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Research Paper

The Role Of Robotics In Improving Aviation Safety

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Abstract: *This paper focuses on the safety related issues assoicated with entry into aircraft fuel tank and role of future automaition in enhancing the safety of aviation maintenance . The analysis will help to demonstrate that in the future, automation of aerospace industry will make the work safer for the human factor. The main objective of the research undertaken was to promote safeworking conditions and focus on automation of dangerous maintaineance related tasks.*

There are number of advantages from this automation, as well as a brief presentation of the mobile robot chosen to make a inspection of the aircraft fuel tank. I tried to analyze several types of mobile robots, and after this analysis and research, I decided that the most suitable mobile robot is the hexapod.

Keywords*: Identification, Control, Human factor, Aircraft, Fuel tank, Robots.*

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I. INTRODUCTION

The maintenance of fuel tank of an aircraft is a highly complex and dangerous task. A high degree of specialized automation will help to reduce the risk factors associated with it. The fulfillment of the required maintenance and repair tasks must be performed by a technical person who must physically enter the fuel tank and this exposes them to many environmental hazards. These potential risks include: fire and explosion, toxic and irritating chemicals, oxygen deficiency, and the limited nature of the fuel tank. In order to prevent associated injuries, maintenance organizations as well as operators must develop specific identification and control procedures to eliminate hazards.

Maintenance and repair technicians entering the aircraft's fuel tank for inspections (fig. 1) or modifications are in close contact with many potential hazards. They are: exposure to toxic and flammable chemical substances, atmospheric conditions that are potentially harmful to health and limited container configuration. Operators and repair stations can protect technical staff against these hazards by developing safety procedures and using automation. To successfully prevent associated accidents, both operators and technical staff need to understand the following:
-Possible accidents / hazards in the fuel tank.
-Prepare for entry into the fuel tank.

2.POSSIBLE ACCIDENTS / HAZARDS IN THE FUEL TANK

The potential dangers that technical staff can experience are in two forms: chemical and physical.

a)Chemical

The most commonly encountered and recognized danger in the tank is the fuel itself. Fuel is a flammable liquid that can ignite under certain environmental conditions, temperature and vapor concentration. The temperature at which the vapors of a flammable liquid can "ignite" is known as the ignition point. A dangerous vapor concentration is present when a fuel vapor reaches a level known as the Lower Flammability Limit (LFL) or Lower Explosive Limit (LEL). These limits are usually expressed as a percentage of the volume. Fuel under LFL / LEL is considered too low for combustion. If the fuel vapor concentration exceeds the upper flammability limit or the upper explosion limit, the fuel is considered too rich to burn. A fuel vapor concentration between these two limits is considered to be within its range of flammability will ignite and burn in contact with a source of ignition. One of the best ways to control unwanted fires and explosions is to keep fuel vapor concentrations below LFL / LEL, preventing it from reaching its range of flammability [13, 14].

Other flammable chemicals may also be present during maintenance and repair in the fuel tank. Low-ignition chemicals (less than 70 ° F (21 ° C)), such as methylethyl kenone (MEK), are more dangerous than fuel in the tank, and its use must be strictly controlled [13].

Chemicals, including fuel, may also present a toxic or irritating hazard. In high concentrations, fuel together with other hydrocarbons can affect the nervous system, causing headaches, dizziness and lack of coordination. Chemicals can cause chronic health problems that can affect the liver and kidneys, irritations to the skin if not controlled [13].

b) Physical

The physical characteristics of the fuel tank may create fire hazards, explosions and toxicity. Entry into it is through an elongated hole having less than 2 ft (0.6 m) long and 1 ft (0.3 m) wide. Although the internal dimensions of fuel tanks vary considerably with the central wing tank, which is the largest, all fuel tanks have a limited volume. A relatively small amount of a chemical within one of these enclosed spaces may create significant levels of flammability or toxic fumes [13].

The wing tanks usually have a single orifice between each frame of the section. The inner portion of the wing fuel tank provides sufficient clarity for the technical staff, with access from the waist up, leaving the legs outside the access hole. The tank becomes smaller as it advances to the outside of the wing, the access decreases significantly and the technical staff can only enter the head and arms. The central reservoir may be large enough to allow access to full technical staff [13,14].

II. PREPARATION FOR ENTERING THE FUEL TANK

Several steps must be completed before technical personnel enter the aircraft fuel tank . The safety procedures are time consuming and expensive. They also put a lot of pressure on limited available resources.These safety steps include: grounding and emptying the tank according to standard practice. Following three final steps need to be taken to ensure safe conditions for technical staff:

1-Ensuring adequate ventilation.
2-Follow-up of recommended ventilation techniques.
3-Monitor and adequately control the air in the fuel tank.

1. Ensure adequate ventilation

One of the important ways to control fire, explosion and toxic accidents associated with working in the open fuel tank is ventilation. The more fresh air is present, the more secure the environment will be in which the technical staff is working. The continous pushing of fresh air into the fuel tank helps prevent fuel vapor concentration from reaching the LFL. Thus preventing fire or possible exposure. Also, fresh air dilutes the vapor concentration of chemicals reducing the risk of toxic exposure. The large volume of fresh air will prevent a condition known as oxygen deficiency.

The normal atmospheric oxygen concentration in the air is 21% [13]. The level of oxygen deficiency (19.5% and below) in one person is manifested by signs of "hunger of oxygen," with headaches, nausea, drowsiness and speech disorders. At a lower oxygen concentration, more severe reactions may cause death by asphyxiation [13].

The cause of oxygen deficiency is often caused by the displacement of oxygen in space. For example, pumping nitrogen into the tank to prevent ignition will cause the oxygen concentration to drop. Oxygen deficiency can also be caused by the oxidation of a material by using oxygen available from space. Oxidation is a chemical reaction that combines atmospheric oxygen with another material to form an oxide. Iron oxide, known as rust, is an example.

2.Recommended ventilation techniques

The physical characteristics of airplane fuel tanks present some inevitable challenges in ensuring adequate ventilation. Some of the challenges are, those spaces where fresh air does enter. These are called "dead spaces"and also small openings between the reservoir sections, which have the ability to inhibit the air flow. Therefore, it is important to plan as accurately as possible to achieve adequate ventilation.

The recommended practice for fuel tank ventilation is the push-pull technique. First, a upstream access hole must be open for an appropriate "push". Then for a "pull", a hole must be opened down stream. Eventually a blower must be located at the pushing hole, forcing the fresh air to enter the tank [13].

3. Properly monitor and control the air in the fuel tank

No technical personnel should enter the fuel tank until it has been properly ventilated. To determine if the atmosphere in the tank is suitable for entry, atmospheric conditions should be continuously checked and monitored. And also oxygen concentration, flammable vapor concentration and toxic vapors. Entry should not be allowed, unless the oxygen concentration is between 19.5 and 23.5%. Concentrations below 19.5% are considered to be - oxygen deficient, and concentrations higher than 23.5% are considered to be - oxygen enriched [13,14].This signifies an increased risk of fire and explosion. Access to technical staff should not be allowed in the tank if one of these conditions exists.

III. AUTOMATION IN THE AEROSPACE INDUSTRY

The competitiveness in aircraft construction, as in other economic sectors is strongly influenced by a manufacturer's ability to adapt to technological change and the speed of a new product. Practice demonstrates that more human operators will move behind the terminals. Intelligently intervening in adapting robots and flexible systems to the degree of organization of production. This is the uniqueness of the product and the manufacturing plan.

Shortening the life span of products and technologies due to the strong impact of the technical-scientific revolution, the high cost of the highly qualified workforce and the increased demands in the field of quality and precision of machining. The difficulty of covering the third shift with human operators of the working day. The fact that 70-80% of the production volume is small and medium in size.

The flexible automation of processing processes is now the "backbone" of the evolutionary process of integration based on computerized production techniques. It is achieved by associating complex devices and machines with sophisticated computerized systems, integrating in a hierarchical unitary view the functions of control, handling, transport and storage. The flexible processing system offers flexible automation to the art status through its exceptional performance in the wide range of small and medium-sized production. And their subsequent development will depend on the contribution of new technologies and technical-scientific achievements as it enters contemporary industrial world.

The structures of the flexible manufacturing units are directly related to the establishment of the leveling of these units. The following are the structures corresponding to 4 levels.

At level 1 is the smallest unit with autonomous manufacturing functions, being a flexible, multifunctional machine tool [1, 5, 8]. For example an automatic machine or a machine tool that concentrates on a number of different machining operations, characterized by:

a) Numerically controlled equipment
b) Multiple processing possibilities (milling, drilling, etc.).
c) The presence of a tool storage device, a device called a tool shop which is not under the influence of the cutting forces and in which the temporary storage of the tools is made encoded.
d) Automatic change and automatic transfer of tools.

At level 2, the flexible cell ("2-nd order system") concentrates on several numerically controlled machine tools. Usually 2-4 machines served by an industrial robot IR, are provided with a CN that provides the cell conduction Flexible CF. The CF can assure the automatic processing of various products and / or component parts of a fixed class with a relatively high degree of autonomy, will also result from the presentation of the driving levels [5, 7, 8].

A simple flexible cell can be composed for example, of three machine tools serviced by an industrial robot and equipped with automatic blade shift mechanisms brought by the transport device (the billets are fitted with semifinished and then machined parts) and with automation panels. We also have the input and output devices of the cell that receive new items and new tools, as well as the outward processing of processed products and / or parts (for reuse) and possibly used tools (for refurbishment). These devices are connected with transfer devices, which bring and evacuate the said objects [1-10].

At Level 3 there are flexible SFF manufacturing systems, usually composed of multiple CF cells, linked by transport devices. In the SFF at this level ("3rd order system"), several types of sub-systems (or subsystems) can be distinguished. Thus, for the transport subsystem, conveyors may be provided with the movement of the blank in one direction within the system. And in other cases the conveyors are controlled by the computer and the semi-products and the parts are therefore palletized (fixed on carrier pallets, especially in the case of semi-finished products, resulting in prismatic products or prismatic parts). The blades are usually inserted into conveyors or trolleys driven by the conveyor and can be moved to any station (platform, post) processing system and in any order, which opens wide possibilities to optimize operation of the whole ensemble. The take-over of the semi-finished products and parts of the transport device, the feeding of the machine tools and the return of the parts after processing on the respective devices are usually made by industrial manipulators and robots, IR and palletizing mechanisms and depaletisation Detachment from the pallet) [1, 4-12].

Within the system of Level 3, there is the possibility of additional activities in relation to those performed at Levels 1 and 2: handling, transport, feeding, processing, evacuation of machined parts, changing tools, measuring and supervising the tools, measuring the parts, monitoring the proper functioning of the installation, etc.

Automated plants ("4th order system"), which includes PLA, PA-assisted planning and design activities, intervene at Level 4 [1, 6, 9].

IV. RESEARCH BASED REASONS FOR INVESTING IN ROBOTS

1.Reduction of operating costs

- Robots helps to reduce both direct costs and operating costs.
- Robots eliminate the costs associated with manual labor - in terms of wages, training, health and safety, holidays and staff management.
- There is no need to provide a minimum level of brightness and heat, and for this reason robots are an opportunity to reduce energy bills.
- Current estimates indicate a 8% energy cost reduction potential for each 1 ° C reduction in heat, while simply extinguishing unnecessary lights can save up to 20%.

2. Increasing the quality and consistency of products

- Robots help ensure consistent high product quality and production process control.
- The risk of errors caused by human factors such as fatigue, distraction, or the effects of a boring and repetitive task is eliminated.
- Process control can be integrated with the robot.
- Inherent accuracy and repeatability translate into high-quality finishes for each manufactured product.

3. Better working conditions for employees

- Robots help improve working conditions.
- It can take over the loads that occur in dusty, elevated or dangerous environments.
- Employee motivation can be improved by training them in robot operations - it leads to valuable programming skills and makes work more stimulating.

4. Growth in production and yield

- Robots can work in long laps, at night and during the weekend with minimal supervision.
- Really allows you to achieve 24-hour productivity to reach maximum production levels and reach deadlines for customers.
- There are no breaks in production due to breaks, illness, lack of concentration or human errors.
- Perform regular loads with minimum tolerances and reduce the number of non-compliant products and production scrap.
- New products can be deployed quickly, which reduces the time needed to start production.
- Programming a new product can be done off-line without interrupting production

5. Increase production flexibility

- Robots provide flexibility to the production line.
- Once the necessary processes are configured in the robot controller, you can easily make the transition from one process to another.
- Allow maximum investment through the use of various attachments attached to robots to allow work with multiple products or more than one process.
- Provides the ability to respond quickly to changing customer requirements and tops.
- Innovative orientation technologies allow for variations in products, processes and workspace.

6. Decrease the amount of scrap and increase yield

- Improved accuracy through the use of robots means increasing the number of finished products that meet the quality standards demanded by customers without the need for further finishing.
- At the same time, reduce the amount of waste resulting from poor quality or inconsistency in handling and finishing.
- Due to the constant high quality of the production process, there is a significant decrease in the number of non-compliant products and the amount of waste resulting, which results in higher yields.

7. Compliance with safety rules, improved health and safety at work

- Robots can take on heavy, unpleasant or life-threatening tasks that are currently being carried out by people.
- Robots significantly reduce the risk of accidents caused by contact with various machine tools or other potentially hazardous situations encountered in various processes or in working with production equipment.
- Helps eliminate the affections associated with repetitive or intense processes.

8. Decrease in personnel fluctuation and recruitment difficulties

- High-skilled staff are hard to find and increasingly expensive to hire.
- Robots are ideal alternatives. Once programmed, it can start working at no cost associated with recruitment or training.
- Robots come, most of the time, with high professional skills included.
- At the same time, it provides a high degree of flexibility both in terms of working patterns and adaptability to different production tasks.
- Robots love the tasks that people hate. Their level of motivation is always high.

9. Reduction of capital costs (inventories, production in progress)

- Due to the robots you can reduce your consumables and losses.
- Less manual work also means less costs due to illness, accidents and insurance.

10. Saving space in high-value production areas

- Robots can be mounted on floors, walls, shelves or ceilings, leading to significant savings in the use of production space.
- Can be programmed to work in limited spaces so that valuable space is gained

V. ROBOTS USED IN AIRPLANE FUEL TANK INSPECTIONS

Entry into the aircraft fuel tank is required for inspections and modifications, but this works may present a risk factor for technical personnel. Working in the fuel tank can be carried out safely if the technical staff is trained and has the necessary equipment for the work. The robots can successfully intervene and play a vital role in this area.

As an example in U.S., Pat. Air Force at their base of the Tinker Air Force Base use an articulated robot for their inspections in the fuel tank. However, Tinker Air Force Base Technical Base specialists consider this robot to be half efficient due to his physical characteristics. This robot is large, must be fixed to the ground and always accompany the human operator in its inspection activities inside the tank.

Following a detailed analysis this paper shows that a hexapod mobile robot is ideal for working in the fuel tank because it has both physical and technical characteristics. The main problem of an autonomous mobile robot is to carry out the control of locomotion on an accidental land. Some of the structures used to build mobile robots were obtained from inspirations related to the animal kingdom, such as a hexapod. A mobil robot with foot has the ability to move on an area with a high degree of difficulty and this is perfect for the aircraft fuel tank. For this ability and more details that will be discussed in a future artical the hexapod robot (fig. 2) was choosen which is perfect for this job.

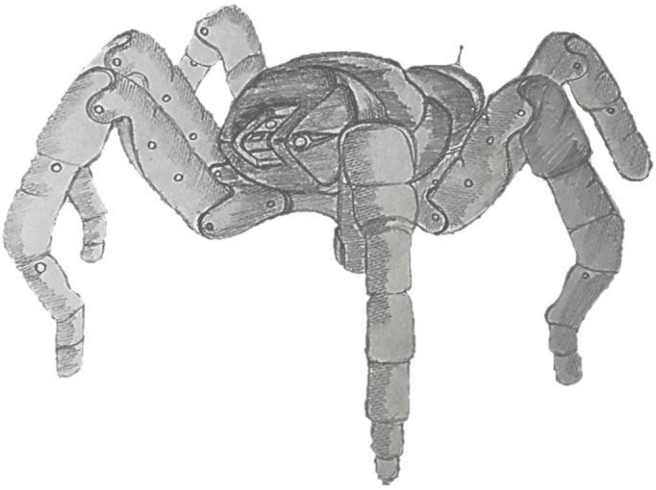

Fig. 2 – Hexapod robot

VI. HEXAPOD ROBOT

A large number of inspections and changes to an aircraft's fuel tanks and their adjacent systems must be made within them. Tasks necessary maintenance and repair must be performed by a technical staff that must enter inside the fuel tank, where it is exposed to many environmental risks. These potential risks include: fire and explosion, toxic and irritating chemicals, oxygen deficiency and limited nature of the fuel tank. To prevent associated injuries maintenance organizations and operators should develop specific procedures to detect and eliminate hazards.

Entry into airplane fuel tank is needed for inspections and modifications, but these works may pose a risk factor for technical staff. Working in the fuel tank can be done safely if technical staff is trained especially has the necessary equipment. In this area robots can intervene successfully.

Therefore, this paper aims to implement a mobile robot. Due to its characteristics, the robot can easily sneak into the fuel tank of the aircraft and the operator can guide robot from outside to facilitate its aircraft maintenance activities. The ability of the robot to operate inisde the fuel tank without human

supervision in the fuel tank will enhance the safety of the maintenance staff and make it more efficient.

The main problem of an autonomous mobile robot is to carry out the control of locomotion on land . Some of the structures used to build mobile robots have been obtained thanks to the inspiration of the animal kingdom, such as the hexapod . Several researchers were inspired and then relied on, emulating the four-legged animals or insects. The most remarkable legged robots, it can be said that is "BigDog", it has four legs and operates military applications, but also “RHex” (Moore, 2002) and “MELMANTIS” (Melmantis, 1997).

A legged robot has the ability to move on land with a high degree of efficiency, and mobile wheeled robots do not have this advantage. Robots with legs can move over landslides, gravel, uneven roads, obstacles or land where there are no roads. However, the ability to control a hexapod robot is a complex issue. The system of a robot locomotion employed, coordinated simultaneous movement and consists of six legs, each with three degrees of freedom (G.D.L.). The Hexapot robot have a total of 18 degrees of freedom. Due to the fact that, the movement of the robot is achieved by interaction of unstructured environment, it is necessary to sense specific use an electronic system for detection of obstacles. However, it should be stressed that the main problem is the coordination of angular movement of the robot's 18 joints during movement, emphasizing the sequence of steps. This problem is resolved by implementing an electronic system dedicated to distributive architecture.

VII. STABILITY AND CONTROL OF HEXAPOD ROBOT

Stability analysis of a robot with multiple legs is necessary to control, especially in dynamic situations on an uneven terrain. The main concept of this type of vehicle stability, is that its center of gravity (CG) of the robot must be kept within a stable regions, to prevent its overthrow. Therefore, under both conditions of static and dynamic, when the robot walks, move or handle, it is essential to monitor the stability of the robot at each point through the use of a criterion of stability in the control. In particular while crossing a frame or uneven terrain. There are several criteria for stability, systems that can be divided into static and dynamic criteria [5, 7, 9]. However, they can be classified on the basis of their stability metric, as follows:

Criteria based on distance: distance between focusing on each polygon support and projection CG (center of gravity) or the distance between support and force vector polygon net, acting on CG, which is the metric stability. Stability edge (SM), established by McGhee, is the most notable distance based on stability, because stability is the edge shown for the first time. MS is defined as the minimum distance between CG and limited support polygonal projection.

Angle-based criteria: use the angle of the polygon support and the net force acting on CG, accounting system stability. Based on the number of indications of its shares, the criterion most notable in this category is the angular edge stability force (FASMA). FASMA is defined as the net force and angle between the line connecting the center of mass of the point of rotation (the plan) and the axis of rotation (in space).

Criteria based on energy: It starts from the energy difference between the robot in two different situations and overthrow the current configuration. The first static based on the stability (ESM) was presented by Messuri and Klein in "Automatic body regulation for Maintaining stability of a legged vehicle During rough-terrain locomotion" and the dynamic (DESM) was presented by Ghasempoor and Sepehr in "a measure of stability for moving base machine manipulators", which was normalized by S. Hirose (NESM) and Garcia (NDESM).

Most of stability criteria falls under the criteria based on time since overthrowing takes place when the time exceeds one of the axes of rolling. However, the criterion based on time can be quite difficult to implement especially on uneven terrain because it requires knowledge of when each axis and the position of each leg. The most notable moment is stability criterion based on dynamic image (DSM), zero moment point (ZMP) and Roll Stability edge (TSM).

Criterion based on force: the focus on the forces acting on the robot. This robot, studied, the contact is generally feet. When inverted, leg strength, except that create rolling axis (or planar point - robot) becomes zero. Although attempts have been made to use this concept for controlling the robot, there is no certainty the exact way of monitoring it. Researchers Garcia, Roan and many others have concluded that a mobile robot is controlled by several feet on three levels: the torso, legs and joints. This criterion is applied to any mobile robot then applies various sensors each level, special controllers etc.

VIII. LEG STRENGTH - EDGE STABILITY

In dynamic situations, it is essential to monitor the stability of the robot every time by using a stability criterion, especially while crossing a frame, an undulating ground [1-10]. According to E. Garcia and P.A.G. Santos, a machine that goes is dynamically stable if the time limit j's support polygon caused by robot / ground forces and moments are positive (in clockwise). It emphasizes that with E. Garcia and P.A.G. Santos used the F × R not R× F . Using R × F, the definition of dynamic stability can be rewritten as: a car running is stable dynamic if time j which limit the support polygon caused by robot / ground forces and moment are negative (reverse clockwise). From Newton's law, the following limits must be met in support of the polygon, each as follows:

$$M_{in,j} = M_{gr,j} + M_{man,j} + M_{sup,j} \qquad (2.1)$$

Where $M_{in,j}$ it is the moment due to the inertial force and moment $M_{gr,j}$ it is the moment due to gravity and $M_{man,j}$ it is the moment is due when handling (external) and force and moment $M_{sup,j}$ it is the moment due when contact force and moment. All times are calculated on j, support polygon limit. From Equation 2.1, the following can be written:

$$M_{sup,j} = -\left(M_{gr,j} + M_{man,j} - M_{in,j}\right) \qquad (2.2)$$

The term in brackets of equation (2.2) is the net moment when acting upon j, support polygon limit, due to all forces and moments handled. Therefore, it can be replaced with $M_{Net,j}$ which may be offset by moments and forces given robot / ground, $M_{sup,j}$. Therefore, in order to have a stable dynamics of the robot, the following equation must be satisfied:

$$M_{sup,j} = -M_{Net,j} \qquad (2.3)$$

Indicating that a robot to be dynamically stable net time, support polygons j limit must be positive (in clockwise), but with the same amplitude as support forces and moments due time. Otherwise, the robot will roll. Assuming the point of contact, the legs point, the equation can be written accounting $M_{sup,j}$:

$$M_{sup,j} = \sum_{i=1}^{n} R_i \times F_i = \sum_{i=1}^{n} f_i \cdot R \times \left(\sqrt{1 + \mu_i^2} \cdot e_{F,i}\right) \qquad (2.4)$$

Where n is the number of the legs, R_i is the position vector perpendicular to the contact of the feet, on the limit j support, F_i foot is in contact force vector, $f_i = \|f_i\|$ amplitude is the normal leg strength, where f_i it is a normal component of F_i shown in Figure 1. μ_i it is the friction of the foot / ground and $e_{F,i}$ is the unit vector of force foot contact, F_i .

Therefore, the dynamic stability of normal strength correlates with the robot foot (f_i), as well as the coefficient of friction (μ_i) and foot positions (R_i) in accordance with E. Garcia and P.A.G. Santos in the paper "A new energy dynamic stability margin for walking machines", in International Conference on Advanced Robotics, pp. 1014-1019, 2003 equations 2.3. and 2.4. However, to analyze the stability of an ideal robot with multiple legs, the friction coefficient is considered high enough to prevent slippage of robot. Therefore, the instability is considered overturning / rolling not slipping. It is assumed that the distribution leg is necoliniar, $\sum_{i=1}^{n}\|R_i\| \neq 0$. Also, all contacts between the legs of the contact surfaces are assumed to be contact point.

Giving the robot with multiple legs (n≥3) with only two forces strictly positive, indicating that only two legs are in contact with the ground, creating j limited support, it is determined that $M_{sup,j}$ it is zero and requires $M_{Net,j}$ to be the same, namely zero . Otherwise, if $M_{Net,j} \neq 0$,equation 2.3 will be satisfied and the robot will roll. Therefore, to be considered dynamic stability, the robot must have at least one foot on the ground with a force strictly positive to negative because of a time limit on support and to offset the positive j, $M_{Net,j}$. If $M_{Net,j}$ is negative, the robot is unstable [6].

Taking into account the assumptions above discussion, it is assumed the following conclusion:

Definition 1 - ideal mobile robot with n foot (n≥3) at time t is dynamically stable if and only if at least three non-collinear legs and a strictly positive force $(f_i > 0)$ at time t. This definition provides a quick method for determining measurable system stability. However disregard R_i, which greatly influences $M_{sup,j}$.

The current relationship between stability and leg strength requires strictly positive forces $(f_i > 0)$; however, the relationship may change to take account of riding on walls, frames, ceilings and surfaces very inclined.

As shown in the above finding, the stability occurs when there are at least three feet forces of the leg strictly positive. Intuitively, stability occurs when the maximum size of the leg forces are all the same, that forces the legs are all the same, that the forces are evenly distributed on all four feet. It is desirable to have an appropriate understanding that provides a normalized current stability of the system based on force amplitude leg. FFSM uses forces the foot to foot stability describe their status. It allows $f_1, f_2, \dots, f_n$ amplitude be normal force support legs, where we are the number of support legs. The product of all forces leg Amplitude be normal force support legs, where we are the number of support legs. The product of all forces leg, $\prod_{i=1}^{n} f_i$ it is used as a basis to define FFSM since

satisfied the definition of 1 instability. FFSM to meet state maximum stability of the robot, the product is normalized between 0 and 1. For this purpose, the ratio of force - the total force measured individual leg, $\frac{f_i}{f_{tot}}$, it is used when $f_{tot} = \sum_{i=1}^{n} f_i$. Is observed that $\sum_{i=1}^{n} \frac{f_i}{f_{tot}} = 1$. The maximum amplitude $\prod_{i=1}^{n} \frac{f_i}{f_{tot}}$ is $\frac{1}{n^n}$ which correlates with the condition of maximum stability of the machine. Because FFSM to result in a number between 0 to state 1 state unstable and stable maximum term n^n it is multiplied by the product. FFSM at time t for a robot with n foot support is defined as:

$$FFSM = S = \prod_{i=1}^{n} \frac{f_i}{f}, \quad 0 \leq S \leq 1 \quad (2.5)$$

Where n is the number of the legs with strictly positive forces on foot and $\bar{f} = \frac{f_{tot}}{n}$ it is the average of all normal forces on foot [5, 7, 9]. Therefore, FFSM is the product fractions to the average of all the forces of the foot forces the foot.

Equation 2.5 provides an amplitude stability margin between zero and one, 0≤S≤1, indicating how close the system is to achieve maximum state of instability or stability condition. As expected, the equation 2.5 show that a uniform distribution of forces improves the stability of the whole system legs. Therefore, maximum stability FFSM = 1, occurs only when the forces are evenly distributed foot, that is to say the standard deviation of the amplitude of the force of the foot is zero.

Given a system n≥4 and m standing m≤n-3, lose contact with the ground, which usually happens on an uneven terrain, the equation 2.5. stability will indicate a zero edge while the system will remain stable with n - m support legs. For example, when a robot walk, configuration changes from quadruped, n = 4 from the tripod, n = 3, a foot loses contact with the ground while the tripod support configuration maintains stability. In order to take account of loss of contact with the ground on purpose, in the calculating FFSM it should be updated accordingly to n← n – m at each iteration in the controller. To ensure that the robot will be stable after switching from n to n -m feet FFSM both states, must be calculated simultaneously while the robot switches. Thus, if n -m is not stable configuration, the robot will recognize and will not fall [7, 9].

Since the FFSM only focuses on the amplitude of the normal component of the forces of the foot, taking into account the cross-section of the leg of the robot, on the assumption that $\alpha > 1$ is a constant, FFSM is the same for all four cases: MFFSM = m (t) S (2.6)

IX. CONCLUSION

This paper aims to implement a hexapod mobile robot. Due to its characteristics, this robot can easily sneak into the fuel tank of the aircraft and the operator can guide the robot from outside to facilitate its aircraft maintenance activities. Due to the fact that, the movement of the robot is achieved by interaction of unstructured environment, it is necessary to sense specific use of an electronic system for detection of obstacles. However, it should be stressed that the main problem is the coordination of angular movement of the hexapod robot's 18 joints during movement, emphasizing the sequence of steps. This problem is solved by implementing an electronic system dedicated to distributive architecture.

Entry into the aircraft fuel tank is required for inspections and modifications, but these works may present a risk factor for technical personnel (fig. 3). Working in the fuel tank can be done safely if the technical staff is trained and has the necessary equipment for the work. In this regard, mobile robots can successfully intervene.

The automation of maintenace of fuel tank is a very challenging task due to the uneven surfaces inside the fuel tank and presence of dangerous chemicals. Robotics automation provides the flexibility needed to achieve shorter production cycles, new ways of packaging as a form and design, and the creation of new product variants and batch manufacturing. Compared with traditional dedicated automations, robot lines are shorter and allow for much better space utilization. Robot automation is an excellent alternative to manual operation. In addition, the increase in working time and total efficiency.The decrease in the number of accidents and the increasing demand for labor protection legislation are good reasons for moving to robots.

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