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DESIGN & DEVELOPMENT OF SWARM ROBOTICS IN WAREHOUSE APPLICATION

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ABSTRACT

Swarm robotics is a relatively new research area inspired from biological systems such as ant or bee colonies. It composes a system consisting of many small robots with simple control mechanisms capable of achieving complex collective behaviors on the swarm level such as aggregation, pattern formation and collective transportation to name a few. However, more research is still required to apply swarm robotics in practice. Within the scope of our knowledge at the moment there are no swarm robotics applications for real-life problems. Swarm robotics is a new approach to the coordination of multi-robot systems which consist of large numbers of relatively simple robots which takes its inspiration from social insects. The most remarkable characteristic of swarm robots are the ability to work cooperatively to achieve a common goal.

Keywords: Swarm robotics; swarm intelligence; klan's mechanism; electronic configuration

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I. INTRODUCTION

Nature has always inspired researchers. By simple observing we can sometimes notice the patterns, the set of rules that make seemingly chaotic processes logical. How do we think and how do we memorize? Why is evolution so important for the survival of species? How do the social insects know how to follow the path to a source of food without the global knowledge? These questions are partially answered by computational intelligence (CI). Partially, because answering some questions we are usually faced with new ones to answer. The answer lies in swarm robotics.

Swarm robotics is a branch of multi-robot systems that embrace the ideas of biological swarms such as insect colonies, flocks of birds and schools of fish. The term "swarm" is used to refer "a large group of locally interacting individuals with common goals". Swarm robotics systems as well as their biological counterparts consist of many individuals exhibiting simple behaviors. While executing these simple behaviors, individuals are capable of producing complex collective behaviors on the swarm level that no individual is able to achieve alone. Ant colony can be viewed as an example – a single ant has limited sensing capabilities and relies only on local information, but by working together the colony is able to perform rather complex foraging, construction and transportation tasks. Swarm robotics systems are characterized by simplicity of individuals, local sensing and communication capabilities, parallelism in task execution, robustness, scalability, heterogeneousness, flexibility decentralized control. Some researchers conclude that even simple passive entities (such as rice) are able to produce interesting behaviors (i.e., form patterns) if stimulated by external force. To analyze potential capabilities of robot swarms, swarm robotics has been studied in the context of producing different collective behaviors to solve tasks such as: aggregation, pattern formation, self-assembly and morphogenesis, object clustering, assembling and construction, collective search and exploration, coordinated motion, collective transportation, self-deployment, foraging and others.

The objective of SI (Swarm intelligence) is to model the simple behavior of the individuals, their local interactions with the environment and neighboring individuals, in order to obtain more complex behaviors that can be used to solve complex problems, mostly optimization problems.

II. CONSTRUCTION

A single leg is a six-bar linkage that consists of the frame, pinions, electric motor, crank, connecting arm, lower rocker, leg and an upper rocker. The ground points for the upper and lower rocker in this configuration are vertically in line to allow a coupled pair of legs to articulate like the front wheels of a typical car for steering. The frame is made of aluminum because aluminum is light in weight and it is very important to reduce the weight of device as much as it is possible. Also other parts i.e. links are made of aluminum. Four gears and two pinions made of nylon material are used. Electric motor is mounted on frame and pinion is connected at the shaft of electric motor. Two gears are in mesh with pinion on either side with the help of leg connection. The leg has a hip joint axially connected to the upper rocker arm in order to limit hip motion and a knee joint axially connected to connecting rod. The connecting rod has three axial connecting sites. The first connecting sites is for connecting knee, second is for crank connection and third is for connecting lower arm with connecting rod for limiting knee joint motion.

Walking mechanism

Generally the walking mechanisms are developed by imitating natures like insects movement. To provide more stable and faster walking, scientists and engineers can implement the relevant biological concepts in their design. In this context, an objective is set in this project to develop a six- legged mobile robot whose structure is based on the biomechanics of insects.

Klans's mechanism

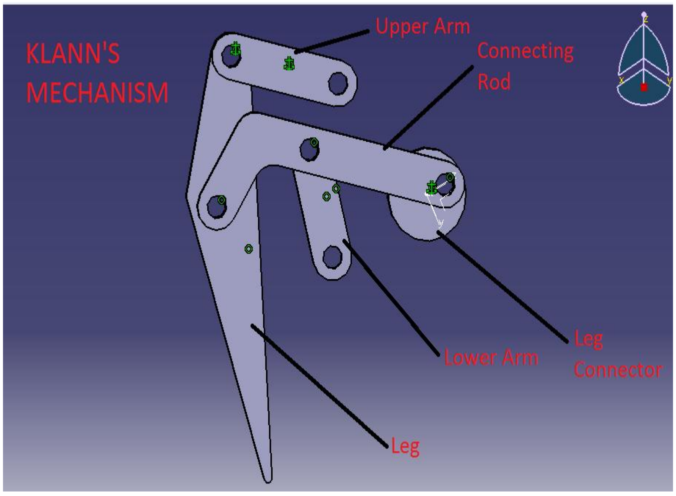

Fig. 1. Klann mechanism

The main objective of our paper is to replace the function of wheel in order to overcome the difficulty of travelling in uneven terrain.

Working

The main objective of our paper is to replace the function of wheel in order to overcome the difficulty of travelling in uneven terrain. The Klann linkage provides many of the benefits of more advanced walking vehicles without some of their limitations. It can step over curbs, climb stairs, or travel into an area that are currently not accessible with wheels but does not require microprocessor control or multitudes of actuator mechanisms. It fits into the technological space between these walking devices and axle-driven wheels. The foot of a walking mechanism is the part of the mechanism that comes in direct contact with the ground as indicated. As the crank turns, the foot traces out a cyclical path relative to the body of the walker; this path is known as the locus. The main advantage of Klann's mechanism robots is their ability to access places impossible for wheeled robots. By copying to the physical structure of legged animals, it may be possible to improve the performance of mobile robots. To provide more stable and faster walking, scientists and engineers can implement the relevant biological concepts in their design. The most forceful motivation for studying Klann's mechanism robots is

- To give access to places which are dirty.
- To give access to places those are dangerous.

It would be difficult to compete with the efficiency of a wheel on smooth hard surfaces but as condition increases rolling friction, this linkage becomes more viable and wheels of similar size cannot handle obstacles that this linkage is capable of. Toys could be developed that would fit in the palm of your hand and just large enough to carry a battery and a small motor.

III. COMPONENTS

1. *Legs*

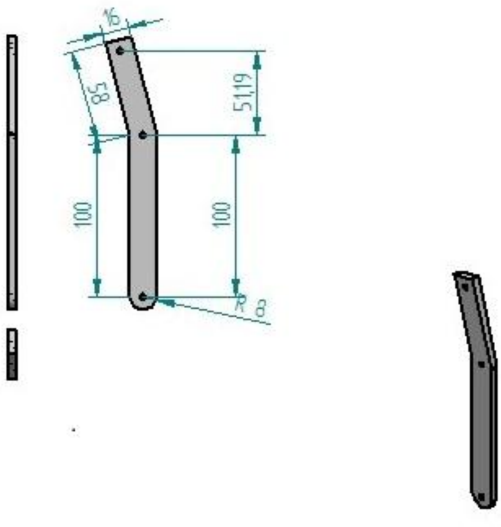

Fig. 2. Leg

A mobile robot needs locomotion mechanisms to make it enable to move through its environment. There are several mechanisms to accomplish this aim. 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. To make a legged robot mobile each leg must have at least two degrees of freedom. It is very difficult to copy these mechanisms for several reasons. The main problems are the mechanical complexity of legs, stability and power consumption. For each loco motion concept, doesn't matter if it is wheeled, leg or a different concept, there are three core issues: stability, the characteristics of ground contact and the type of environment. When the surface becomes soft wheeled locomotion offers some inefficiency, due to increasing rolling friction more motor power is required to move. It is proven that legged locomotion is more power efficient on soft ground than wheeled locomotion, because legged locomotion consists only of point contacts with the ground and the leg is moved through the air.

This means that only a single set of point contacts is required, so the quality of the ground does not matter, as long as the robot is able to handle the ground. But exactly the single set of point contacts offers one of the most complex problems in legged locomotion, the stability problem. 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. 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 forelegs 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. 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. But adding degrees of freedom causes also some disadvantages, because for moving additional joints and more servos are required, this increases the power consumption and the weight of the robot. Furthermore controlling the robot becomes more complex, because more motors have to be controlled and actuated at the same time. 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.

2. *Base, Gear, Side plates*

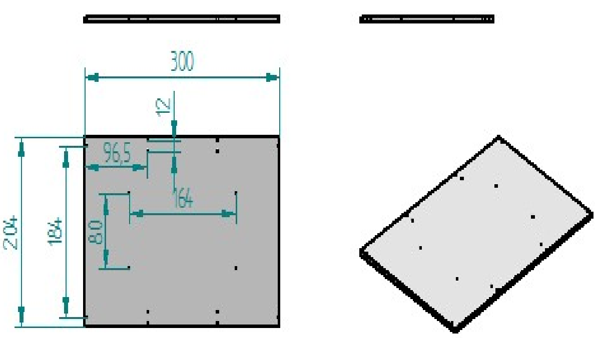

Fig. 3. Base Plate

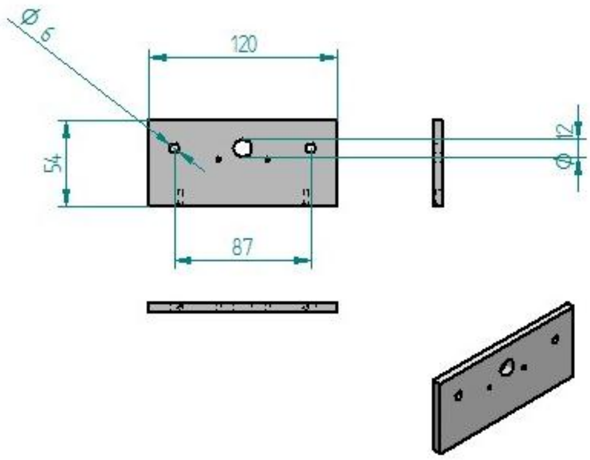

Fig. 4. Gear Plate

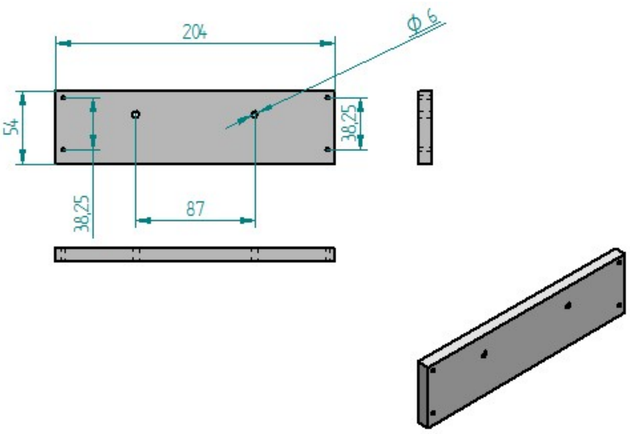

Fig. 5. Side Plate

The model consists of a gear plates and side plates which are fixed vertical to the base plate. The base plate and the frames are made of acrylic. Acrylic is lightweight, soft, and warm, with a wool-like feel. The polymer is formed by free-radical polymerization in aqueous suspension. It is a transparent thermoplastic homopolymer known more commonly by the trade name "plexiglass." Acrylic is very much same as polycarbonate. Acrylic doesn't contain the potentially harmful substance bisphenol-A (BPA) and Polycarbonate tends to have higher impact strength. Acrylic is readily available and inexpensive. Acrylic is an incredibly useful plastic for applications requiring transparency where high impact resistance is not an issue. Acrylic is very scratch resistant compared to other clear plastics. It is a lighter alternative to glass and an economic substitute for polycarbonate in applications where strength is not a crucial factor. It can be cut into extremely fine shapes using laser cutting technology because the material vaporizes upon impact with the concentrated laser energy.

3. *Upper arm & Lower arm*

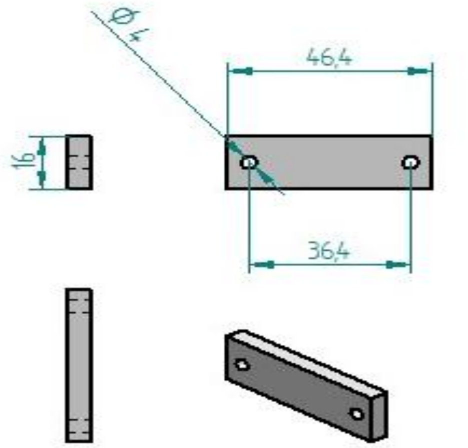

Fig. 6. Upper Arm

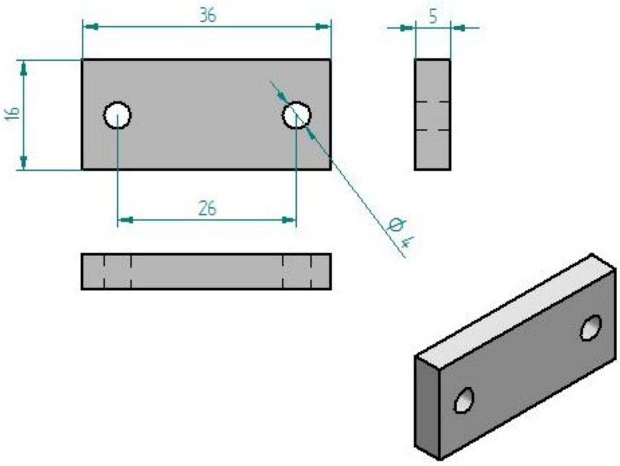

Fig. 7. Lower Arm

A mechanical linkage is an assembly of bodies connected to manage forces and movement. The movement of a body, or link, is studied using geometry so the link is considered to be rigid. The connections between links are modeled as providing ideal movement, pure rotation or sliding for example, and are called joints. A linkage modeled as a network of rigid links and ideal joints is called a kinematic chain. Linkages may be constructed from open chains, closed chains, or a combination of open and closed chains. Each link in a chain is connected by a joint to one or more other links. Thus, kinematic chain can be modeled as a graph in which the links are paths and the joints are vertices, which is called a linkage graph. The movement of an ideal joint is generally associated with a subgroup of the group of Euclidean displacements. The number of parameters in the subgroup is called the degrees of freedom (DOF) of the joint. Mechanical linkages are usually designed to transform a given input force and movement into a desired output force and movement. The ratio of the output force to the input force is known as the mechanical advantage of the linkage, while the ratio of the input speed to the output speed is known as the speed ratio. The speed ratio and mechanical advantage are defined so they yield the same number in an ideal linkage.

IV. CALCULATIONS

Motor Specification:
Speed = 30 rpm
Power = 18 watt
Voltage = 12 v

Gear dimensions:
Number of teeth
$Z_P = 23$
$Z_G = 63$

Diameter of Gears and Pinions:
$D_P = 22.60$ mm
$D_G = 62.30$ mm

CALCULATION OF GEAR AND PINION:
Motor Specification:
Power = 18 watt
Voltage = 12 v

(1) Take 10 rpm for 1st iteration,

$P = \frac{2\pi NT}{60}$

$18 = \frac{2\pi \times 10 \times T}{60}$

T= 17.188 N-m …Ans

(2) Take 20 rpm for 2nd iteration

$18 = \frac{2\pi \times 20 \times T}{60}$

T= 8.594 N-m …Ans

(3) Take 30 rpm for 3rd iteration

$18 = \frac{2\pi \times 30 \times T}{60}$

T= 5.72 N-m … (A) …Ans

The 3rd iteration torque value is satisfied for our design weight and capacity.

So, taking T=5.729 N-m and 30 rpm.
Input speed = 30 rpm
Output speed = 10 rpm ... (Assume)

Gear ratio (G) = Reduction ratio (i)

$i = \frac{Input speed}{Output Speed}$

$= \frac{30}{10}$

$\boldsymbol{i = 3}$

Gear-ratio=3

$i = \sqrt{i}$

$= \sqrt{3}$

$i = 1.7320$

$i_1 = 0.8\,[i^2 \frac{k1}{k2}]^{1/3}$

Gear and pinion are same material, i.e. mild steel,

So, K1 = K2

$i_1 = 0.8[3^2]^{1/3}$

$\boldsymbol{i_1 = 2.7826}$

For better design, assume 20^0 full depth system, for that minimum number of teeth of Pinion is,

$z_{min} = \frac{2}{sin^2\ \alpha}$

$= \frac{2}{sin^2\ 20}$

$= 17.097$

$\boldsymbol{z_{min}}$ **=18**

Where,

$i_1 = \frac{Z_G}{Z_P}$

$2.7826 = \frac{Z_G}{18}$

$Z_G = 50.08$

Table 1.

Number of teeth	Diameters of gear
18	50.08
19	52.8694
20	55.652
21	58.4346
22	61.2172
23	63.998

In this table find the gear and pinion teeth, so we are assuming

$\boldsymbol{Z_P = 23}$

$\boldsymbol{Z_G = 64}$

Input speed = 30 rpm

T = T_{design} =5.729 N-m

d_p= 25mm = 0.025 m

… (This standard pitch diameter of pinion value taken from V.B. Bhandari and reference paper)

T = $\frac{P_f \times d_p}{2}$

5.729 = $\frac{P_f \times 0.025}{2}$

$\boldsymbol{P_f}$ **= 458.32 N** **…Ans**

$P_{eff} = \frac{P_f \times C_S}{C_V}$

$P_{eff} = \frac{458.32 \times 1.5}{C_V}$

$\boldsymbol{P_{eff}}$ **= 687.48 N**

Where, C_V is neglected because rpm is very low.

Beam strength

$\boldsymbol{S_b = m.b.\sigma_b.y}$

Where, b= 10, module =10 m …. (Standard value from V.B. Bhandari)

Now, the gear and pinion material are same the mild steel of ultimate tensile strength Is 30C8,

(S_{ut}) = 500 N/mm^2

(S_{yt}) = 400 N/mm^2

…. (From V.B. Bhandari table no. 2.2, page no. 31)

$\boldsymbol{\sigma_b = \frac{S_{ut}}{3}}$

$= \frac{500}{3}$

σ_b **= 166.667 N/mm^2** **…Ans**

Lewis's strength equation,

Y = 0.484 - $\frac{2.87}{Z_P}$

Y = 0.359 **…Ans**

Now,

S_b =166.667$\times$ $10m \times m \times 0.359$

$\boldsymbol{S_b}$ **=598.33 $\boldsymbol{m^2}$N** **…(B)**

Equate (A) = (B)

598.33m^2= 572.9

m = 0.9785

m≅ 1

d_p= 0.9785$\times$ 23

$\boldsymbol{d_p}$ **= 22.60 mm**

d_G = mZ_G

= 0.9785$\times$ 64

$\boldsymbol{d_G}$ **= 62.64 mm**

Now, Factor of safety (FOS)

$\boldsymbol{S_b}$ **= FOS$\times$ $\boldsymbol{P_{eff}}$**

598.33m^2= FOS$\times$ 687.48

FOS = 0.8703

FOS ≅ 1

Hence, FOS is 1 our design is safe.

CALCULATION FOR SHAFT:

Motor Specification:

Speed = 30 rpm

Power = 18 watt

Voltage = 12 v

Torque, T = 5.294$\times$ 10^{-3} N-mm

The motor shaft is made of mild steel and allowable shear stress of mild steel for shaft is 42mpa (42N/mm^2)

.. (Standard value from V.B. Bhandari)

$T = \frac{\pi d^3}{16} \times \tau_s$

$5.294 \times 10^{-3} = \frac{\pi d^3}{16} \times 42$

$d^3 = 40.125$

d = 6.3356 mm … Ans

d ≅ 8mm

The diameter of shaft is 8mm is taken from table in V.B. Bhandari.

V. CONCLUSION

This project can step over curbs, climb stairs, or travel into areas that are currently not accessible with wheels but does not require microprocessor control or multitudes of actuator mechanisms.

It would be difficult to compete with the efficiency of a wheel on smooth hard surfaces but as conditions increase rolling friction, this linkage becomes more viable and wheels of similar size cannot handle obstacles that this linkage is capable of.

The most forceful motivation for studying legged robots is to give access to places that are inaccessible or too dangerous for human beings. Legged robots can be used for rescue work after earthquakes and in hazardous places such as the inside of a nuclear reactor, giving biologically inspired autonomous legged robots great potential. Thus in our paper we have proposed a method to replace the function of wheel in order to overcome the difficulty of travelling in uneven terrain. The most important benefit of this mechanism is that, it does not require microprocessor control or large amount of actuator mechanisms.

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