ADVANCEMENT IN FOREST MANAGEMENT USING ROBOTICS

18CHAA0 - ENVIRONMENTAL SCIENCE

Submitted by

K. ASHWIN

917721G012

V. MILAN JOSE

917721G056

T. LOGESHKUMARAN

917721G049

Guided by

Dr. M. Velayudham
Assistant professor

Department of Chemistry

THIAGARAJAR COLLEGE OF ENGINEERING
(An Autonomous Institution Affiliated To Anna University)

MADURAI – 625 015

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THIAGARAJAR COLLEGE OF ENGINEERING

(An Autonomous Institution Affiliated to Anna University)

MADURAI – 625 015.

CERTIFICATE

Certified that this is a bonafide record of the 18CHAA0 Case study & Viva Voce done by **Mr.K.Ashwin** (917721G012)**, Mr.V.Milan Jose (**917721G056) and **Mr.T.Logeshkumaran** (917721G049) of Second Semester B.E/B.Tech during the year 2020 - 2021.

Signature of the Guide   Signature of H.D.CHEM

Station: Madurai   Date:

Submitted for Viva-Voce examination held at Thiagarajar College of Engineering, Madurai – 625 015, on __________________.

INTERNAL EXAMINER   EXTERNAL EXAMINER   H.D.CHEMISTRY

<u>CERTIFICATE</u>

This is to certify that the **18CHAA0 case study** report entitled ***"Advancement in forest management using Robotics ",*** being submitted by Mr. k. Ashwin, Mr. V. Milan Jose and Mr. T. Logeshkumaran

Mr. T. Logeshkumaran	
Mr. V. Milan Jose	
Mr. K. Ashwin	**Dr. M. Velayudham**
(B.E. STUDENT)	**(GUIDE)**

Station: Madurai

Date:

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ABSTRACT

CHAPTER 1

INTRODUCTION

Fire has been closely associated with mankind from the beginnings of civilization. The Discovery of fire and its uses have directly or indirectly permitted man to live and survive in the temperate zone. Forests are a major natural resource, which plays a crucial role in maintaining environmental balance. The health of the forest in any given area is a true indicator of the ecological condition prevailing in that area. The frequent occurrence of forest fires has been one of the major reasons for the depletion and extinction of most of our valuable plant and animal species. Even human beings are adversely affected either directly or indirectly by the havoc of these killer fires. Thus forest fires are considered to be a potential hazard with physical, biological, ecological & environmental consequences. Forest fire results in partial or complete degradation of vegetation cover thus modifying the radiation balance by increasing the surface albedo, and water runoff and raising the soil erosion

1.1. Categories of Forest Fires

Fire in the most accepted manner can be defined as that it is uncontained and freely spreading combustion which consumes the natural fuels of a forest i.e. duff, litter, grass, dead branch, wood, snags, logs, stumps, weeds, brush, foliage and to some extent green trees. Forest fires have been categorized into three categories. Ground fires: A true Ground fire is not easily predictable as it spreads within rather than on top of organic matter. It consumes organic matter like duff, musk, or peat present beneath the surface litter of the forest floor. It has the unique characteristic of having a smoldering edge with no flame and little smoke. Ground fires are most hard to handle, and control agencies should have p roper policies and practices. Surface fire: Surface fire is characterized by a fast-moving fire, which consumes small vegetation and surface litter along with loose debris..

1.2. Advantages of natural fires

Fire is a natural phenomenon which takes place in forest ecosystem to reduce accumulated fuel. Thus natural fires play crucial role in the maintenance and self balance of the forest ecosystem. If these natural fires are intentionally suppressed it may cause a wild fire in near future. Plants & animals are naturally adapted to natural fire. Thus if the forest fire is natural it plays very crucial role in maintaining the balance of self sustained ecosystem and thus maintaining life on earth.

1.3. Effects of fire

Effects of fire should be understood properly in terms of economic loss. We can formulate good public and private forest policy & forest practices for forest management. Apart from physical removal of material from the forest as in logging, fire is the only means of quickly removing large quantities of woody and other vegetative materials. Fire has heat effects which destroys vegetation and kills animals' life. The residual chemical effect are also deleterious for the soil.

1.3.1. Short term effects

In short term, effects of forest fire consumes vegetation, woody debris and soil organic matter. It also heats soil and water streams. It kills animals which unable to escape due to excessive heat. It also increases air pollution in effected areas due to burning of carbon materials. It affects the daily earners who are dependent on various forest products for their livelihood. . It affects the daily earners who are dependent on various forest products for their livelihood.

1.3.2. Long-term effects

Soil productivity is greatly affected which changes the forest structure & due to which future vegetation development will be affected, and it may induce soil erosion. It will adversely affect abundance, density, and distribution of creatures right from microbes to megafauna. Fire serves an important function in maintaining the health of certain ecosystems, but as a result of changes in climate and human use and misuse of fire, fires have become a threat to many forests and their biodiversity.

1.4. Research Motivation

Forests are a valuable wealth of our earth. They play a vital role in sustaining life and other processes related with living organisms. They maintain healthy environment and provides ample resources for human development. All living beings directly or indirectly depend on forests. But forest fires or wild fire and deforestation are greatest enemy of these mute resources. Forest fires damage much of our forest biomass and cause havoc for various plants and animals by putting them in endangered category or at the verge of extinction. As a science student and nature lover, I have been inspired by these killer fires to work something for our forests especially in my study area which is also present in my home state.

1.5. Problem Statement

Apart from other natural hazards like landslides and earthquakes, Forest fires and deforestation are one of the major disasters in the forest. There are many indigenous and endangered species in the forest that are affected by the forest fire and deforestation. Since there is a sudden increase in the global temperature there is an immediate need for controlling forest fires and preserving forest.

CHAPTER 2

LITERATURE REVIEW

Technically, fire is defined as the rapid combustion of fuel, heat and oxygen. All these three elements are in some proportion to start and spread fire. It is a chemical reaction of any substance that will ignite and burn to release a lot of energy in the form of heat and light . To start a fire an external source of heat is required along with a oxygen. Heat is measured in terms of temperature. Fuel is any material capable of burning. In forests, fuels are vegetation, branches, needles, standing dead trees, leaves, and man-made flammable structures .

The main objective of this literature review is to provide an overview of the understanding of the effects of forest fire on the natural vegetation and how forest fire acts as a forest management tool. It was basically understood that the forest fire occurs naturally or humans induce fire to accomplish their management objectives such as to reduce precarious fuels preventing from wildfires and manage forest for environmental conservation, various production and recreation

In general, forest fire leads to further conversion of the natural habitat. Most of the recommendations cited in this literature review conveys that fire acts as forest management tools but it also alters the natural ecosystem where the well-established vegetations are disturbed. The natural forest fire occurs unexpectedly but we can prevent wildfires from its occurrence by implementing the practice of prescribed burning thereby reducing the hazardous fuels. Now we came to know that fire act as a forest management tool but we should keep in mind that management of forest with pine tree using fire can eliminate oak regeneration. In other words, the behavior and response to the fire by one population or community of vegetation is different to others

2.1. Causes of forest fires

Basically causes of forest fire have been classified into three main categories

1. **Natural**

These are the fires which cannot be averted as these occurs naturally due to lightening, rolling of stones & rubbing of dry bamboos due to strong wind.

2. **Intentional/ Deliberate**

Mainly intentional fires are created for the better growth of fodder grass. These fires are also been set by villagers to drive away the herbivores animals which destroy their crops. Sometimes villages get annoyed with forest Department and deliberately set fire without knowing its consequences. Villagers also set fire for collecting forest products like honey, gum, Mahua flowers etc. Railway transport also causes forest fires occasionally. Forest Department people can't do much if the fire is caused deliberately by local dwellers.

3. **Unintentional/ Accidental**

Unintentional/ Accidental fires are result of carelessness of human beings such as throwing of burning match stick or cigarette/ bidis. Other fires which occur accidentally are the spread of fire from labour camps, from picnic sites and other recreational areas due to human activities. These types of fires are controlled by certain parameters like its proximity to settlements and distances from roads. Although it is not easy to account natural or deliberate fires but the areas prone to fires can be detected and mapped.

2.2. Parameters responsible for forests fire

Three factors are required for any fire to take place: These are availability of air, fuel and heat. All these three factors depend on many factors. Forest fire does not depend on any single factor instead its behaviour, intensity and spread depends on various integrated factors.

1. **Vegetation type / density**: Dense and dry vegetation are more susceptible to fire in comparison to moist and sparse one. Moisture content of vegetation delays ignition.
2. **Climatic factors**: Climate plays the dominant role in ascertaining the fire prone areas as they are the main determining factor of vegetation of a given region. Thus drier the climate the more prone is the site for fire.
3. **Physiographic Factors:** Physiographic factors include altitude, aspect and topography of a region. These are the factors, which are mainly responsible for variation in climatic conditions. Thus they indirectly affect the vegetation. Aspect plays one of the major roles in the spread of fire like southern slops which are more or less directly exposed to sun rays are more vulnerable to fire
4. **Edaphic factors**: Soil plays a vital role in the growth, development & anchoring of the vegetation. And vegetation after decay adds to the fertility of the soil
5. **Main causes of forest fire in Indian content**: Following area the main cause of fire:
   - Those people who are involved in cutting & stealing of wood and illegal activities in forests sometimes deliberately create fire to drive away the attention of forest department.
   - Sometimes Forest Department peoples themselves set fire to clear the blockades of inspection path.
   - To collect non-wood forest products from interior of the forest villagers use to deliberately set fires.
   - For getting fresh grass in the next season people sometime create fire deliberately in the fringes of forest area.

2.3. Forest degradation and its impact

Despite that the overall forest cover in the country is on increase, most of the forest areas in the country are ecologically in various stages of retrogression. The forest ecosystems are reeling under acute form of degradation, which has adversely affected the Indian society, both socially and economically. Owing to various other factors, the deterioration of the forest is the major cause for increase in both physical as well as socio-economic vulnerability of country to disasters. It has been widely accepted that deforestation increases the intensity of natural disasters and is often the factor that transforms a natural hazard or climatic extreme into a disaster In ecologically more sensitive and destabilized areas like Himalayas and Western Ghats, the impact of deforestation/ degradation has been more severe. In the recent past, as a result of so called developmental activities, particularly in sensitive regions, the environment has been very adversely affected, resulting into exponential increase in fragility of land mass. Deforestation and other allied land degradation activities such as water logging, flooding, ravines, shifting cultivation, mining, salinisation, soil erosion, landslides / rock falls and desertification have affected more than half of the total geographical area of the country. The deforestation in the form of mangrove removal has made coastal regions of the country susceptible to erosion and damage to human settlements.

The deforestation and destruction of other natural resources have compelled people from rural areas to migrate in search of new livelihood in urban areas, resulting into unplanned settlement even in high risk zones i.e. seismic zones, steep hillsides and flood-prone areas. The mushroom growths of slums in various metropolitan cities of the country are also at maximum risk to natural and human induced disasters.

CHAPTER 3

PROBLEM DESCRIPTION

3.1 Environmental problem

3.1.1 Effects of fire on ecosystem

Forest fires effects globally because it emits lots of carbon leading to global warming & consequently it will lead to biodiversity changes. At regional and local level, biomass stock & hydrological cycle are adversely effected leading to deleterious effects on coral reefs and functioning of plants and animals species are also effected. Due to increased percentage of smoke in environment, photosynthetic activity is reduced, and thus health of human beings and animals is also effected. The trees which fall due to forest fires become fuel for coming years & thus the frequency of forest fire increases and it may lead to growth of fire prone species in large quantity. e.g. Phyrophytic grasses. Fire can be followed by insect colonization and infection which disturbs the ecological balance. The replacement of vast areas of forest with Pyrophytic grasslands is one of the must negative ecological impacts of fire, in tropical rain forests. These processes have already been observed in
parts of Indonesia and Amazonia

3.1.2 Effects of forest fire on plant diversity

Severe fires have had a significant negative impact on plant diversity. Agricultural clearing is one of the major causes of fire in Tropical forests. In forest where human activities are in excess, the deforestation fires sometimes leads to complete burning of the forest leading the bare soil. Those forests which are not adapted to fire, fire can kill virtually all seedlings sprouts, lianas and young trees, because they are not protected by thick bark. Damage to seed bank, seedlings, & saplings, hinders the recovery of original species.

3.1.3 Effects of forest fire on forest fauna

Forest fires very adversely effects animals not only by killing them but also by long term effects such as stress, habitat loss, territories, shelter & food. The loss of key organisms in forest ecosystem, such as invertebrates, pollinators and decomposers will slow the recovery rate of forest.

Territorial, habitat & shelter loss: Due to destruction of dead logs & many standing cavities in trees which are the home for many small mammal species such as bats, lemur and cavity nesting birds are effected. Thus many birds and mammals are displaced resulting in loss of wildlife and consequently disturbance of biodiversity.

Loss of food: Due to loss of fruit trees, many animals and birds species are declined as they are dependent for their food on these trees. For example fruit eating birds such as Hornbill has declined dramatically in tropical forests due to forest fire. Population of some small carnivores has declined due to running away of small mammals such as rodents which are food for these carnivores. Arthropods community which are food source for omnivores & carnivores are also destroyed with leaf litter in fire

3.2 IMPORTANT DEFINITIONS

Forest fire management is associated with various terms like ‘Risk’, ‘hazard’ ‘danger’ ‘vulnerability’ ‘severity’ etc., if we really want to understand forest fire terminology then these technical terms should be explained properly.

Fire Hazard: Fire hazard is physical event of certain magnitude in a given area and at a given time, which has the potential to disrupt the functionality of a society, its economy & its environment.

Fire vulnerability: Fire vulnerability is the degree of loss to biotic and abiotic elements of the
environment to a given magnitude of fire hazard. It is expressed in a scale between '0' (no damage) to
'1' (total damage).

1. As per definition of United Nations ISDR (2002), Vulnerability is a set of conditions and processes resulting from physical, social, economical and environmental factor, which increase susceptibility of community to the impact of hazards.
2. **Amount**: It simply termed as the quantity of elements at risk. e.g. number of peoples, number of trees, number of animals etc.
3. **Capacity**: Capacity is defined as the skills and operational resources to cope up with the fire risk factors so that the damage can be reduced or Capacity is defined as the ability, strength and skills of various elements at risk to use the available resources to cope with the fire risk.
4. **Fire Risk**: Fire risk is expected losses due to fire hazard to various elements at risk over specific time. Thus it is measured in terms of expected loss e.g. economic loss, number of lives loss and extent of physical damage. Mathematically fire risk expressed as Risk =Hazard * Vulnerability * Amount Risk= Hazard*[Vulnerability / Capacity]
5. **Fire Severity**: Fire severity refers to the magnitude of significant negative impact on wind land systems

3.3 ENVIRONMENTAL EFFECTS DUE TO DEFORESTATION

Loss of Habitat: One of the most dangerous and unsettling effects of deforestation is the loss of animal and plant species due to their loss of habitat. 70% of land animals and plant species live in forests. Not only does deforestation threaten species known to us, but also those unknown. The trees of the rainforest that provide shelter for some species also provide the canopy that regulates the temperature.

Increased Green House Gases: In addition to the loss of habitat, the lack of trees also allows a greater amount of greenhouse gases to be released into the atmosphere. Healthy forests absorb carbon dioxide from the atmosphere, acting as valuable carbon sinks. Deforested areas lose that ability and release more carbon.

Water in Atmosphere: The trees also help control the level of water in the atmosphere by helping to regulate the water cycle. In deforested areas, there is less water in the air to be returned to the soil. This then causes dryer soil and the inability to grow crops.

Soil Erosion and Flooding: Further effects of deforestation include soil erosion and coastal flooding. Trees help the land retain water and topsoil, which provides the rich nutrients to sustain additional forest life.

Destruction of Home Land: As large amounts of forests are cleared away, allowing exposed earth to whither and die and the habitats of innumerable species to be destroyed, the indigenous communities who live there depend on the forest to sustain their way of life are also under threat. The loss of forests has an immediate and direct effect on their lifestyle that we in the highly industrialized parts of the world, despite our own dependency on what the rainforest provides, will never know. The level of immediacy is exponentially greater for indigenous peoples. The governments of nations with rainforests within their borders often attempt to evict indigenous tribes before the actual clear-cutting begins. This is one of the pre-emptive effects of deforestation.

OBJECTIVE

- To detect the various types of robots that can be used to reduce forest fires and preserve the forest.
- To determine the best design for the robot used to prevent the forest fire and that help preserve nature
- To develop a robot that can preserve the forest as well as fight against forest fire which is environmentally friendly so that it does not affect the forest fauna and flora.

CHAPTER 4

METHODOLOGY

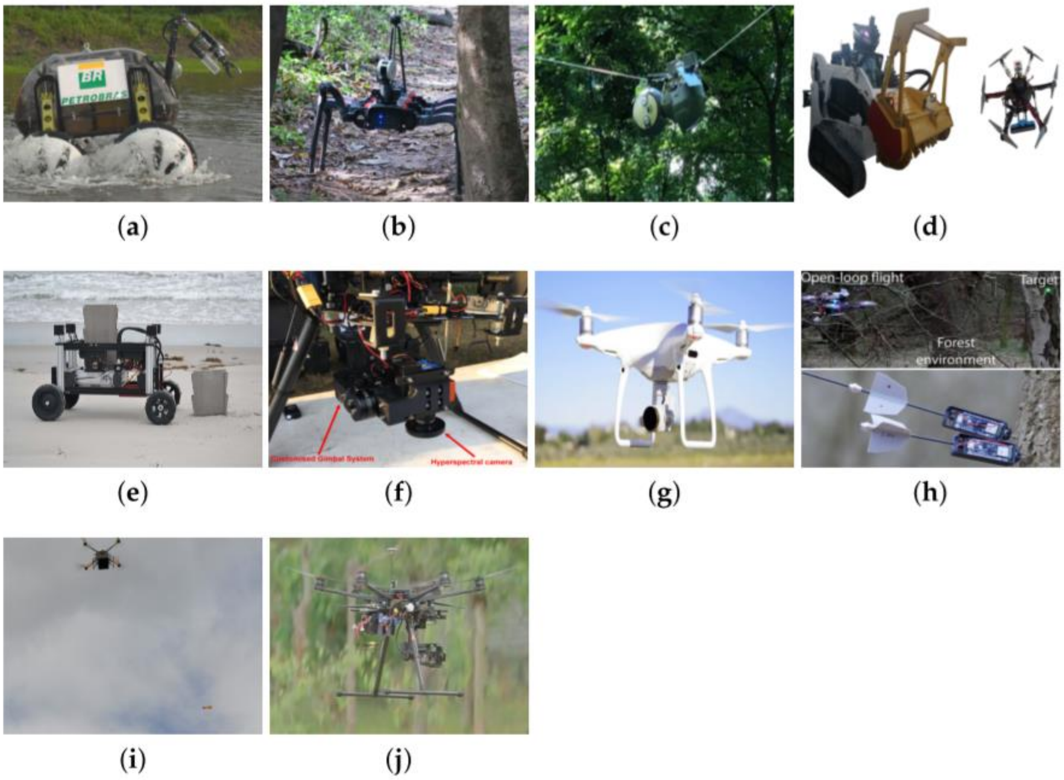
4 ROBOTIC APPLICATIONS IN FOREST

Robotic applications in the forestry area are divided into the following subsections: environmental preservation and monitoring; wildfire firefighting; inventory operations; and forest planting, pruning, and harvesting. Therefore, the following sections address the various types of robotic system applications in forest environments individually.

4.1. ENVIRONMENT PREVENTION AND MONITORING

Chico Mendes is a wheel-legged amphibious robot with active reconfiguration, capable of walking on gas pipelines, land, water, swamps and sand, as shown in Figure a. To control the robot's distance from the ground along with its orientation, the distance to the ground along with its gradient stability margin and traction indices, the robot has an optimal multi-objective control approach. With this approach, the robot increased the maximum tilt angle from 35◦ to 44.8◦, an improvement of 28%. The robot also has a robotic arm with sensors for water quality and gas, Red, Green and Blue (RGB) camera and sampling support located on the final actuator, to monitor possible gas leaks and water pollution, in addition to checking out dengue outbreaks.

Sloth Bots: Eliminating the high irregularities of the soil and the dependence on wind conditions, the SlothBot robot makes its locomotion along wires trapped between the trees



Legged robot, as shown in Figure b, was used to carry out environmental monitoring activities in the Rainforest. This type of locomotion system was adopted because the Rainforest is characterized by being an unstructured and difficult to access environment: in addition to being a wild environment, it is a dangerous environment for
human beings. In addition to allowing locomotion that adapts to the terrain slope, the robot is equipped with a Light Detection and Ranging (LiDAR) that maps the environment around it to perform autonomous navigation through the Simultaneous Localization and Mapping (SLAM) algorithm.

Sloth Bots: Eliminating the high irregularities of the soil and the dependence on wind conditions, the SlothBot robot makes its locomotion along wires trapped between the trees, as shown in Figure c. As a direct advantage, the system allows long-term environmental monitoring through low energy consumption. Through a mesh of planar wires, connecting different regions of interest, the SlothBot moves from the initial position to the desired one collecting sensory data of temperature and luminosity. It has an exclusive C-shaped mechanical system to change direction in bifurcation situations.

Scouts : The task is carried out through a swarm of Scouts, small UAV with Collective SLAM. The Scouts (Figure d) are looking for new Regions of Interest (ROI) for the Ranger robot (a robot that cuts and grinds the vegetation, transforming it into mulch) to define a region of operation
to perform cleaning task planning.

Romu Robots: To reduce hydraulic erosion activities in natural environments, they developed the Romu robot (Figure e) which has four wheels mounted on vertical linear actuators to assist in the task of fixing steel piles to the ground. By means of a vibratory hammer system and the reduction of the height of the robot, the system was able to fix the piles in sandy soils to a depth of 6–8 cm. Based on a computer simulation, where several piles were fixed in sandy terrain, when simulating a stream of water going down the sandy terrain, 50% of the soil that would be lost was retained by the barrier, indicating its great application potential [15]. Although this application is not in a forest, the challenges are similar, since the dunes environment is non-structured. In this sense, the sandy soil, the steep slope, the dust winds and changes in ambient lighting and temperature impose challenges for the development of locomotion systems, navigation algorithms and protective structures forth robot’s electronic components.

shape of the sensor device is inspired by Samara seeds (Figure i), which perform a helical movement during the free fall. Therefore, whether by the method of sensor launching or by dropping, the use of UAV is essential for displacement along the forest during the performance of forest monitoring tasks a UAV equipped with thermal and RGB cameras (Figure j) was used to carry out the monitoring and preservation activities of a group of koalas on the Sunshine Coast, Australia. To detect koalas through Forward-Looking InfraRed (FLIR) thermal and RGB cameras, the researchers used two distinct algorithms: Pixel Intensity Threshold (PIT) and Template Matching Binary Mask (TMBM). PIT can differentiate animals from background vegetation through the thermal signature of living beings, but it is not able to differentiate between species. To solve this problem, they developed the TMBM algorithm, which, through testing in a real scenario, was able to detect koalas in their natural environment at different altitudes (20–30 m) with different average detection times (1.3–1.6 s).

4.2. FOREST FIRE OR WILD FIRE FIGHTING

Unlike the monitoring of forest activities, wildfire fighting activities require direct intervention (traditionally through firefighting trucks and planes) in the forest environment so that there is a minimum of damage not only to the fauna and flora but also to the populations that live in such locations. Although forest monitoring via satellites is of paramount importance in the fight against illegal deforestation when there are forest fires they do not contribute to the extinction of the fire. In this case, this function is entirely dependent on the replenishment of several teams of firefighters, water trucks, and firefighters aircraft. The robotic applications for wildfire fighting can contribute to faster, safer, and more efficient action of spraying water or retarding agents in forest regions. The design of firefighting robots has requirements such as having a mechanical structure resistant to high temperatures and concentrations of gases and dust, high payload capacity, and a locomotion system designed to transport large payloads through rough terrain and be used for multitasking.

A Six-Wheel Drive (6WD) autonomous ground vehicle, developed by military product manufacturer Lockheed Martin, was adapted to perform firefighting operations. The Fire Ox robot can be integrated with an existing infrastructure or used individually, as it has a tank with a capacity of 250 gallons and an electrical generator of up to 1000 W. This robot can be operated using a remote control and RGB and Infrared (IR) cameras. Another company in the military sector, Milrem Robotics, has developed two versions

of robots to firefighting operations, one to extinguish the fire and the other to assist in the transportation of hoses in hostile and difficult-to-access environments.Figure a exhibits the Multiscope Rescue with Hydra, a firefighting robot equipped with a modular foam and/or water monitor with a flow rate of 3000 L/min, which can rotate 360◦ and disperse liquids (foam and/or water) at a distance up to 62 m. The robot has two sprinklers located on its front that serve as a protection system. To increase the system autonomy, the robot is powered in a hybrid way (diesel engine and battery pack) reaching a maximum autonomy of 12 h.

(a) (b) (c)

Figure 4.2

The version of the robot capable of transporting hoses, as shown in Figure b and entitled Multiscope Rescue Hose Cartridge, has the same locomotion system as the hydra version, but it has a hose cartridge specially designed to streamline the process unloading. Through a control system by teleoperation or waypoint navigation, hoses can be quickly redirected to other locations without exposing firefighters to risky situations. Unlike previous fire fighting robots, the AirCore TAF35 has a liquid jet system for

nebulizing large amounts of water without using high pressure. The AirCore TAF35 includes a caterpillar system, since the unmanned vehicle weighs about 3900 kg and is powered by a diesel engine with 71 HP which has a maximum autonomy of up to 7 h. Due to its special spray system, the robot generates a sound noise of up to 84 dB. With a speed of 9 km/h and a maximum water flow capacity of up to 4700 L/min, this robot is capable of efficiently extinguishing large-scale wildfires. The system has a water jet that can reach a distance of up to 80 m and can be controlled by remote control at a distance of up to 300 m, allowing a human operator to carry out his activities safely. Thermite RS1 and Thermite RS3 robots have a water propulsion system that resembles
Multiscope Rescue with Hydra and AirCore TAF35 robots, respectively. Thermite RS3 is a larger, faster version with a higher water flow than the Thermite RS1. Thermite RS3 has a Positive Pressure Ventilation (PPV) ventilator system, similar to the AirCore TAF35, capable of delivering up to 2500 GPM, about 9464 L/min. Created in 2017 by Shark Robotics, the French robot Colossus (Figure c) was designed
to assist the work of firefighters, not to replace them. In this sense, in addition to having a water sprayer for firefighting, the robot can be used to carry a payload of up to 500 kg (equipment and/or injured people/animals). The robot’s chassis is made of Aluminum welded aeronautical steel, a light and resistant material capable of withstanding thermal waves of up to 900 ◦C, with a total weight of 500 kg. The Colossus is capable of moving at a maximum speed of 4.5 km/h, on terrain with a slope of up to 40◦ and overcoming obstacles of up to 30 cm.

4.3. FOR INVENTORY OPERATIONS

A group of researchers assessed the performance of SLAM-aided stem mapping for forest inventory with a small-footprint mobile LiDAR. Using the FGI ROAMER R2 vehicle (Figure a) moving at 4 km/h, between open and dense forest regions, they compared three forms of navigation: only by Global Navigation Satellite System (GNSS), using GNSS + IMU and adopting SLAM + IMU. The proposed SLAM algorithm was the Improved Maximum Likelihood Estimation (IMLE). For the open forest regions, the SLAM algorithm was shown not to be feasible, as in this region there are few detection characteristics available and the GNSS signals have greater availability. On the other hand, in regions of dense forest, the precision of the SLAM + IMU technique was 38% higher than the use of GNSS + IMU .

A location algorithm based on the LiDAR Odometry and Mapping (LOAM) in real-time approach was used in a forwarder unit (Komatsu Forest 931.1, as depicted in Figure b) to perform the mapping of trees during autonomous navigation in a heavy canopy forest region. The idea was to build a unique 2D topological graph from the map's point cloud and find an optimal relationship between the global and local topology. The detection of trunks was done by clustering the data of the point cloud for a given predetermined value. The correspondence between the local and global maps was carried out by searching for triangles based on dissimilarity and calculating pairs of corresponding vertices. As a result, the work obtained a location accuracy about 0.3 m with 12 cm of standard deviation and with the processing of data in real time for speeds of up to 0.5 m/s

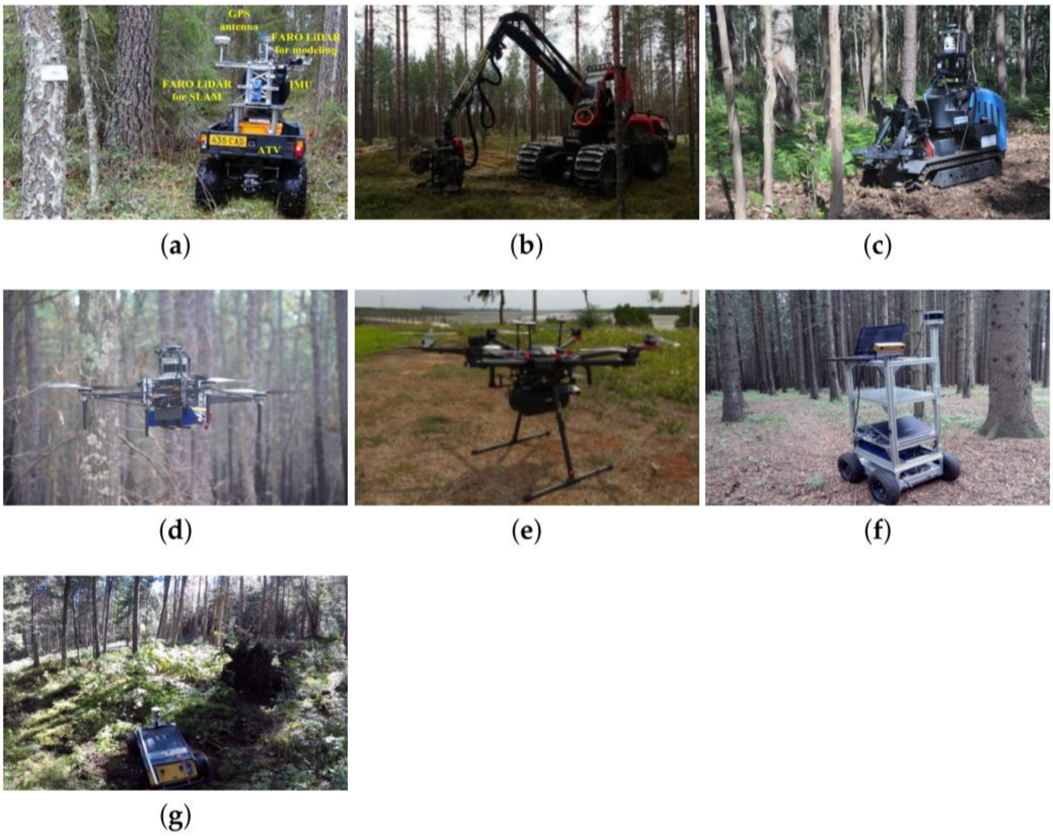


Figure 4.3

The AgRob V18 forest robot (Figure c) was developed to collect forest biomass . The robot has a modular sensor tower, used to detect the fauna and flora around it. Because the locomotion system is of the Caterpillar type powered by a diesel engine, the IMU data are severely affected by the robot's vibration. For this reason, the researchers studied several approaches to perform autonomous robot localization and navigation, such as LOAM (recommended for structured environments), Advanced implementation of LOAM (A-LOAM) implemented in C++ to improve the speed of algorithm execution, and Lightweight and Ground-Optimized LiDAR Odometry and Mapping (LeGO-LOAM). Among the three approaches, the SLAM technique that achieved the best performance was LeGO-LOAM. According to Giusti et al., an UAV (ARDrone) was used to perform visual-based

navigation in a forest environment by extracting images from three different points of view (front and left and right side views) and using Deep Neural Networks (DNN) to classify the images received and estimate the direction of the trajectory to be followed. This type of application can assist in carrying out inventory operations, as described in . Chen et al. developed a UAV (Figure d) with an end-to-end pipeline for tree diameter estimation based on Semantic LOAM (S-LOAM), to increase robustness, scalability and performance in forest environments. The pipeline consists of 3D point cloud labeling with virtual reality, range image segmentation with a Fully Convolutional Neural Network (FCNN), landmark instance detection with trellis graphs and S-LOAM . When carrying out practical tests, the UAV was able to detect 29 trees (out of a total of 35) with an average error of 0.67 in. Another method of estimating biomass in forest areas has been used in mangrove
forests, in the northeast of Hainan Island, China . In this case,Wang et al. performed an estimate of abovabove-groundmass using an upscaling method from field plots, UAV
(Figure e) LiDAR data and Sentinel-2 imagery based on a point-line-polygon framework.

Pierzchała et al. used the Superdroid 4WD IG52 DB robot (Figure f) in a Norwegian forest, characterized by having a semi-structured flat terrain with little undergrowth. They used a 3D graph-SLAM approach, Random Sample Consensus (RANSAC), to identify the soil and Signed Distance (SD) to represent the standard height of measurements for the estimation of DBH. Due to the chosen environment (Figure a) having few obstacles, the proposed method obtained a mean estimation error of DHB of 2 cm, and, for tree positioning accuracy, the mean error was 0.0476 m.

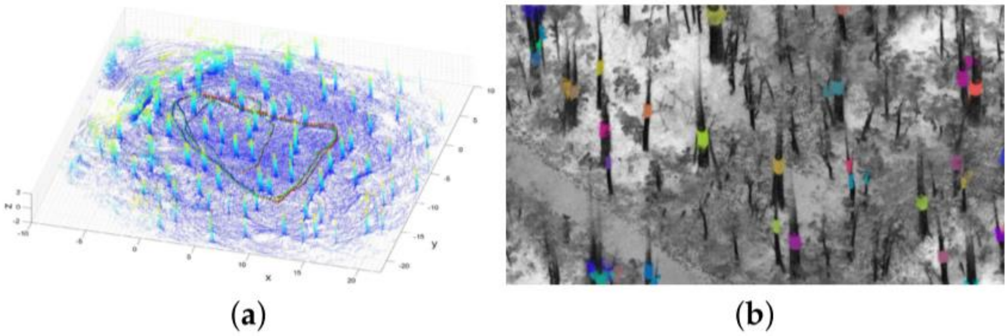


Figure 4.4

In a similar work, Tremblay et al. analyzed several methods of automatic threedimensional mapping for tree diameter measurements in inventory operations. After considering a cylinder fitting for DBH estimation, different combinations of methods for determining circles were tested. All methods were combined using a median voting system. To evaluate the performance of the methods (Figure b), the researchers used the Clearpath Husky A200 robot (Figure g), containing a Velodyne LiDAR, an IMU, wheel encoders for odometry and a RGB camera. The robot was used in different types of forests (young, mixed, mature and maple) since each species of tree has a type of texture, which can directly affect the performance of DBH estimation. After performing several tests, the DBH estimation method that obtained the best performance was the vertical Axis + nonlinear least-squares cylinder, while Axis linear least-squares obtained the worst. The environment that obtained the best performance was mature, with well-spaced trees and visible trunks . The Warthog robot, also from Clearpath, was used to move in subarctic and arctic environments based on the Iterative-Closest Point (ICP) algorithm. In an environment with snow and ice, due to its large moment of inertia, even after completing a curve, the robot remains slightly rotating. According to Baril et al. , for this type of scenario, angular displacement is the main characteristic that interferes with odometry systems. Thus, when

performing inventory operations in environments with ice and snow, it is necessary to evaluate the kinematic model (ideal differential-drive, extended differential drive, radius-of-curvature-based and full linear) that best adapts to the type of terrain chosen. In a self-supervised detection method for forest land surfaces based on the
Support Vector Machine (SVM) machine learning algorithm is implemented in the Pioneer 3-AT robot. Delaunay Triangulation was used to model the ground plane. Even under major changes in lighting and ground cover (with and without snow), the self-supervised learning method achieved an average accuracy of 81.46%, while the method using morphological operators reached 95.21% and the classical supervised classifier obtained 74.27% . This type of application may assist in reducing unwanted regions in the mapping activity of trees in forest inventory operations.

4.4. PLANTING, PRUNING, AND HARVESTING

To develop technological solutions that positively impact the environment, Birch and Rhodes developed the Tree Rover tree planter prototype, as depicted in Figure a. Guided by a GNSS system, the 4WD robot is capable of planting up to 10 tree seedlings. It has an exclusive system that pierces the earth, deposits the seedling with a compressed air system and finally covers the hole by pressing the local terrain. The Multiscope Forester Planter (Figure b) is already a commercial planter robot, with a payload with a capacity of 380 seedlings. With a modular structure mounted on a Caterpillar system, the robot can reach up to 20 km/h, with a planting speed of 6.5 h/ha in temperate forest environments and has two control systems: teleoperation or waypoint navigati. Built on the same locomotion system as the Multiscope Forester Planter, the Multiscope Forester Brushcutter (Figure c) has a brush cutting tool and a hydraulic power unit, instead of the planting payload, to be used in forest mowing applications. Due to the modular structure of both robots, both tasks can be performed during the execution of forestry activities.

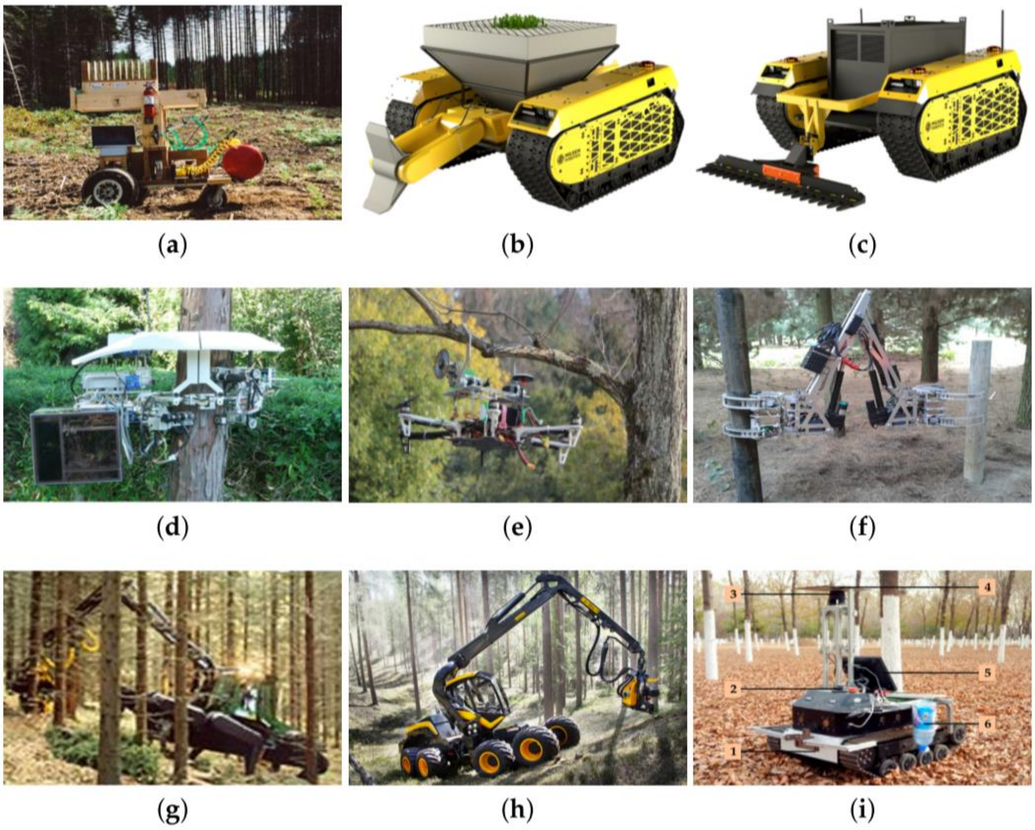


Figure 4.5

Robots used in tree pruning tasks must be able to climb trees, prune and descend. However, as described in, this task has several challenges, such as cutting the branches without letting the cutting tool be grabbed and pruning the tree without damaging the trunk, in addition to saving energy. To solve these problems, Ishigure et al. developed a pruning robot (as shown climbing a tree in Figure d) with a movable bar mounted on the guide bar of the chainsaw so that it can move even if a branch is stuck in the chainsaw. To prevent the robot from damaging the tree trunk, it has a control system that always keeps the chainsaw parallel to the tree trunk. To save energy, the robot has a system for measuring the electric current consumed by the chainsaw; in this way, only when it detects a high consumption of electric current will it supply a higher voltage to the chainsaw, otherwise the voltage will remain low, resulting in a 34% reduction in energy consumption . The pruning of trees located close to electric power transmission lines, unlike the aforementioned work, besides being dangerous, the way pruning depends on where the electric power transmission line is passing relative to the tree, that is, on the side, above or through the tree. In , the authors described a UAV that has a circular saw and two claws attached to its body so that, after flying to the position where the branch to be removed is, it hangs on the branch and performs a circular cutting movement around the branch (as shown hanging from a branch in Figures e and 4.6). The system, despite being in an initial testing phase, proved to be capable of pruning branches while being remotely controlled by a human.

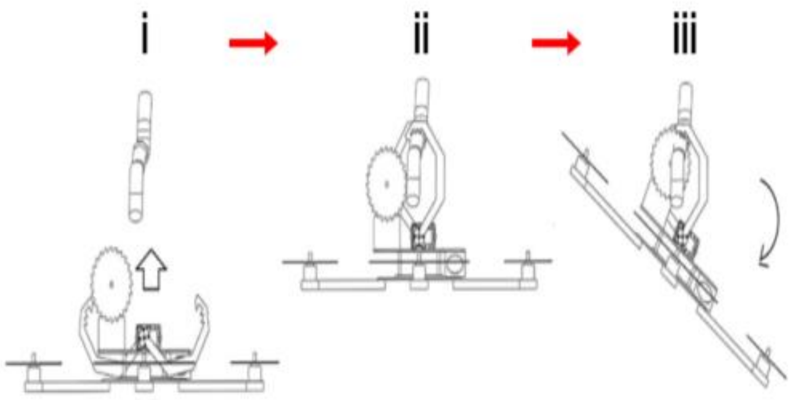


Figure 4.6

Unlike the types of locomotion commonly used in forests, the robot developed by Scion has a tree to tree locomotion system, using fixing claws (Figure f). The complete system has nine Degrees of Freedom (DoF) and can remain fixed only in one tree and move from one tree to the other with a minimum distance of 1 m and a maximum distance of 2.2 m. The tree localization is done through the application of the Hough Transform (HT) under RGB images. The method was evaluated under different lighting

conditions and it was still possible to detect the trunks. The system's path planning is based on the K-Means algorithm, which prioritizes the search for paths that visit a larger number of trees. This type of robot was developed to perform tasks of measuring tree girth, location and mainly for pruning, as this locomotion system eliminates the need for a human to place/remove the pruning robot from the tree. Developed in the 1990s, the fully independent hydraulic six-legged walking machine
(MECANT robot) was one of the first legged robots built to be used in unstructured environments. Despite the technological limits of that time, MECANT was built using the off-the-shelf concept. Although the robot is guided by a human being, the architecture of the leg control system (3-DoF) and body position and orientation (6-DoF) is complex, separated into the following tasks: body path planner, gait planner, foothold planner, transfer and support trajectory planner and support force planner . Legged robots do not need constant contact with the ground to get around and can adjust their posture according to the terrain slope . This robot was the precursor to the walking forest harvester (Plustech Oy), illustrated in Figure g, which did not get a good acceptance from the forest machine market. Unlike the walking forest harvester, the harvester machine based on the Cut-To-Length
(CTL) method depicted in Figure h has wheels and performs log harvesting intelligently in boreal forest. The harvester CTL has a robotic arm that, in addition to slaughtering and stripping, measures the base and diameter of each harvested trunk and compares both with the averages of specific species and with the harvest history. Using an algorithm based on the data of each trunk, the harvester CTL optimizes each trunk to achieve the highest possible processing value. To reduce impacts on the environment, during harvesting, the CTL harvester covers its tracks with branches and

tree debris to reduce damage to forest soil. Even today, rubber extraction is considered a manual task. Using LiDAR sensors and
low-cost gyroscopes, Zhang et al. clustered the cloud of tree trunk points and extracted the central point of the trunks based on the Gauss–Newton method to create navigation lines for the robot itself to move around the environment using a Fuzzy control system. With this technique, the robotic platform (Figure i) moved by a caterpillar system obtained a Root Mean Square (RMS) side error less than 10.32 cm, making it possible to carry out the rubber harvest in an automated way.

Figure 4.7

CHAPTER 5

PRESENT WORK

5.1 COLLECTING DATA FROM PUBLIC

The useful data are collected from people using the google forms which will help us in future works. We are planned to design CAD model of fire fighting robot using solidworks or by any 3D software. We created a google forms and send people to know how should the robot will look like so that it will effective. They also expressed the views.

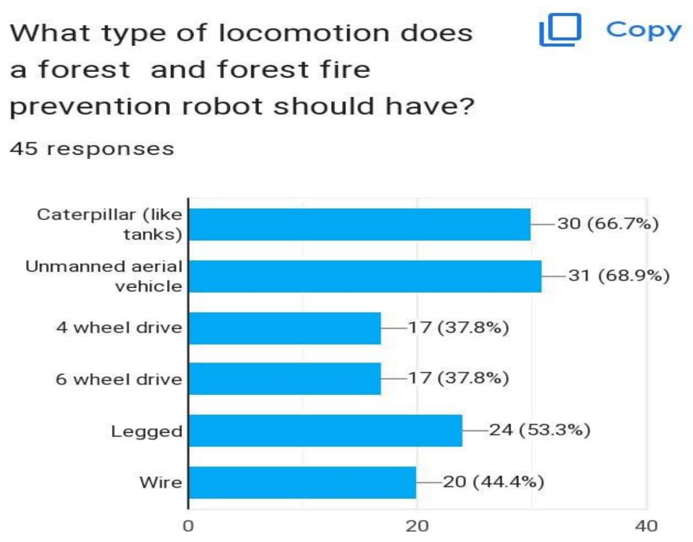


Figure 5.a

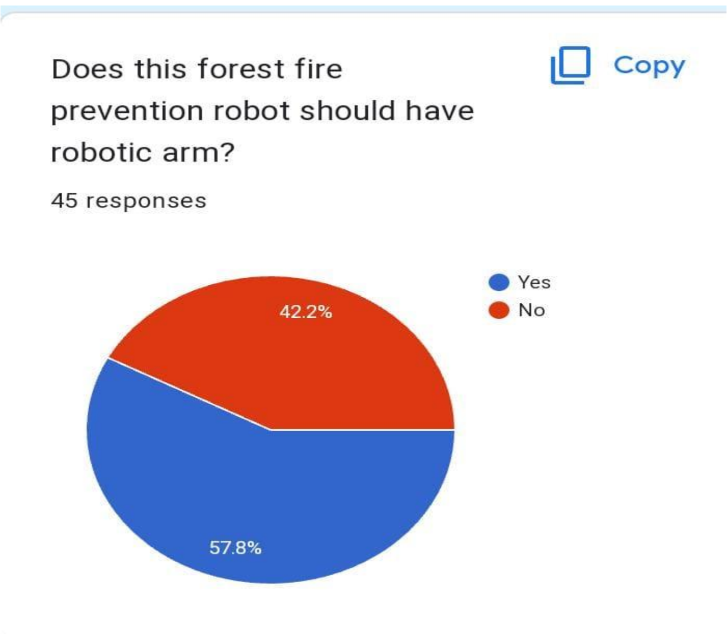


Figure 5.b

Robot locomotion is the collective name for the various methods that robots use to transport themselves from place to place.

Types of locomotion

- Walking

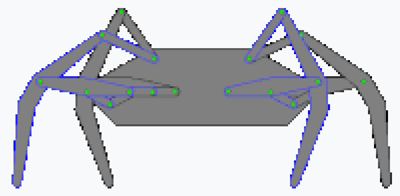


Figure 5.c Klann linkage walking motion

Walking robots simulate human or animal gait, as a replacement for wheeled motion. Legged motion makes it possible to negotiate uneven surfaces, steps, and other areas that would be difficult for a wheeled robot to reach, as well as causes less damage to environmental terrain as wheeled robots, which would erode it.[1]

Hexapod robots are based on insect locomotion, most popularly the cockroach[2] and stick insect, whose neurological and sensory output is less complex than other animals. Multiple legs allow several different gaits, even if a leg is damaged, making their movements more useful in robots transporting objects.

Examples of advanced running robots include ASIMO, BigDog, HUBO 2 , RunBot, and Toyota Partner Robot.

- Wheeled locomotion

Wheeled motion is the **most popular locomotion mechanism in robotics**. This mechanism enables a robot to move rapidly and requires less energy when compared to other types of robotic locomotion mechanisms. In addition, the wheeled mechanism is easy to control due to its good stability and the simplicity of the mechanism

Figure 5.d

- Slip or skid locomotion

  In Slip/Skid locomotion the vehicles use tracks as available in a tank. The robot is steered by moving tracks with different speeds in the same or opposite direction. It offers stability because of large contact area of ground and track

  Figure 5.e

- Aerial locomotion

  Flying opens new opportunities to robotically perform services and tasks like search and rescue, observation, mapping or even inspection and maintenance. As such, substantial interest in aerial robots has grown in recent years. Key areas to be addressed include innovative Unmanned Aerial Vehicles design, autonomous missions, guidance, navigation and control, and multi-vehicle coordination

  Figure 5.f

- Robotic arm

  A robotic arm is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be the sum total of the mechanism or may be part of a more complex robot.

Figure 5.g

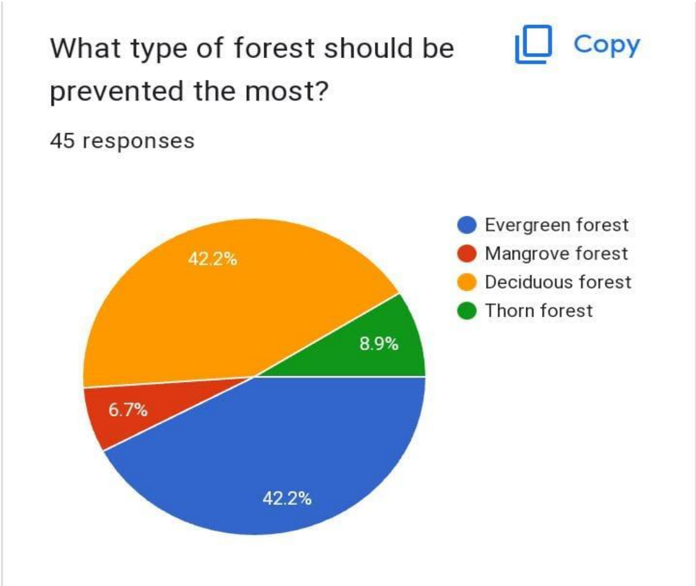
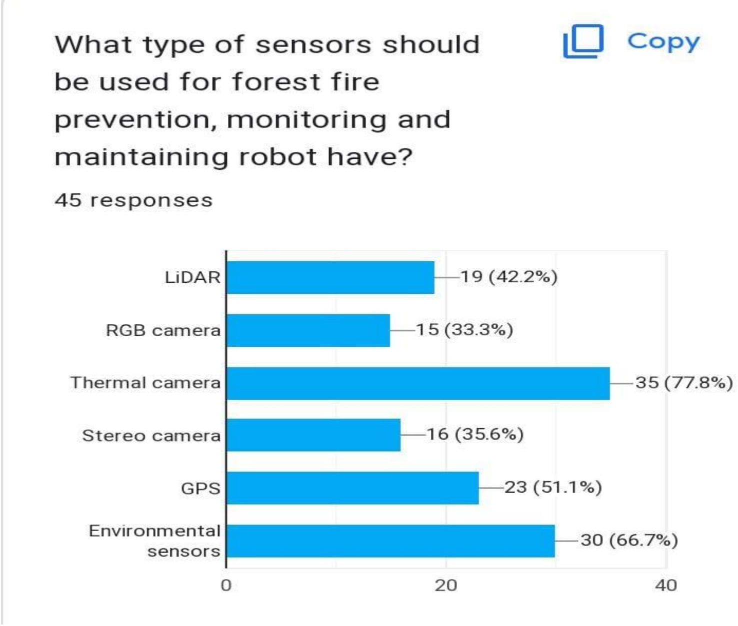


Figure 5.h



Types of sensors can be used

- Thermal camera

A thermal camera is an advanced electronic device incorporated with an integrated display. A thermal camera is a device utilized to capture an image of an object using infrared radiation emitted from an object Figure 5.i

- Environment sensor

  Environmental sensors are a series of **sensors that monitor the environment and identify the quality of the environment**. Environmental sensors include: soil sensors, temperature and humidity sensors, gas sensors, rainfall sensors, light sensors, wind speed and direction sensors, etc.

  Figure 5.j

- GPS

  The Global Positioning System (GPS), originally Navstar GPS, is **a satellite-based radionavigation system owned by** the United States government and operated by the United States Space Force. It is one of the global navigation satellite systems (GNSS) that provides geolocation and time information.

  Figure 5.k

Figure 5.l

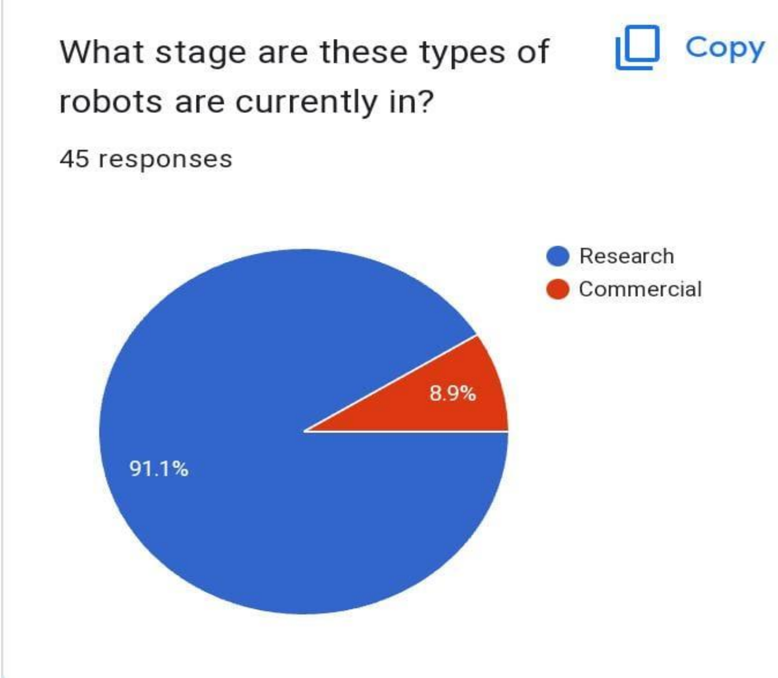
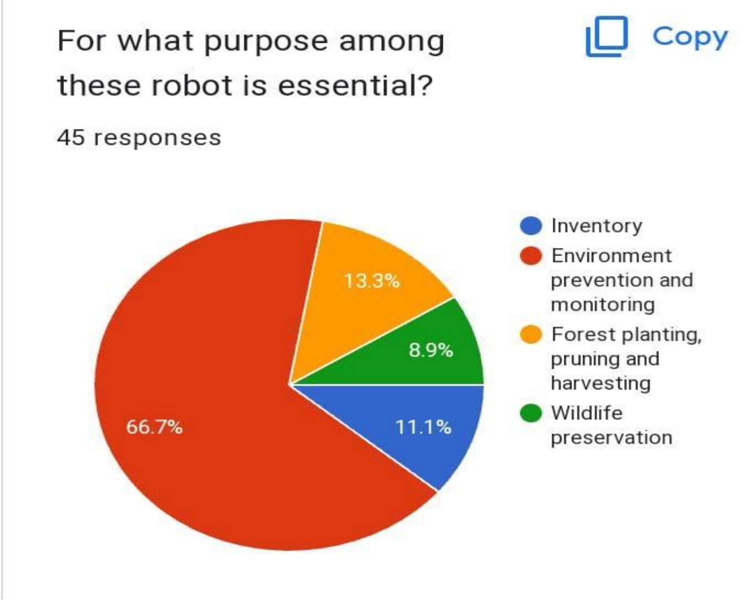


Figure 5.m

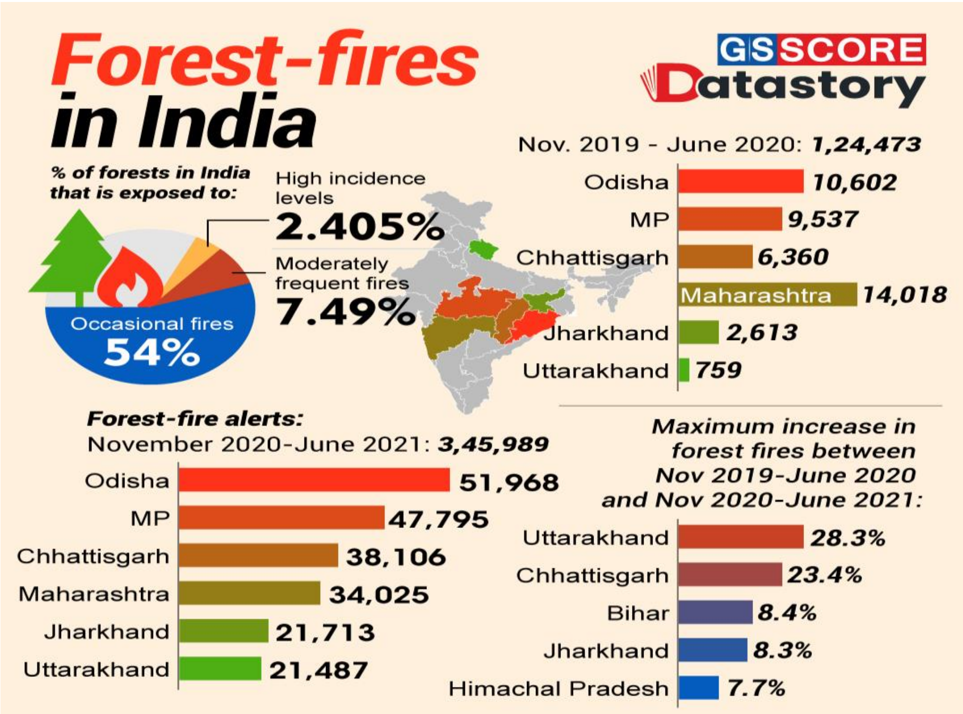


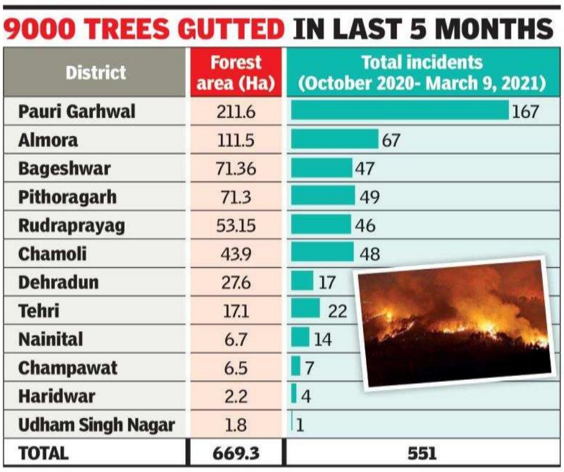
From the above chart, the robot should be mainly designed and developed for environmental prevention and monitoring. From these information, we must analyze it into its depth and start design the robots. We are currently looking for a best robotic course in internet. If we get one, we will definitely start learning it for further purpose.

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1. IMPACTS OF FOREST FIRE.





District	Forest area (Ha)	Total incidents (October 2020- March 9, 2021)
Pauri Garhwal	211.6	167
Almora	111.5	67
Bageshwar	71.36	47
Pithoragarh	71.3	49
Rudraprayag	53.15	46
Chamoli	43.9	48
Dehradun	27.6	17
Tehri	17.1	22
Nainital	6.7	14
Champawat	6.5	7
Haridwar	2.2	4
Udham Singh Nagar	1.8	1
TOTAL	669.3	551

6.2. ROBOTIC APPLICATIONS IN FOREST

Table 1. Comparison of the analyzed robotic applications for environmental preservation and monitoring.

Robot	Final Application	Locomotion System	Localization Sensors	Sensors Used to Perform the Task
Chico Mendes [10]	Preservation and monitoring	Wheel-Legged	Global Positioning System (GPS)	Water probe, gas sensor and 3D camera
Legged robot [12]	Monitoring	Legged	Light Detection and Ranging (LiDAR)	RGB camera
SlothBot [13]	Monitoring	Wire traversing	-	Temperature and luminosity
Ranger and Scout [14]	Preservation and monitoring	Caterpillar and Unmanned Aerial Vehicle (UAV)	Global Navigation Satellite System (GNSS) and LiDAR	Stereo, multispectral and infrared cameras
Romu [15]	Preservation	Four-wheel drive (4WD)	-	-
UAV robot 1 [16]	Monitoring	UAV	GPS	Hyperspectral camera
UAV robot 2 [17]	Monitoring	UAV	GPS	RGB camera
UAV robot 3 [18]	Monitoring	UAV	-	RGB camera
UAV robot 4 [19]	Monitoring	UAV	-	Temperature, humidity and pressure
UAV robot 5 [20]	Preservation and monitoring	UAV	GPS and Inertial Measurement Unit (IMU)	Thermal and RGB cameras

Regarding the information presented in Table 1, the following observations can be made:

- **Monitoring**: The Chico Mendes robot monitors possible gas leaks in the interior of the Amazon and the SlothBot monitors the ambient temperature and luminosity. Therefore, the locomotion system is directly affected by the type of environmental monitoring to be performed.
- **Swarm:** Forest are unstructured environments. This characteristic directly affects the time of travel and the execution of any tasks to be performed. Therefore, the integration of the concept of swarm of robots with robots of different types of locomotion systems (land, air or sea) can compensate for the time of executing tasks in such environments.
- **Artificial intelligence**: Artificial intelligence was used in conjunction with robotic systems in identification processes, using natural environment characteristics (vegetation indexes) and CNN.

Table 2. Comparison between the analyzed robotic applications for wildfire fighting.

Robot	Locomotion System	Weight (kg)	Payload Weight (kg)	Water Flow (L/min)	Velocity (km/h)	Autonomy (h)	Grade Slope (°)	Side Slope (°)
Fire Ox [21]	Six-wheel drive (6WD)	–	–	–	–	–	30	–
Multiscope Rescue with Hydra [22]	Caterpillar	1630	1200	3000	20	12	30	–
Multiscope Rescue Hose Cartridge [23]	Caterpillar	1630	1200	–	20	15	30	–
Magirus AirCore TAF35 [25]	Caterpillar	3900	–	4700	9	7	30	15
Thermite RS1 [26]	Caterpillar	725	–	4732	9.65	20	26.57	19.29
Thermite RS3 [26]	Caterpillar	1588	–	9464	12.87	20	26.57	19.29
Colossus [24]	Caterpillar	500	500	–	4.5	12	40	35

Regarding the information presented in Table 2, the following observations can be made:

• **Weight and Payload**: To transport more equipment and/or injured people with less environmental impact (less soil compaction), the robotic system should be light and capable of transporting large payloads. Therefore, the robot + payload set must have a low center of gravity to avoid falls during firefighting activities.

• **Water Flow**: To reduce the spread of fires is desirable to apply a large water flow, since water reduces the temperature existing in place, removing the existing heat of reaction, putting out the fire. Therefore, the greater is the water flow (9464 L/min for Thermite RS3), the faster the fire will go out and the more forest areas will be preserved.

• **Velocity:** Although the water flow helps the firefighting, to control large-scale fires with a limited number of robots, the faster the robot travels the more areas can be covered. In this sense, robotic systems must be agile and easy to move around in hostile and difficult to access terrains.

• **Autonomy**: The firefighting activity requires time to remove all the heat from the place, and, in the case of a forest fire, delays in the firefighting can mean the extinguishment of species of fauna and flora. Therefore, the greater is the autonomy of the robot, the longer is the period in which the robot will remain firefighting and, consequently, more species of fauna and flora can be saved.

• **Grade and side slope**: Although all the robots analyzed are capable of operating on types of surfaces commonly found in urban and rural areas, such as concrete and clay soil, each robot in Table 2 has a different maximum grade and side slope. In this sense, the higher are these values, the greater is its ability to operate in rugged environments.

Table 3. Comparison of the analyzed robotic applications for inventory operations.

Robot	Locomotion System	Used Sensors	Computer Vision Algorithm
FGI ROAMER R2 [27]	4WD	GNSS, IMU, LiDAR	SLAM + IMU
Komatsu Forest 931.1 [9]	4WD	RTK GNSS, LiDAR	LOAM
AgRob V18 [28]	Caterpillar	GNSS, LiDAR, thermal and RGB cameras	LeGO-LOAM
ARDrone [34]	UAV	RGB and grayscale cameras	DNN
Forest robot 1 [29]	UAV	LiDAR	SLOAM
Forest robot 2 [30]	UAV	LiDAR	G-LiDAR-S2 model
Superdroid [31]	4WD	GPS, LiDAR, IMU and stereo camera	3D graph-SLAM
Husky A200 [32]	4WD	LiDAR, IMU, encoders and RGB camera	DBH estimation
Warthog [35]	4WD	LiDAR, IMU and encoders	ICP algorithm
Pioneer 3-AT [36]	4WD	XB3 camera and LiDAR	LIDAR/camera-based

Considering the information presented in Table 3, the following analysis can be done:

• **Used Sensors**: Although in forest environments the signals from GNSS devices are severely impaired, some applications use such devices, while in others the navigation was accomplished exclusively by LiDAR sensors.
• **SLAM**: Several types of SLAM were used since, although all applications are in forest environments, each type of forest (tropical, temperate), in each season and each type of soil can directly interfere with the navigation technique used.

For example, the LOAM technique discarded by Reis et al.was used by Li et al. and obtained satisfactory results.

Table 4. Comparison of the analyzed robotic applications in forest for planting, pruning and harvesting.

Final Application	Robot	Locomotion System	Sensors	Actuators
Planting	TreeRover [37]	4WD	GNSS	Compressed air machine
	Multiscope Forester Planter [38]	Caterpillar	–	Forester planter
	Multiscope Forester Brushcutter [39]	Caterpillar	–	Forester brushcutter
Pruning	Pruning robot 1 [40]	4WS	Posture sensor	Chainsaw
	Pruning robot 2 [41]	UAV	Back-electromotive force module	Circular saw
	Pruning robot 3 [42]	Legged robot	LiDAR and RGB camera	–
Harvesting	MECANT [46]	Legged robot	–	–
	Walking forest harvester [43]	Legged robot	–	Chainsaw on a robotic arm
	Harvester CTL [44]	Legged robot	–	Chainsaw on a robotic arm
	Harvesting robot [45]	Caterpillar	LiDAR and gyroscope	Gauss-Newton

Regarding the information presented in Table 4, the following observations can be made:

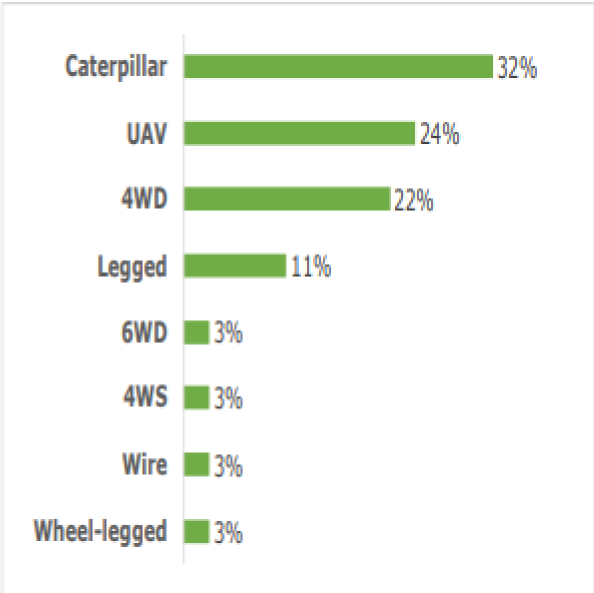
• **Used Sensors**: As most applications were teleoperated, few sensors were used and, therefore, this strategy enhances cost reduction.

• **Used Actuators**: Different reasons for pruning result in different locomotion and cutting systems. Thus, periodic pruning tasks were performed using UAV (with mini saws), whereas daily log harvesting tasks were performed by legged robots (with chain saws).

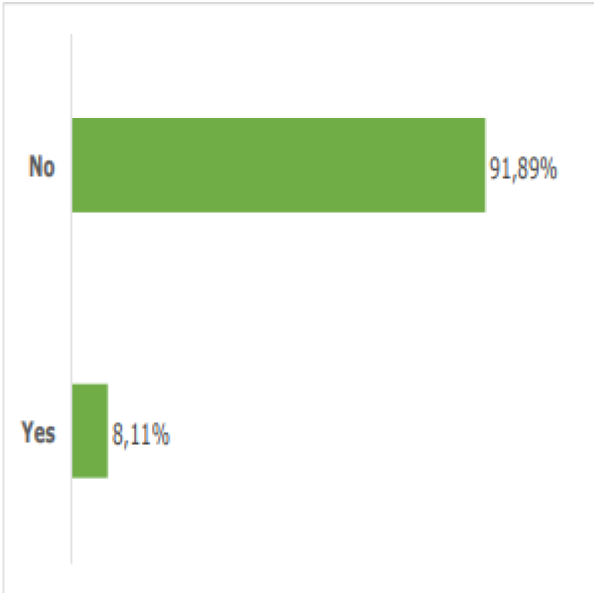
• **Locomotion Systems**: The reasons for using certain types of locomotion must not only be well defined, but they must also exhibit results that satisfy the forest machine market.

DISCUSSION:

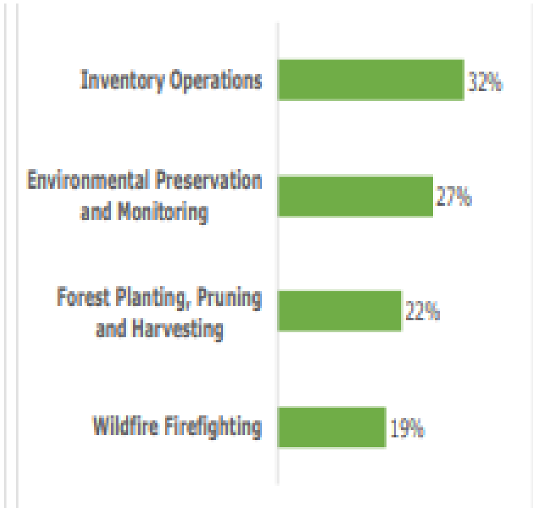
As done for the work related to the development of robotic systems applied in agricultural environments, the collection of several data in common for the different types of robotic systems applications in forest environments was carried out, the results of which are shown in Figure 9.



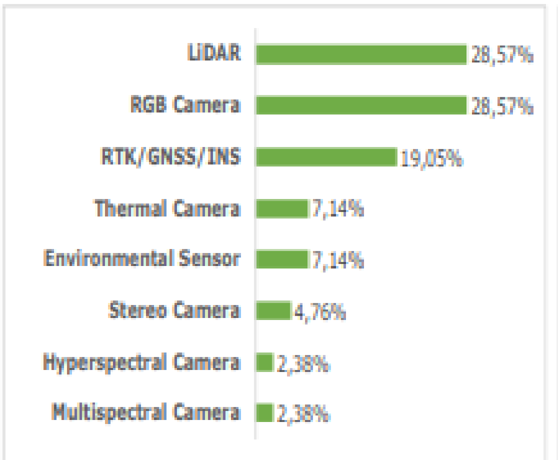
(a) Locomotion System.



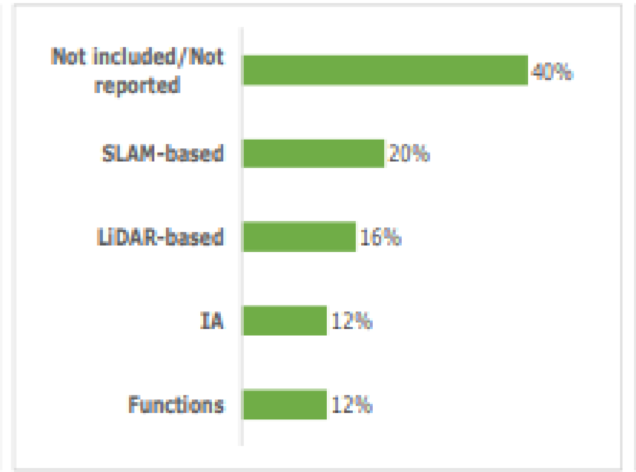
(b) Robotic Arm.



(c) Final Application.



(d) Sensors.



(e)Computer Vision Algorithm.

After analyzing the various graphs shown in Figure 9, the data reveal that most of the forest robots analyzed have caterpillars (Figure 9a), do not have robotic arms (Figure 9b) and are related to the execution of inventory operations (Figure 9c). Although most robots use LiDAR and RGB cameras (28.57%, according to Figure 9d), most of the studies (40%, according to Figure 9e) do not include or report computer vision algorithms. The data also reveal that most robotic systems developed to perform forestry tasks of environmental preservation, monitoring, wildfire firefighting, inventory operations, planting, pruning and harvesting were developed by companies/researchers from the United states.

CHAPTER 7
CONCLUSION

A forest fire spreads rapidly due to abundance of wood, which serves as a good fuel for the fire. Also controlling forest fires becomes difficult as the area is large and application of water and other fire preventive materials (like fire extinguisher) becomes difficult. Hence, we introduced a way by implementing robots for extinguishing fire. It has advantageous features such as the ability to detect the source of fire, extinguish it and increase the knowledge about fire behavior from the incident area. This robot can extinguish different types of fire without spreading in shortest time.

The robot is more likely to fight fire in the face of barriers. A related category of robots is a special aspect of this robot. It would be financially stable, particularly if limited work on exceptional materials is to be resumed on the assumption.

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CHAPTER 8

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