complexity of the additional legs. In electrically controlled and individually actuated legs, this overhead may be considerable.

2.1.4 OCTAPEDS

Walkers with eight legs may maintain four legs on the ground at all times, and have four legs in the return stroke. The support polygon is a quadrilateral, with an area approximately twice that of the triangular support polygon of the hexapod with the same leg-base and track. This makes the vehicle much more capable of tolerating uneven walking surfaces, as the centroid position projection has a much greater locus of stable positions.

Fig 2.1.4

However, if the legs are non-compliant, the potential for a rocking condition can occur. This would occur on an uneven surface, where three legs find purchase, but rigidity of leg and frame prevents the fourth from reaching the surface. If the centroid changes position, due perhaps to leg movement, the walker body may shift weight onto the free leg, causing it to move ground ward, simultaneously lifting the leg which was on the ground before. The body would experience a rapid rocking motion, and perhaps some impact as the foot hits the ground. This could be dubbed the "restaurant table" effect.

2.1.5 MORE THAN EIGHT LEGS

Although walking machines have been designed with more than eight legs, these machines are rare. The extra complication of the extra legs does not usually create sufficient stability benefits to make the complication worthwhile.

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Fig 2.1.5

The overall layout of the walking machine will be determined by the number of legs it has, and how it uses them to travel. However, there is more than this required to make a practical walker, as described in the following section.

MECHANICAL DESIGN OF WALKING MACHINES

Although the superstructures of walking machines can be innovative, generally it is the legs that are of most interest. In spite of the wide variety of walker types, the mechanical principles that the legs use are remarkably limited. The vast majority of walking machines have leg mechanisms that are effectively pantographs. In natural walkers too, if muscle/ligament assemblies are considered as extensible links, the pantograph is also the dominant mechanism.

Pantographs

The reason that pantographs are so ubiquitous is their simplicity and versatility. They are a form of four bar linkage, which in the usual configuration, where point O is fixed, have the interesting property that whatever the kinematic motion experienced by the point A in Figure below, it is mimicked by point E, in an amplified form. The amplification or scaling factor depends on the proportions of the links.

The pantograph is a two degree of freedom mechanism - to completely define its position requires knowledge of two parameters. In this case, the x and y coordinates of the driving point A are required to be known, before the position of the foot, E, can be determined.

Although this property of pantographs is used to create a suitable foot trajectory, there are other modes of operating the pantograph. The motion of point E is determined by moving point A horizontally and Point O Vertically. This leg Mechanism is effective to propel the adaptive suspension system successfully but this method suffers from requiring two actuators per leg.

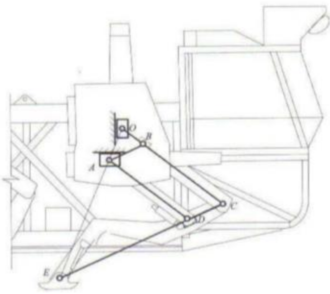

Fig 2.2.1

This limitation is common to most of the pantograph-based leg mechanisms. a further limitation of this design is that some leg kinematic control system must be implemented to determine the trajectory of the foot point. This control system usually incorporates ground sensing and must have kinematic control to maintain the vehicle body position in relation to the ground.

Another attempt to use a pantograph leg in a simple walker is that shown in figure below

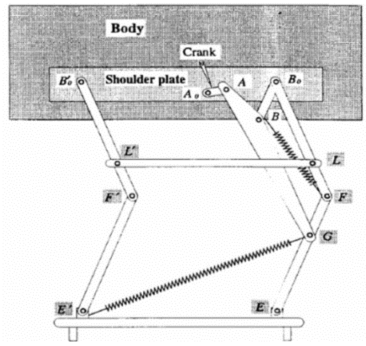

Fig 2.2.2

In this design the follower point of the pantograph is attached to a four-bar chain at point-B. The four bar linkage comprises the link AOA, AB, BBO with the link AOB being fixed. The link BBO is common to both the four bar mechanism and the pantograph.

The major advantage of this layout is that the leg can now be powered by a single rotary actuator per leg - the two degree of freedom pantograph is effectively reduced to a single degree of freedom mechanism, as the coupler point trajectory fully defines a two dimensional curve. Another advantage is that the foot point trajectory is determined by the four bar chain's coupler point motion. The motion of this point can be synthesized to completely define a suitable foot point trajectory. The need for foot trajectory control and ground sensing functions is removed.

2.2 DRIVES AND POWER SUPPLY

Most of the walking machines described in previous sections are laboratory prototypes. Many of them are electrically powered, and have tethers or connecting cables through which power and sometimes control information can be supplied.

Although the limbs are operated by pneumatic or hydraulic actuators, the pneumatic compressors or hydraulic pumps are driven by internal combustion engines. Some electric vehicles may carry their power source in the form of batteries. The range of possible motive power sources for walking machines is limited by similar factors to those that limit motor vehicle power sources, primarily energy density. The weight of fuel or stored energy in battery form and the weight of the structure and drive systems needs to be minimized, as transporting the weight of the vehicle is the main consumer of power.

One of the most notable disadvantages of most walking machine prototypes is their energy inefficiency. Due to a combination of high weight, numerous actuators, conversion losses, sensor and control system power, these machines are much less efficient than wheeled vehicles and especially biological walkers. Though the efficiency of animals is a remote target, it may be possible to design a walking machine with energy consumption per distance travelled similar to that obtained for wheeled off-road vehicles.

ADVANTAGES OVER WHEELS OR TRACKS

Walking vehicles have many advantages over wheeled or tracked vehicles. These may be listed as follows:

Contact with the ground at discrete points

The rims of wheels have continuous contact with the ground over which they travel. Walking machines place their feet, and once placed, frictional forces prevent further movement of the foot and movement is confined within the linkage system of the leg. The dynamics of the vehicle body is determined by the leg kinematics alone, whereas in wheeled vehicles, the body position is continuously affected by the contour of the road surface. Vehicle suspension mitigates this effect on modern vehicles, but it is entirely eliminated in walking machines.

Elimination of roads

Although heavy usage would lead to tracks forming, as found when animals move along the same path regularly, walking machines do not require roads or other prepared surface to walk on. With light traffic, a legged vehicle should leave only a series of discrete footprints.

Fig 2.4

Minimal contact area with ground

In walking machines, the total ground area touched is the area of each footprint times the number of footprints per distance travelled. This is considerably less than the area moved over by a wheeled or tracked vehicle, which is the width of tyre or track times the distance travelled. For example, in an area of land where land mines have been randomly deployed, the continuous track of a wheeled vehicle increases the chance of a land mine being triggered, whereas a walker touches a much smaller area of the land over which it travels, and there would be reduced risk of triggering mines.

Reduced ground pressure

As a walking machine may carry a foot of practically any size, the average ground pressure it exerts can be made extremely small. In wheeled vehicles, the diameter of the wheels places a physical limit on the length of footprint. Although tyres can be made wide, the maximum contact patch size is limited, and ground pressure cannot easily be reduced below a certain value. Tracked vehicles can have a large contact area, and hence are preferred where low ground pressure is advantageous, for example vehicles that operate in snow or swamps. A walking machine could be competitive with a tracked vehicle in these conditions, although this still depends on the reduced body weight that could result from improved design of walkers.

Vehicle height

If a walking machine has a mammalian type body plan, with the legs attached underneath its body, then the body is carried higher off the ground than the body of a conventional wheeled or tracked vehicles would be. This body position may be advantageous where the vehicle is intended as a moveable vantage point, for example in game viewing applications. Greater vehicle height would also enhance wading abilities.

Increased traction

Wheeled vehicles are subject to slip, especially when applying high tractive effort on loose, slippery or wet surfaces. A suitable walking machine, with sharp feet to increase ground pressure, and hence penetration, could apply more tractive effort than a wheeled vehicle.

Amphibious potential

With a suitable leg arrangement carrying a set of floats or pontoons, a walking machine could be made an effective amphibious vehicle. If the area of float can be made large enough, then vertical displacement of the weight carrying floats can be less than the foot lift of the returning leg. This means the vehicle could walk on the surface of water, as returning floats would be lifted clear of the water surface, and placed forward of the current float. Such type of vehicle could also walk on land, with extremely low ground pressure.

Climbing abilities

With the addition of suitable foot attachment devices, such as electro-magnets for steel surfaces, or suction devices for smooth surfaces, such as glass, it should be possible to make a walking machine travel vertically or even upside down. The foot attachment mechanism would need to have grip control, releasing grip to allow the leg to be lifted on the return stroke and acquiring it when the leg is on its duty cycle. The Siemens pipe climbing robot is an example of this type of robot, although it seems to attach itself by exerting pressure on the pipe walls, much like a rock climber does when chimneying". The walking beam had an intended role as an inspection platform for doing non-destructive testing on aircraft exteriors and used vacuum pads to attach itself to the aircraft surface. Wheeled machines have never successfully been used as climbers.

2.3 DISADVANTAGES WITH RESPECT TO WHEELS OR TRACKS

The fact that vehicles that use wheels or tracks are the only types of vehicles currently being constructed in any significant numbers, and given that many attempts have been made to create walking machines, there must be severe disadvantages to using walking machines for transportation. These include:

Complication

Wheels are extremely simple, in the simplest form, a circular plate with a central hole. The wheel is widely considered one of human kind's greatest inventions. It is probably the simplest device that can

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be used for land transportation. It requires no ground sensing, and with suitable vehicle design, no balance control. Steering is easily achieved. With suspension and drive to all wheels, wheeled vehicles can have good off-road abilities, but their primarily realm is tarred roads in the modern world.

Tracks are somewhat more complex than wheels, being equivalent to a set of wheels that carry their own small section of roadway with them. Indeed, it is only in the last 100 years that tracked vehicles have been used, and even today they are limited to specialist uses such as earth moving, military and arctic conditions.

Walking vehicles are generally orders of magnitude more complex. There are many joints, kinematic links, sensors, software, multiple actuators, difficult manoeuvrability issues and stability issues that all make most current walking machines extremely complex. Though dreamers have often dreamt of such machines, it is only in the last 40 years that any progress has been made in achieving the dream.

Inefficiency

As mentioned earlier walking machines are not fuel-efficient, especially considering the slow speeds at which they travel. Wheels running on a good road surface are the most efficient way to travel on land. It is no surprise that ultra-efficient solar challenge race cars all use wheels.

Tracks are considerably less efficient than wheels. This is primarily due to the energy required to move the track itself. The large number of revolute joints connecting the track sections, with their associated friction, means that simply turning a track absorbs considerable power, although it is hard to accumulate data or find a means of comparing tracks to legs in terms of transport efficiency, a brief consideration would indicate that walking machines could be made to be similar in efficiency to tracked vehicles.

Cost

The cost of construction will generally be related to its complexity. Given the complexity of most current walkers it is not surprising that none has entered production, as presumably they could not be sold at a reasonable price.

However, tracked vehicles are also extremely costly in relation to wheeled ones. Even specialist wheeled vehicles command a premium price. If a sufficiently simple, hence cheap, walking machine could be constructed, and located in specific marketing and operational niches, it may be possible to sell these at a competitive price.

DESIGN CRITERIA

Applying the principle of parsimony (also known as the “KIS” (Keep It Simple) principle or Occam’s razor) makes the criteria for an envisaged walking machine much clearer. This principle is not mentioned facetiously, but as a conscious reminder that complexity is what has kept most walking machines confined to laboratories. The KIS philosophy will need to be applied continuously during design and development of such a machine. In this light, the criteria which the prospective walking machine should meet are:

- Static balance, so that no balance control system is required.
- Active Propulsion, as powered legs will extend the navigable terrain immensely.
- Minimal Power Consumption.
- Minimum number of prime movers, to simplify implementation and maintenance of the machine. if a single prime mover can be used, the control system for the prime mover can be greatly simplified.
- The Prime mover should preferably require a rotary motion rather than linear motion, as rotary prime movers are varied, simple and can be easily portable, particularly internal combustion engines and electric motors. Hydraulic or Pneumatic linear actuators require more

sophisticated systems and still require a rotary prime mover to be portable.

- Deterministic foot trajectory, to eliminate the need for ground sensing, impact control and leg kinematic control systems.
- A slow return mechanism to reduce dynamic loads in the leg's return stroke.
- A stiff mechanism, to ensure that body movement is controlled by leg position.
- Variable foot size to enable the machine management/interface with the surrounding area.
- Hinged legs or legs with knees, so waling vehicle body can be maintained in the same horizontal plane, minimizing changes in the potential energy.
- A scalable design to allow testing and validation on reduced scale for the prototype that can be applied for a full-sized vehicle.

It may be feasible to construct such a walking machine if a suitable linkage could be found. With hindsight, a four-bar chain coupled to a pantograph as shown in Figure could have been used. In 2000, a brief article in New Scientist magazine [29] supplied the idea for a new type of linkage. Although interest was largely intuitive, and initially sceptical, it was sufficient to warrant further study. The article concerned a new type of leg mechanism, used by an eccentric Dutch kinetic sculptor to make large plastic machines that were blown by the wind across beaches near the North Sea. Theo Jansen and his "strandbeest".

Theo Jansen's "strandbeest"

The idea for a new type of linkage came from an article in New Scientist magazine, concerning the work of Theo Jansen, a Dutch physicist / artist creating a series of kinetic sculptures, collectively named "strandbeest", He has constructed a wide variety of machines, all based on a similar principle. More of his creations can be seen at his web site and in his book.

Examination of this mechanism shows that it could provide legs that meet the design criteria listed in above section. The "strandbeest" are large enough that they could be used for transportation. They operate successfully on beaches and so have demonstrable off-road performance. However they are primarily intended as kinetic sculptures, and would not be practical as transportation vehicles in their present forms.

The primary problems with Jansen's "strandbeest" are the method of construction, and the layout of the machines. They are constructed from plastic tube, said to be electrical conduit. The joining methods are not clear, but the main components appear to be lashed together with twine. It is doubtful whether this type of construction would be suitable for a working transport vehicle.

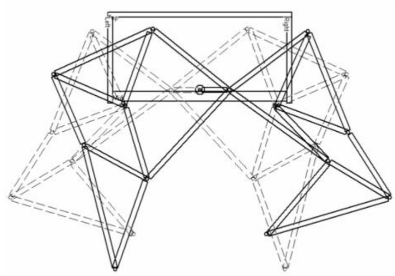

Fig 3.1

The second problem is that all legs are driven from a single central crankshaft, as shown in Figure. The rear mounted legs effectively turn in reverse relative to the front legs. However, the horizontal velocity of the foot is asymmetrical i.e., it moves faster at the beginning of the cycle than it does at the end, or vice versa. This shows the velocity of the foot, for a mechanism with the same proportions that Jansen uses the front legs experience the profile as shown by moving from left to right between the two purple vertical lines, which indicate the foot fall and foot lift positions. The rear mounted legs will experience velocity changes in the opposite direction, that is, the velocity changes would be as indicated by moving from the right vertical line, towards the left.

The feet therefore experience longitudinal movements in relation to each other as the machine walks, and they cannot remain firmly planted on the ground. At least one foot must move to accommodate the pull exerted by the mechanism.

It is no surprise that many of Jansen's "strandbeest" actually use wheels as feet - the wheels are there to allow for this movement. Technically this gait should not be considered a walk, it more closely resembles ice skating or a skiing gait.

Fig 3.2

CONCEPTUAL DESIGN OF WALKING MECHANISM IN CAD

Solid works is one of the best CAD Solid modelling software, Solid works is also known as "DSS Solidworks".DSS means the Dassault Systems, the developer of this CAD Software. This is CAD Software, which helps to create 2D or 3D Solid models without any complexity, faster and in the cost effective way. The main advantage of the solid works is that very easy to use, simple graphics user interface and much more friendly, as compared with other CAD Solid modelling software's it contains solid modelling, motion, simulation, toolbox, tool analyst, circuit works etc..

The Solid Works software enables you to design models quickly and precisely. Solid Works designs are

- Defined by 3D design
- Based on components

3D Design:

Solid Works uses a 3D design approach. As you design a part, from the initial sketch to the final model, you create a 3D entity. From this 3D entity, you can create 2D drawings, or you can mate different components to create 3D assemblies. You can also create 2D drawings of 3D assemblies.

Components Based:

One of the most powerful features in the Solid works application is that any change you make to a part is reflected in any associated drawings or assemblies.

Terminology:

The following terms appear throughout the Solid Works software and the documentation: as shown in the figure below

Origin:
Appears as two gray arrows and represents the (0, 0, 0) coordinate of the model. When a sketch is active, a sketch origin appears in red and represents the (0, 0, 0) coordinate of the sketch. You can add dimensions and relations to a model origin, but not to a sketch origin.
Plane:
Flat construction geometry. You can use planes for adding a 2D sketch, section view of a model, a neutral plane in a draft feature, and so on.
Axis:
Straight line used to create model geometry, features, or patterns. You can create an axis in a number of different ways, including intersecting two planes.
Face:
Boundaries that help define the shape of a model or a surface. A face is a selectable area (planar or non-planar) of a model or surface. For example, a rectangular solid has six faces.
Edge:
Location where two faces or surfaces meet along a distance. You can select edges for sketching, dimensioning, and many other operations.
Vertex:
Point at which two or more lines or edges intersect. You can select vertices for sketching, dimensioning, and many other operations.

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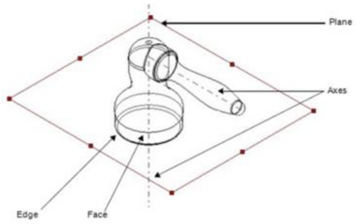

Design intent:

Design intent determines how you want your model to react as a result of any changes you need to make to the model. Design intent is primarily about planning. Deciding how to create the model determines how changes affect the model. The closer your design implementation is to your design intent, the greater the integrity of the model. Various factors contribute to the design process, including

- Current needs. Understand the purpose of the model to design it efficiently.
- Future considerations. Anticipate potential requirements to minimize redesign efforts when changing the model.

The design process usually involves the following steps:

- Identify needs
- Conceptualize model based on identified needs
- Develop model based on the concepts
- Analyze model development results
- Prototype the model
- Construct the mode
- Edit the model if needed

Design Method:

After you identify needs and isolate the appropriate concepts, you can develop the model using the following steps:

- Sketches. Create the sketches, and decide how to dimension, where to apply relations, and so on.
- Features. Select the appropriate features, determine the best features to apply, decide in what order to apply those features, and so on
- Assemblies. If the model is an assembly, select what components to mate what types of mates to apply, and so on.

Sketches.

Creating a model begins with a sketch. From the sketch, you can create features. You can combine one or more features to make a part. Then, you can then combine and mate the appropriate parts to create an assembly. From the parts or assemblies, you can then create drawings. A sketch is a 2D profile or cross section. To create a 2D sketch, you use a plane or a planar face. In addition to 2D sketches, you can also create 3D sketches that include a Z axis, as well as the X and Y axes. There are various ways of creating a sketch. All sketches include the following elements:

- Origin
- Planes
- Dimensions
- Relations

Solid works Animator:

With the Solid Works Animator application, you can animate and capture Solid Works assemblies in motion. Solid Works Animator generates .avi files that you can play on any Windows-based computer. In conjunction with the Photo Works software, the Solid Works Animator application can output photo-realistic animations.

Suppose that your company is at a convention with competing companies. To stand out from the competition, you can create .avi files that animate your products. This way, your customers can see the vanity door open and close, or see the faucet handles turn on and off. Animation helps your customers visualize models in a real-world situation.

The Solid Works Animator application allows you to create a fly-around animation, an exploded view animation, or a collapsed

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view animation. Additionally, you can explicitly create motion paths for various components in your Solid Works assembly.

Basic walking mechanism :

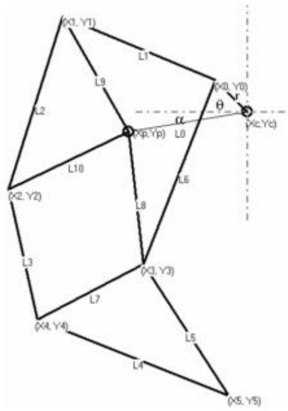


Fig 4.1

Considering the sketch of the linkage shown in Figure, it is possible to derive the motion of the foot point, (x5, y5), as a function of the crank angle θ. This requires knowledge of the lengths of the links, which can be represented as a vector.

$L= [l_0, l_1, l_2, l_3, l_4, l_5, l_6, l_7, l_8, l_9, l_{10}]$ equation 1

Where l0 represents the distance between the crank shaft and the fixed pivot, and the other subscripts represent lengths of the links as named in Figure.

The crank radius is taken as a constant, r, rotating about the crank centre point (x_c, y_c). The fixed pin position is given by (x_p, y_p), and is inclined by angle α to the horizontal. The fixed pin coordinates (x_p, y_p) are given by:

$X_p=x_c+(l_0*\sin\alpha)$

equation2 $y_p=y_c+(l_0*\cos\alpha)$

equation 3

The positions of the various nodes of the linkage can be represented as a vector of points

$N= [(x_0, y_0), (x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4), (x_5, y_5)]$ equation 4

Considering Node 0, we can write the following equations.

$X_0=x_c+(r*\sin\theta)$

equation 5

$Y_0=y_c+(r*\cos\theta)$

equation 6

The position of Node 1 is determined by the intersection of the arcs made by Link 1 around (x_0, y_0) and the arc of Link 9 around point (x_p, y_p).

$(x_1-x_0)^2+(y_1-y_0)^2=(l_1)^2$

equation 7

$(x_1-x_p)^2+(y_1-y_p)^2=(l_9)^2$

equation 8

Simplifying equation 7

$X_1=x_0+-[(l_1)^2-(y_1-y_2)^2]^{1/2}$

equation 9

Simplifying equation 8

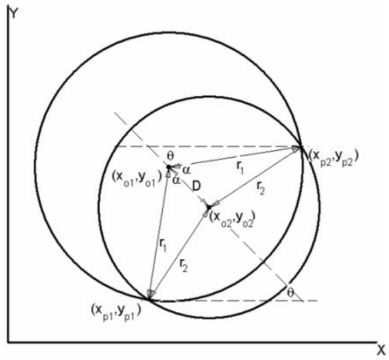
$X_1=x_p+-[(l_9)^2-(y_1-y_p)^2]^{1/2}$

equation 10

Equating equations 9 and equation 10

$X_0+-[(l_1)^2-(y_1-y_0)^2]^{1/2}=x_p+-[(l_9)^2-(y_1-y_p)^2]^{1/2}$ equation 11

Unfortunately, equation 11 cannot be easily solved for y1, due to the presence of square root on both sides of the equation. There will always be terms in $\{[(y_1-y_{0p})^2]^{1/2}\}$ which cannot be eliminated, making an algebraic solution difficult as discussed earlier. The actual method of solution derives from the co-ordinate geometry, specifically the intersection points is as shown in the figure below.



The following Equations for intersection points (x_{p1},y_{p1}) and (x_{p2},y_{p2}) are standard in the fields of co-ordinate geometry.

$X_{p1}=x_{01}+r_1\cos(\theta+\alpha)$

equation 12

$Y_{p1}=y_{01}+r_1\sin(\theta+\alpha)$

equation 13

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$Y_{p2}=y_{01}+r_1\sin(\theta-\alpha)$ equation 14

$X_{p2}=x_{01}+r_1\cos(\theta-\alpha)$ equation 15

Where,

$\alpha=\tan^{-1}[(y_{02}-y_{01})/(x_{02}-x_{01})]$ equation 16

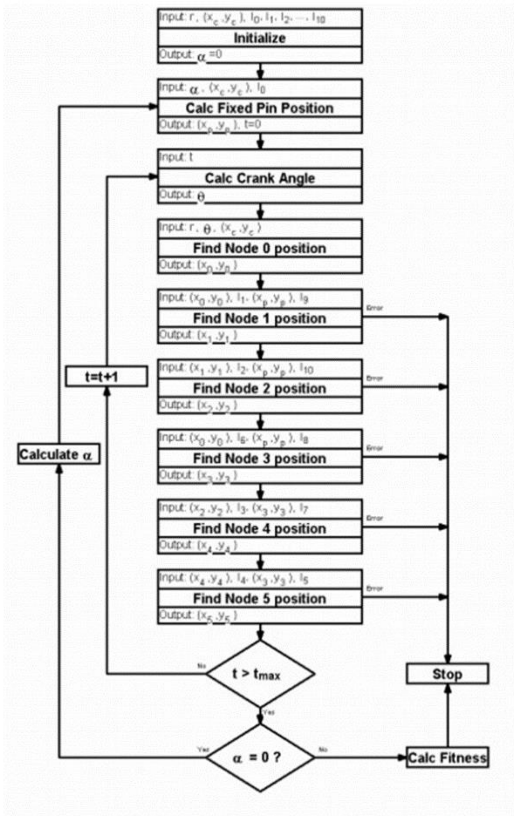
$\alpha=\cos^{-1}[(D^2+r_1^2-r_2^2)/(2*D*r_1)]$ equation 17

$D=[(x_{02}-x_{01})^2+(y_{02}-y_{01})^2]^{1/2}$ equation 18

Although the equations 12 to 15 yield the positions of both the intersection points, only one point is relevant at each node. The software solution contains additional information to ensure that the correct intersection is possible, In addition the software checks the condition of correct intersection points, such as overlapping circles, etc

Computer model

The solution to solving this mechanism uses repeated application of the simple method outlined. Each node is considered as the intersection of two circular arcs, and by moving sequentially from node 0 to node 5, the positions of all nodes can be found. This method is shown graphically in the flow chart, below



The inner loop of the algorithm detailed in Figure shows that a single revolution of the crank is broken up into a number of time slices, which are equivalent to angular positions, given that the drive shaft is assumed to be rotating at a constant angular velocity. In the software implementation, the maximum number of time slices permitted is 256, but there is no theoretical upper limit on how finely the time may be sliced. So t ranges from 0 to 255, although t_{max}= 239 is usually used, as this equates to 240 time slices with an angular position change between each of 1.5°.

Calculation of mechanism orientation angle, α

The above figure further shows that the orientation angle α is calculated after the mechanism has been solved once for a complete revolution. This is achieved by scanning through the foot positions and comparing the velocities of two points which correspond to crank positions 180° apart. When points with the most similar velocities are found, these two points are

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taken as the points when the foot will touch the ground, and 180° later, when the foot will leave the ground, i.e. The points that delimit the walking cycle. This algorithm has an implicit assumption that the duty cycle of the leg is 50%, as 180° of the 360° of a full revolution are spent with the foot grounded.

The slope of a straight line that connects the two points found is taken as the correct orientation angle for the mechanism. Rotating the entire mechanism through this angle will result in the connecting line being horizontal, and so the walking part of the foot trajectory is also kept more-or-less horizontal. This makes evaluation of usefulness for walking much easier.

The reason velocities are compared is that minimizing the speed difference between the feet arriving on the ground and those feet leaving the ground will limit the amount of slip or scuffing that may occur as the vehicle's weight is shifted from one set of legs to another.

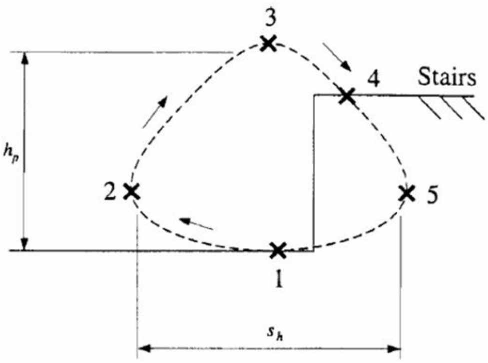
Once the mechanism's orientation has been adjusted, the positions of all nodes are recalculated for all crank angles. These new node positions are used as the basis for evaluating the foot trajectory amongst other things.

Foot point trajactories for walking

The Path followed by the foot of a walking machine is of crucial importance to the machine's correct functioning. There is a relationship between the trajectory provided by the mechanism and the overall design and format of the walking machine. The general idea of the is project is to develop a walking mechanism from Jansen's work which states that the foot should follow a triangular path as shown in the figure below.

Fig 4.2

The figure below shows the trajectory, the foot would follow as in the walking machine from left side of the page towards the right side, up a single stair. The mechanism starts with the foot at the midpoint of its stride, at point 1. The foot leaves the ground at point 2, and travels on its return stroke through points 3 and 4 to point 5, where the foot is again taking the vehicle's weight. This sketch shows the additional point, point 4, which would be where the foot may strike a step in a staircase - Shieh's robot was intended to be able to climb stairs.



The foot trajectory shown in Figure is not necessarily the optimum trajectory shape. The problem with this specific trajectory is the curve between points 2 and 5, the walking portion of the cycle. The vehicle body, being connected to the foot by a rigid leg, would experience a motion inverse to this foot curve. Vehicle occupants would feel the vehicle rising and falling. A better foot trajectory would have this portion of the curve as near to a horizontal straight line as possible, keeping the body horizontal on a horizontal walking surface. Note that flatter lower portion in Jansen's trajectory in the above case.

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The flatness of the walking curve can be determined by obtaining a straight line fit to the trajectory points using a least squares linear regression. The correlation coefficient of the regression is taken as a measure of the flatness. The future work can be varied to quantify flatness.

Duty Cycle

The duty cycle of a leg mechanism is the proportion of the total cycle time that the leg is touching the ground, making it capable of bearing weight. Mathematically this can be expressed as

$$DC=T1/T2$$

Where

DC = Duty cycle
T1 = loaded time
Tt = total leg cycle time

Initial look out into the properties of the Jansen mechanism were to see if mechanisms with 75% duty could be found, such a mechanism would allow the design of a statically balanced quadruped machine layout. Unfortunately, no such mechanism was found, using a simple exhaustive search algorithm. Later searches all implicitly accept mechanisms with a 50% duty cycle.

Mechanism size

Clearly, the smaller the mechanism the better performance. Smaller mechanism will be lighter, have stiffer links and have lower inertial loads. The size of the mechanism can be represented by the sum of the length of the links as.

$$L_l = \sum_{i=1}^{10} l_i$$

Where

Ll = Total link length
li = Length of link i

Mechanism Compactness

The trajectories of the farthest nods will determine how much space a particular mechanism will need to operate within. some arrangements will require a larger space than others, which will turn affect the detail design of any walking, machine based on this leg proportions. The areas required to operate in is taken as being limited by the leftmost point of node 4's trajectory, the top most point of node 1, the top most extent is given by node 0, and the lowest point is node5.Compactness can be expressed as an area, given by

$$A = \frac{\left(x_{4(\min)} + x_{0(\max)}\right)}{2} \times \frac{\left(y_{1(\min)} + y_{5(\max)}\right)}{2}$$

Where

x4(min) = minimum x value of node 4's trajectory
x0 (max) = maximum x value of node 0's trajectory
y1 (min) = minimum y value of node 1's trajectory
y5 (max) = maximum y value of node 5's trajectory

Stride length

The longer the stride of a mechanism, the faster it will be able to move the machine for a given motor speed. This parameter corresponds to Sh. For a Jansen walker, this length, which we will call S_l, would be given by

$$s_l = \left(x_{5(fl)} - x_{5(ff)}\right)$$

Where

S_l = stride length
x5((f_l) = node 5's trajectory x value, at foot lift, at the end of the stride
x5(f_f) = node 5's trajectory x value, at foot fall, at start of the stride

Average Speed

Maximum average foot speed corresponds to maximum stride length, in that longer strides will have higher average foot speeds. However, considering foot speed eliminates an implicit assumption about the timing of foot/ground contact events. This parameter is measured by averaging all the instantaneous velocity values.

$$V_{ave} = \frac{\sum_{i=ff}^{fl}(x_{i+1} - x_i)}{N_w \times t}$$

Where,

Vave = average foot speed

ff = crank index at foot fall

fl =crank index at foot lift

xi, x i+1 = foot x position at instant I, i+1

Nw =number of time slices during the walking machine = fl-ff

T = time for one crank revolution

Speed Fluctuation

Speed fluctuation determines how "smooth" the vehicle feels when walking. The hope is to avoid major mechanism speed changes as the pairs of legs change. This phenomenon cannot be avoided entirely, due to the fundamental simple harmonic nature of rotating mechanisms, but it may be minimized. The speed fluctuation is quantified by considering the distribution of foot speeds as a Gaussian distribution, and taking the fluctuation parameter as 1 standard deviation. Mathematically this parameter, which we can call Vf, can be expressed as:

$$V_f = \frac{\sum_{i=ff}^{fl}(v_i - v_{ave})^2}{N_w}$$

Where

V_f = foot speed fluctuation factor

Ff, fl = crank index at foot fall and lift

V_i = foot velocity at instant i

V_{ave} = average foot speed from the above equation

Foot lift

During the return part of the walking cycle, the foot point should be raised off the ground. This is the height hp. The higher the foot is lifted, the more capable it will be of avoiding surface irregularities between footfalls. Conversely, the higher the foot is lifted, the more energy is expended overcoming gravity, and the foot's travel path is longer, requiring faster foot motion. The required degree of lift required will depend on the intended duty of the walker. Rough terrain vehicles will need to lift their feet higher and pay a corresponding energy cost.

$$h_p = y_{5(\max)} - y_{5(\min)}$$

Where,

h_p = foot lift

$Y_{5(max)}$ = maximum y value during node 5's entire trajectory

$Y_{5(min)}$ = minimum y value during node 5's entire trajectory

Body Lift

As mentioned earlier, the amount of vertical movement the vehicle body experiences is a function of the curvature of the foot point trajectory when the foot is in ground contact. Minimization of body

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lift will make the vehicle smoother to travel in, and will also influence power consumption. This parameter can be measured by considering the vertical component of the foot node's trajectory:

$$L_b = y_{5(w\max)} - y_{5(w\min)}$$

Where

L_b = body lift

$Y_{5(w_{max})}$ = maximum y value during node 5's walking trajectory

$Y_{5(w_{min})}$ = minimum y value during node 5's walking trajectory

Body carriage height

The overall height at which the body will be carried will depend on the lengths of the two vertically adjoining links that carry it. Different purpose may have different requirements. If the walker was intended as a moveable vantage point, then the body would be carried high, on long legs. A small stable walker may require short legs to make it more difficult to overturn. The carriage height is taken as the vertical distance between the foot node and the fixed pin position.

$$H_b = y_{ref} - y_{5(i)}$$

Where,

H_b= body carriage

y_{ref} = the position of some reference point on the vehicle body

$y_{5(i)}$ = the value y of node 5's walking trajectory, at instant i

Approach and departure angles

In common with wheeled off-road vehicles, a walking machine would be limited in the change of angle of terrain that it could walk over. If it encounters a slope steeper than a certain angle, then its foot would not be able to find place, and the machine would be stopped. In the Jansen mechanism, the limiting factor would be the position of node 4, the "knee" of the mechanism. This would act as the leading edge of the machine, and would be the first to touch an approaching steep slope. In a wheeled vehicle this limit is a function of the geometric positions of wheels and the body. In walking machines, especially those with Jansen mechanism legs, this limit would vary with foot and knee position.

Similarly, when walking down a sloped surface onto a horizontal surface, the rear portion of the vehicle may become caught on the ground behind the machine. The rear legs would be unable to find foot positions and the machine may stop. If the front legs had traction, the machine may able to drag the rear section until the legs can reach the surface.

Steering ability

An interesting property of the Jansen mechanism is that the stride length and foot trajectory can be easily changed by moving the fixed pin position. This effect is suggested as a simple means of steering a walking machine. Different mechanism has different responses to fixed pin position changes, so those with "better" response are preferred, all other factors being equal.

Power Consumption

Although power consumption primarily depends on vehicle weight, factors such as transmission angle (especially when considering friction) and link geometry can have a substantial influence on the energy required to walk

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the machine. It is a stated design criterion that this parameter be minimized

Structural considerations

The load carrying ability of the leg will determine the success of the walking machine. The Jansen mechanism has superior intrinsic structural properties to a pantograph, due to the fact that walking loads are transmitted along at least two paths in the Jansen leg, whereas in a pantograph, loads are carried by a single set of links. However, different Jansen linkages will adopt different shapes during their cycle, which may influence their ability to carry load, or to move smoothly when loaded. This parameter is difficult to quantify.

Reversibility

Although the Jansen mechanism can rotate in either direction, one direction will be favoured, as this may lead to lower loads or apply loads in a preferred direction. All mechanism found work best when walking such that the lower link attaching to the crank, link 6, is loaded in tension. Reversing the direction would load this link in compression, which necessitates a heavier link, to resist buckling. Mechanisms that can rotate in either direction with minimum impact on link loading will be better suited to a practical walking machine.

SAMPLE CALCULATIONS

Here,

l_0 = 25.2 cm

l_1 = 32.9 cm

l_2 = 36.7 cm

l_3 = 25.9 cm

l_4 = 43.2 cm

l_5 = 32.2 cm

l_6 = 40.7 cm

l_7 = 24.1 cm

l_8 = 25.8 cm

l_9 = 27.3 cm

l_{10}= 26.4 cm

Taking the ratio as 10

Then,

l_0 = 2.52 cm

l_1 = 3.29 cm

l_2 = 3.67 cm

l_3 = 2.59 cm

l_4 = 4.32 cm

l_5 = 3.22 cm

l_6 = 4.07 cm

l_7 = 2.41 cm

l_8 = 2.58 cm

l_9 = 2.73 cm

l_{10}= 2.64 cm

On solving all the above equations,

We get,

α = 20.5, (x_c,y_c) = (0,0) , (x_0,y_0) = (15,15)

At $\theta = 10^0$

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$(x_1,y_1) = (-60.7,-17.13)$

$(x_2,y_2) = (-38.68,-68.4)$

$(x_3,y_3) = (10.72, -53.8)$

$(x_4,y_4) = (-4.14,-87.35)$

$(x_5,y_5) = (58.09,-66.31)$

At $\theta = 30^0$

$(x_1,y_1) = (-63.07,-0.83)$

$(x_2,y_2) = (-55.06,-56.05)$

$(x_3,y_3) = (-3.57,-54.74)$

$(x_4,y_4) = (-26.61,-83.3)$

$(x_5,y_5) = (38.95,-79.09)$

At $\theta = 45^0$

$(x_1,y_1) = (-59.5,20.78)$

$(x_2,y_2) = (-70.92,-33.84)$

$(x_3,y_3) = (-22.07,-50.22)$

$(x_4,y_4) = (-53.5,-69.18)$

$(x_5,y_5) = (9.55,-87.64)$

At $\theta = 90^0$

$(x_1,y_1) = (-27.41,56.81)$

$(x_2,y_2) = (-74.08,26.21)$

$(x_3,y_3) = (-51.12,-19.9)$

$(x_4,y_4) = (-86.74,-11.08)$

$(x_5,y_5) = (-55.22,-68.72)$

Duty Cycle (DC) = 2sec/2sec = 1

Compactness (A) = $\{(-86.74/2)*(-83.44)\}$
$= -43.37 * -41.72$
$= 1809.39$

Stride Length (s_l) = 58.09+55.22
= 113.31

Foot Lift (h_p) = 68.72-66.31
= 2.41

Body Lift (l_b) = -66.31+79.09
= 12.78

Body Carriage Height (H_b) = 10+87.64
= 97.64

DESIGN OF WALKING MACHINE WITH CAD

Basic designing of the walking machine in the CAD which is Solid Works in this case. The layout of the user interface of the welcome screen looks as shown in the figure below. The Front plane, Top plane and the Right plane are considered for the modelling of the individual parts of the walking machine.

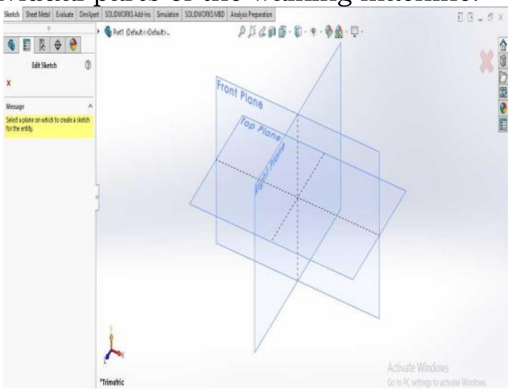

Fig 6.1

Part design:

The individual links for the machine are modelled from the sketcher tool and extruding the part to be a link. The dimensions of the link are as shown in the figure which was obtained from the general algorithm (GA), on the condition

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which was discussed in the earlier sections

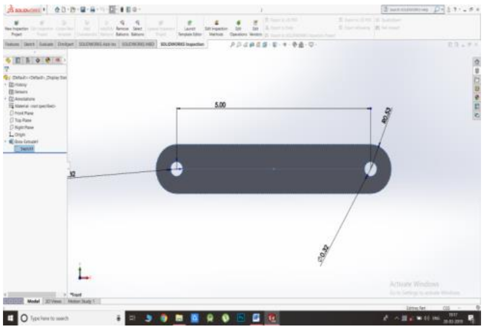

Fig 6.2

The final outcome of the link is as shown in the figure

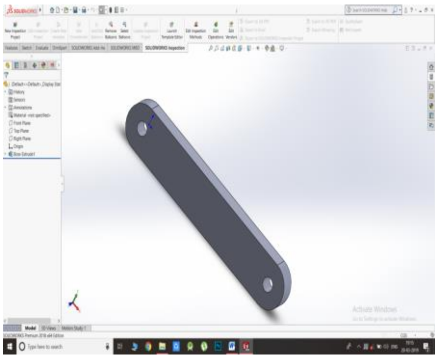

Fig 6.3

Designing of leg

After the modelling of the individual links, the final leg was to be modelled as the criteria which was obtained from the general algorithm (GA)

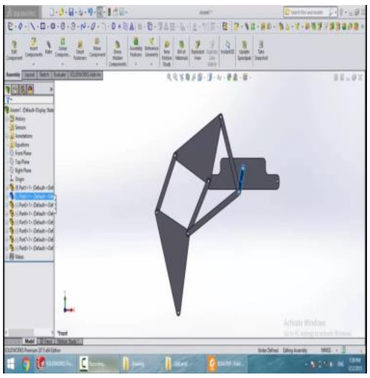

Fig 6.4

Chassis

A rigorous search was made about a good configuration to hold (or) make space for six legs in such a way that the leg don't crash while moving into for that, extensive analysis was made for non-crashing parts. Each link was placed in such a way that all the links are placed in 3 layers to occupy minimum space and maintained the design criteria like stability, power consumption, etc which we extensively discussed in the earlier chapters.

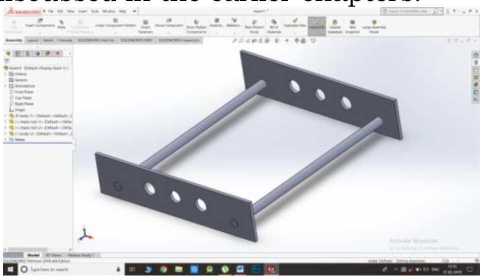

Fig 6.5

The outcome of the extensive work resulted in the chassis as shown in the figure above. Which is ready to be assembled with the legs and the motors.

Assembly

Assembling of the walking machine is done with basic commands like mate. Where the links are constrained to the joints as per the design as shown in the figure below

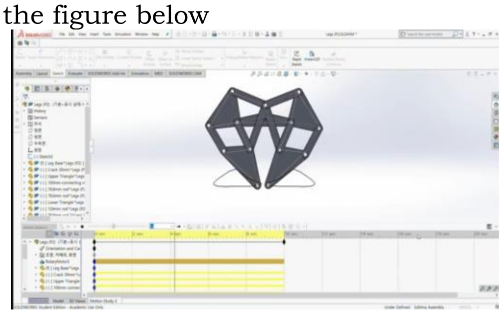

Fig 6.6

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Motor Attachment:

In order to simulate the working conditions of the hexapod walking machine there needs to be prime mover to power the machine, in this case a electric motor with 200 RPM is attached and other legs are constrained with the powered leg such that 3 legs are in contact with the ground for the stability issue, as the foot raise , foot fall and the foot movement in the return stroke plays a vital role in the efficiency and maintaining stability of the machine as discussed in the earlier sections, is shown in the figure below

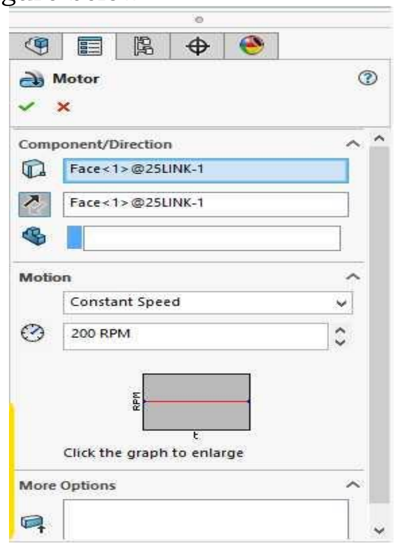

Fig 6.7

3D PRINTING INTRODUCTION

3D printing is any of various processes in which material is joined or solidified under computer control to create a three-dimensional object,[1] with material being added together (such as liquid molecules or powder grains being fused together), typically layer by layer. In the 1990s, 3D printing techniques were considered suitable only for the production of functional or aesthetical prototypes and a more appropriate term was rapid prototyping. Today, the precision, repeatability and material range have increased to the point that 3D printing is considered as an industrial production technology, with the name of additive manufacturing. 3D printed objects can have a very complex shape or geometry and are always produced starting from a digital 3D model or a CAD file. There are many different 3D printing processes, that can be grouped into seven categories:

- Vat photopolymerization
- Material jetting
- Binder jetting
- Powder bed fusion
- Material extrusion
- Directed energy deposition
- Sheet lamination

The most commonly used 3D Printing process is a material extrusion technique called fused deposition modelling (FDM).[3] Metal Powder bed fusion is gaining prominence lately during the immense applications of metal parts in the industry. In 3D Printing, a three-dimensional object is built from computer-aided design (CAD) model, usually by successively adding material layer by layer, unlike the conventional machining process, where material is removed from a stock item, or the casting and forging processes which date to antiquity.

The term "3D printing" originally referred to a process that deposits a

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binder material onto a powder bed with inkjet printer heads layer by layer. More recently, the term is being used in popular vernacular to encompass a wider variety of additive manufacturing techniques. United States and global technical standards use the official term additive manufacturing for this broader sense.

HISTORY

1981:

Early additive manufacturing equipment and materials were developed in the 1980s. In 1981, Hideo Kodama of Nagoya Municipal Industrial Research Institute invented two additive methods for fabricating three-dimensional plastic models with photo-hardening thermoset polymer, where the UV exposure area is controlled by a mask pattern or a scanning fiber transmitter.

1984:

On 16 July 1984, Alain Le Méhauté, Olivier de Witte, and Jean Claude André filed their patent for the stereolithography process. The application of the French inventors was abandoned by the French General Electric Company (now Alcatel-Alstom) and CILAS (The Laser Consortium). The claimed reason was "for lack of business perspective".

Three weeks later in 1984, Chuck Hull of 3D Systems Corporation filed his own patent for a stereolithography fabrication system, in which layers are added by curing photopolymers with ultraviolet light lasers. Hull defined the process as a "system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed,". Hull's contribution was the STL (Stereolithography) file format and the digital slicing and infill strategies common to many processes today.

1988:

The technology used by most 3D printers to date—especially hobbyist and consumer-oriented models—is fused deposition modelling, a special application of plastic extrusion, developed in 1988 by S. Scott Crump and commercialized by his company Stratasys, which marketed its first FDM machine in 1992.

AM processes for metal sintering or melting (such as selective laser sintering, direct metal laser sintering, and selective laser melting) usually went by their own individual names in the 1980s and 1990s. At the time, all metalworking was done by processes that we now call non-additive (casting, fabrication, stamping, and machining); although plenty of automation was applied to those technologies (such as by robot welding and CNC), the idea of a tool or head moving through a 3D work envelope transforming a mass of raw material into a desired shape with a toolpath was associated in metalworking only with processes that removed metal (rather than adding it), such as CNC milling, CNC EDM, and many others. But the automated techniques that added metal, which would later be called additive manufacturing, were beginning to challenge that assumption. By the mid-1990s, new techniques for material deposition were developed at Stanford and Carnegie Mellon University, including micro casting and sprayed materials. Sacrificial and support materials had also become more common, enabling new object geometries.

1993:

The term 3D printing originally referred to a powder bed process employing standard and custom inkjet print heads, developed at MIT in 1993 and commercialized by Solingen Technologies, Extrude Hone Corporation, and Z Corporation.

The year 1993 also saw the start of a company called Solids cape, introducing a high-precision polymer jet fabrication system with soluble support structures, (categorized as a "dot-on-dot" technique).

1995:

In 1995 the Fraunhofer Institute developed the selective laser melting process.

2009:

Fused Deposition Modelling (FDM) printing process patents expired in 2009.

As the various additive processes matured, it became clear that soon metal removal would no longer be the only metalworking process done through a tool or head moving through a 3D work envelope transforming a mass of raw material into a desired shape layer by layer. The 2010s were the first decade in which metal end use parts such as engine brackets and large nuts would be grown (either before or instead of machining) in job production rather than obligately being machined from bar stock or plate. It is still the case that casting, fabrication, stamping, and machining are more prevalent than additive manufacturing in metalworking, but AM is now beginning to make significant inroads, and with the advantages of design for additive manufacturing, it is clear to engineers that much more is to come.

As technology matured, several authors had begun to speculate that 3D printing could aid in sustainable development in the developing world.

2012:

Fila Bot develops a system for closing the loop with plastic and allows for any FDM or FFF 3D printer to be able to print with a wider range of plastics.

2013:

NASA employees Samantha Snabes and Matthew Fiedler create first prototype of large-format, affordable 3D printer, Gigabot, and launch 3D printing company re:3D.

2018:

3D develops a system that uses plastic pellets that can be made by grinding up waste plastic.

GENERAL PRINCIPLES

Modelling

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3D printable models may be created with a computer-aided design (CAD) package, via a 3D scanner, or by a plain digital camera and photogrammetry software. 3D printed models created with CAD result in reduced errors and can be corrected before printing, allowing verification in the design of the object before it is printed.[30] The manual modelling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting. 3D scanning is a process of collecting digital data on the shape and appearance of a real object, creating a digital model based on it.

CAD models can be saved in the stereo lithography file format (STL), a de facto CAD file format for additive manufacturing that stores data based on triangulations of the surface of CAD models. STL is not tailored for additive manufacturing because it generates large file sizes of topology optimized parts and lattice structures due to the large number of surfaces involved. A newer CAD file format, the Additive Manufacturing File format (AMF) was introduced in 2011 to solve this problem. It stores information using curved triangulations.

Printing

Before printing a 3D model from an STL file, it must first be examined for errors. Most CAD applications produce errors in output STL files, of the following types:

- holes;
- faces normal;
- self-intersections;
- noise shells;
- manifold errors.

A step in the STL generation known as "repair" fixes such problems in the original model. Generally, STLs that have been produced from a model obtained through 3D scanning often have more of these errors. This is due to how 3D scanning works-as it is often by point-to-point acquisition, 3D reconstruction will include errors in most cases.

Once completed, the STL file needs to be processed by a piece of software called a "slicer," which converts the model into a series of thin layers and produces a G-code file containing instructions tailored to a specific type of 3D printer (FDM printers). [citation needed] This G-code file can then be printed with 3D printing client software (which loads the G-code, and uses it to instruct the 3D printer during the 3D printing process).

Printer resolution describes layer thickness and X–Y resolution in dots per inch (dpi) or micrometres (µm). Typical layer thickness is around 100 µm (250 DPI), although some machines can print layers as thin as 16 µm (1,600 DPI).[39] X–Y resolution is comparable to that of laser printers. The particles (3D dots) are around 50 to 100 µm (510 to 250 DPI) in diameter. [citation needed] For that printer resolution, specifying a mesh resolution of 0.01–0.03 mm and a chord length ≤ 0.016 mm generate an optimal STL output file for a given model input file. Specifying higher resolution results in larger files without increase in print quality.

Construction of a model with contemporary methods can take anywhere from several hours to several days, depending on the method used and the size and complexity of the model. Additive systems can typically reduce this time to a few hours, although it varies widely depending on the type of machine used and the size and number of models being produced simultaneously.

Traditional techniques like injection moulding can be less expensive for manufacturing polymer products in high quantities, but additive manufacturing can be faster, more flexible and less expensive when producing relatively small quantities of parts. 3D printers give designers and concept development teams the ability to produce parts and concept models using a desktop size printer.

Finishing

Though the printer-produced resolution is sufficient for many applications, greater accuracy can be achieved by printing a slightly oversized version of the desired object in standard resolution and then removing material using a higher-resolution subtractive process.

The layered structure of all Additive Manufacturing processes leads inevitably to a strain-stepping effect on part surfaces which are curved or tilted in respect to the building platform. The effects strongly depend on the orientation of a part surface inside the building process.

Some printable polymers such as ABS, allow the surface finish to be smoothed and improved using chemical vapor processes based on acetone or similar solvents.

Some additive manufacturing techniques are capable of using multiple materials in the course of constructing parts. These techniques are able to print in multiple colours and colour combinations simultaneously, and would not necessarily require painting.

Some printing techniques require internal supports to be built for overhanging features during construction. These supports must be mechanically removed or dissolved upon completion of the print.

All of the commercialized metal 3D printers involve cutting the metal component off the metal substrate after deposition. A new process for the GMAW 3D printing allows for substrate surface modifications to remove aluminium or steel.

Parts Printed

Fig 7.1

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These are the parts or links printed using 3D printing technology. All these five parts are combined to form a single leg.

Print Failures

Fig 7.2

Fig 7.3

These are the print failures faced during the printing of the parts. These failures are due to less infill thickness.

COMPONENTS USED MICRO CONTROLLER (ESP32-CAM)

ESP32-CAM is a low-cost ESP32-based development board with onboard camera, small in size. It is an ideal solution for IoT application, prototypes constructions and DIY projects. The board integrates Wi-Fi, traditional Bluetooth and low power BLE, with 2 high-performance 32-bit LX6 CPUs. It adopts 7-stage pipeline architecture, on-chip sensor, Hall sensor, temperature sensor and so on, and its main frequency adjustment ranges from 80MHz to 240MHz. Fully compliant with Wi-Fi 802.11b/g/n/e/i and Bluetooth 4.2 standards, it can be used as a master mode to build an independent network controller, or as a slave to other host MCUs to add networking capabilities to existing devices ESP32-CAM can be widely used in various IoT applications. It is suitable for home smart devices, industrial wireless control, wireless monitoring, QR wireless identification, wireless positioning system signals and other IoT applications.

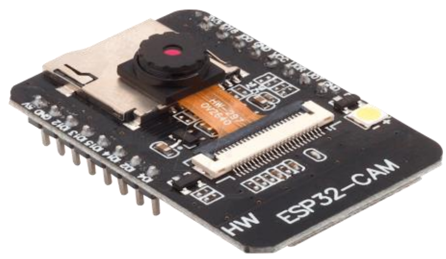

Fig 8.1

Summary

Microcontroller ESP32-CAM SPI Flash Default 32Mbit

RAM

Built-in 520 KB, external 4MPSR

Bluetooth

Bluetooth 4.2 BR/EDR and BLE standards

Wi-Fi

802.11b/g/n/e/i

Support Interface

UART, SPI, I2C, PWM

Support TF card

maximum support 4G

IO port 9

Serial Port Baud-rate Default 115200 bps

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Image Output Format JPEG (OV2640 support only), BMP, GRAYSCALE
Spectrum Range 2412 ~2484MHz
Security WPA/WPA2/WPA2-Enterprise/WPS
Power supply range 5V
Clock speed 160MHz

MOTORS (SG 90 Micro Servo Motor)

The SG 90 servo motor is converted into DC geared motor.

60 RPM Side Shaft 30mm Diameter High Performance DC Gear Motor is suitable for small robots / automation systems. It has sturdy construction with gear box built to handle stall torque produced by the motor. Drive shaft is supported from both sides with metal bushes. Motor runs smoothly from 4V to 6V and gives 60 RPM at 6V. Motor has 6mm diameter, 18mm length drive shaft with D shape for excellent coupling.

Fig 8.2

Specifications

- Speed 4.8V: 0.11 sec/60°
- Torque: 4.8V: 2.20 kg-cm, 6.0V: 2.50 kg-cm
- Voltage 4V to 6V
- Shaft diameter 30mm
- Height 29mm
- Gear assembly Spur
- Gear type Metal
- Motor weight 14gms

MOTOR DRIVERS

A motor driver is a device or group of devices that serves to govern in some predetermined manner the performance of an electric motor. A motor driver might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and faults.

Fig 8.3

6V BATTERY

Battery is a part of a circuit that provides the electricity. Battery can be said as the source to provide electricity to the circuit. So, its main function is to supply electric power in order for electric items to work.

A battery is a device consisting of one or more electro chemical cells with external connection provided to power electric device. A battery has a positive terminal or cathode and a negative terminal or anode. The terminal marked positive is at a higher electrical potential energy then is the terminal marks negative terminal have electron that is flow external circuit

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and deliver energy here for battery are connected in series and it is use to power supply to BLDC motor, than motor is make forward and backward to wheel.

Features

- Light weight, high capacity and density
- No explosion or burning risk
- International standard safety performance, Low self-discharging rate, highly endurable
- Batteries with less than 3% self-discharge rate per month, High and consistency
- Able to freely assemble and flexible usage
- Custom-made battery size, shape and capacity, environment friendly.

Fig 8.4

BATTERY CHARGER

A battery charger or recharge is a device used to put energy into a secondary or rechargeable battery by forcing an electric current through it. The charging protocol depends on the size and tyre of the battery being charged. Some batteries have high tolerance for overcharging and can be charge by connection to constant voltage source or constant voltage source or constant voltage source. Microprocessor controller to adjust the charging current, determine the sate of charge and cut off at the end of charge.

Fig 8.5

CONNECTING/JUMPER WIRES

Connecting wire is a piece of wire used to attach two circuits or components together. The gauge or the size of the wire must be large enough to support the amount of current flow. Wires are used to join parts of a circuit. Electricity flows through wires.

Its main function is to provide electrical items the power they need to work, Provided by battery.

Jumper wires are of 3 types. They are:

- Male to Male (M2M)
- Male to Female (M2F)
- Female to Female (F2F)

Fig 8.6

FINAL PROTOTYPE

Final assembly of product is as shown in figures

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Fig 9.1

Fig 9.2

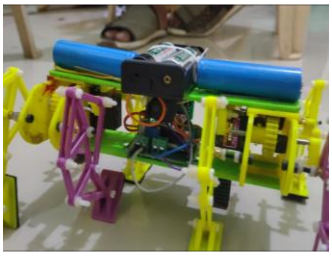

Fig 9.3

CONCLUSION

In conclusion the Jansen linkage demonstrates an exceptional use of a combination of four –bar linkages using one motor to move the entire leg. It is a simple and inexpensive structure that creates a complex path using circular motion. Despite being a recent invention, the Jansen linkage has already proven its energy efficiency and usefulness. With further advancements, the possibilities for the Jansen linkage are limitless.

REFERENCES

- SW Kim, H Jung, Y Kim, H Kim, SH Han, DH Kim. Analysis and Design of a Legged Walking Robot Based on Jansen Mechanism. In SCIS & ISIS, 2010, 920-924.
- S Patnaik. Analysis Of Theo Jansen Mechanism (Strandbeest) And Its Comparative Advantages Over Wheel Based Mine Excavation System, Analysis, 5(7), 2015.
- K Komoda, H Wagatsuma. A proposal of the extended mechanism for Theo Jansen linkage to modify the walking elliptic orbit and a study of cyclic base function, Proceedings of the 7th Annual Dynamic Walking Conference (DWC'12), 2012.
- BL Jansen, E Doubskirov, JC. Verlinden. Animaris Geneticus Parvus: Design of a complex multi-body walking mechanism. Rapid Prototyping Journal, 20(4), 2014, 311-319.
- T Jansen. The Great Pretender, 10 Publishers 2007.