MARKOV CHAIN APPROACH FOR

CHANGE POINT DETECTION

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CERTIFICATE

This is to certify that the work titled **"Markov Chain Approach to Change Point Detection"** submitted by **Mayank Popli (081246)** and **Shrey Singh(071606)** in partial fulfilment for the award of degree of **B. Tech. Computer Science Engineering** of Jaypee University of Information Technology, Waknaghat has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

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Signature of Supervisor ……………………..

Name of Supervisor ……………………..

Designation ……………………..

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SUMMARY

In the last few years, the occurrences of natural disasters have been continuing changing our lives, damaging property and life styles in many different ways. So here we talk about a system that can be used to prevent enormous damage from natural disasters. Our project is aimed at developing a system that would be used in Fire departments to not only alert them of fire but also tell the probability of a forest fire to take place depending on factors like Temperature, humidity, smoke detection, levels of CO and CO_2 and previous data which would show the trend in which forest fires happen. This trend varies as per the regions which are prone to forest fires. In this system, a wireless sensor network is utilized as a weather station network, sending weather information and disasters' alerts. The weather information is analysed by using various techniques to announce the disasters' alerts.

In our project we use the Markov chain Monte Carlo approach that uses various parameters and tells us the probability of fire to take place on the next day. Further we take this results produced by our program in C++ and use it in MATLAB to produce graphs which help us detect the change points. These change points vary for every region depending on the variation in parameters in these regions. These change points also help us find out the particular part of the year in which forest fires occur very often in a particular region.

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LIST OF ABBREVIATIONS

WNS	:	Wireless Network System
GIS	:	Geographic Information System
GPS	:	Global Positioning System
UAV	:	Unmanned aerial vehicle
GOES	:	Geostationary Operational Environment Satellite
AVHRR	:	Advanced Very High Resolution Radiometer
DMSP-OLS	:	Defence Meteorological Satellite Program-Operational Line Scan system
JFMC	:	Joint Forest management committees
EDC	:	Eco-development committee
FDR	:	Fire Danger Rating

LIST OF FIGURES

Chapter 1

1. Introduction

As per the latest state of forests report of the Forest Survey of India the actual forest cover of India is 19.27% of the geographic area, corresponding to 63.3 million hectares. Only 38 million hectares of forests are well stocked with a crown density more than 40%. It is this resource that has to meet the demands of a population of more than 1 billion people and around 450 million cattle. As such, country has to meet the needs of 16% of the world's population from 1% of the world forest resources.**[**4**]** Thus the country's forests face a huge threat. Degradation caused by forest fires [22] jeopardizes the Indian forests. Fires caused huge damage in the year 2007 affecting huge territories in addition to the prominent number of human casualties [23]. Forest fires remains to be a potential threat to ecological systems, infrastructure and human lives. The practical and effective option to minimize the damage caused by the forest fire is to detect the fires at their early stages and reacting fast to prevent the spread of the fire. Hereafter, hefty efforts have been taken to ease the early detection of forest fires, usually being carried out with the help of human surveillance.

A forest fire is any uncontrolled fire in combustible vegetation that occurs in the countryside or a wilderness area. Also other names are used to describe the phenomenon depending on the type of vegetation being burned such as brush fire, bushfire, wildfire, desert fire, dry grass fire, hill fire, peat fire, vegetation fire, and veldfire.**[**4**]** A forest fire differs from other fires because of its extensive size, the speed at which it spreads out from its original source, its potential to change direction unexpectedly, and its ability to jump huge gaps such as roads, rivers and fire breaks. Forest fires can be characterized in terms of the cause of ignition, along with their physical properties such as speed of propagation, the combustible material present, and the effect of weather on the fire.

Forest fires today occur on every continent except Antarctica. Fossil records and human history contain accounts of forest fires, as forest fires can occur in periodic intervals. Forest fires can cause broad damage, both to property as well as human life, but they also have various useful effects on wilderness areas. A few types of plants depend on the effects of fire for growth and reproduction, although large forest fires may also have negative environmental effects. **[**12**]**

Strategies of forest fire prevention, detection, and control have varied over the years, and international forest fire management experts encourage further development of technology and research. One of the more controversial methods is controlled burning: permitting or even igniting smaller fires to minimize the amount of flammable material available for a potential forest fire. While some wildfires burn in remote forested regions, they can cause extensive destruction of homes and other property situated in the wildland-urban interface: a sector of transition between developed areas and undeveloped wilderness. [9]

Fast and effective detection is a key factor in forest fire fighting. Early discovery efforts were focused on early response, accurate results in both daytime and night time, and the ability to prioritize fire danger. Early satellite-derived fire analyses were hand-drawn on maps at a distant site and sent via overnight mail to the fire manager. It was during the Yellowstone fires of 1988, that a data station was started in West Yellowstone, permitting the delivery of satellite-based forest fire data in approximately four hours.

Currently, public hotlines, forest fire lookouts in towers, and land and aerial patrols are used as a means of early detection of forest fires. However, accurate human surveillance may be limited by operator fatigue, time of day, time of year, and geographic site. Electronic systems have grown popularity in recent years as a probable resolution to human operator error. These systems may be semi- or fully automated and make use of systems based on the risk area and degree of human occurrence, as suggested by GIS data analyses.[13]

This project helps to build up a system which will be used in forest as well as fire departments around the country to alert them if there is a fire as well as tell the probability of a forest fire that might take place depending on various factors. Forest fires today depend on Temperature, humidity, smoke detection, levels of CO and CO_2 and previous data which would show the trend in which forest fires happen. This trend is different for different regions around the globe which are prone to forest fires as the factors mentioned above vary in case of each of them. In this system, a wireless sensor network can be utilized as a weather station network, to send and receive data and weather information. This weather data is further analysed by using various techniques to announce the disasters' alerts. In this project we use Markov chain Monte Carlo approach to find out the probability and also detect change points with the help of the graph we get from after applying the markov chain approach on the data.[15]

1.1 Forest Fires

- A forest fire is a natural disaster consisting of a fire which destroys a forested area, and can be a great danger to people who live in forests as well as wildlife. Forest fires are generally started by lightning, but also by human carelessness or arson, and can burn thousands of square kilometres.
- Forest fires, also known as forest fires, vegetation fire, grass fire, brush fire or bush fire, is common in vegetated areas of Australia, South Africa, United States and Canada, where climates are sufficiently moist to allow the growth of trees, but feature extended hot and dry periods.**[**12**][**8**]**
- A Forest fire is caused by the drying out of branches, leaves and therefore becomes highly flammable.
- To prevent fires, there are large fire-fighter services including planes, fire trucks, as well as small extinguishers depending on the severity of the fire.**[**1**]**

1.2 Problems Faced

A forest fire differs from other fires by its extensive size, the speed at which it can spread out from its original source, its potential to change direction unexpectedly, and its ability to jump gaps such as roads, rivers and fire breaks.**[**7**]**

Forest fires can do things like:

- Crawling – Fire spreads from bush to bush
- Crown – Fire spreads at an incredible pace through the top of the forest. These are hazardous as it can deprive people under the fire of oxygen to feed the fire.
- Jumping / Spotting - Burning branches and leaves carried away by wind

1.3 Solutions by Forest Department

According to a report, **Solutions to the Rising Costs of Fighting Fires in the Wildland-Urban Interface** was completed by Headwaters Economics, a Montana-based independent, non-profit research group.**[**17**]**

This report outlines ten possible solutions:

1. MAPPING: To publish maps to identify areas with high probability of wildland fires.
2. EDUCATION: To increase awareness of the financial consequences of home building in fire-prone areas.
3. REDIRECT FEDERAL AID TOWARD LAND USE PLANNING: To provide technical assistance and monetary incentives to help local government's direct future development away from the wildland-urban interface.**[**15**]**
4. COST SHARE AGREEMENTS: Add incentives for counties to sign agreements that share the costs of wildland fire-fighting between local and federal entities;
5. LAND ACQUISITION: Purchase lands or easements on lands that are fire-prone and at risk of conversion to growth.
6. A NATIONAL FIRE INSURANCE AND MORTGAGE PROGRAM: To apply lessons from efforts to prevent development in floodplains.
7. INSURANCE: To allow insurance companies to charge higher premiums in fire-prone areas.
8. ZONING: To limit development in the wildland-urban Interface with local planning and zoning ordinances.
9. ELIMINATE MORTGAGE INTEREST DEDUCTIONS: Eliminate home interest mortgage deductions for new homes in the wildland-urban interface.
10. REDUCE FEDERAL FIREFIGHTING BUDGETS: Induce federal land managers to shift more of the cost of wildland fire-fighting to local governments.

Chapter 2

2. Literature Survey

India contains a variety of climate zones, including the tropical south, northwestern deserts, Himalayan Mountains, and the wet north-east. Forests are extensively distributed in the country. India's forests are endowed with a variety of biomes and biological communities. The forest vegetation across the country varies from tropical evergreen forests in the West Coast and in the Northeast to alpine forests in the Himalayas in the North. In between the two limits, there are semi-evergreen forests, deciduous forests, sub-tropical broad-leaved hill forests, sub-tropical pine forests, and sub-tropical montane temperate forests. With increasing population pressure, the forest cover of the country is declining at an alarming rate. Along with various factors, wildfires are a major cause of degradation of Indian forests.

The forests of the country are under tremendous pressure because of this fact. One major cause for forest degradation in the country is forest fires. While statistical data on fire loss are weak, it is estimated that the proportion of forest areas prone to forest fires annually ranges from 33% in some states to over 90% in other. About 90% of the forest fires in India are created by humans. The usual fire season in India is from the month of February to mid June. India witnessed the most severe forest fires in the recent time during the summer of 1995 in the hills of Uttar Pradesh & Himachal Pradesh. The affect of these fires were very severe and attracted the attention of whole nation. The fires affected an area of 677,700 ha.**[**6**]**

The Forest Survey of India, data on forest fire attribute around 50% of the forest areas as fire prone. This does not mean that country's 50% area is affected by fires annually. Very heavy, heavy and frequent forest fire damages are noticed only around 0.8%, 0.14% and 5.16% of the forest areas respectively. Therefore, only 6.17% of the forests are prone to severe fire damage. In the absolute term, out of the 63 million hectares of forests an area of around 3.73 million hectares can be presumed to be affected by fires annually. **[**8**]**

Forest fires today are a chief environmental concern, causing economical and ecological damage while endangering lives across the world. The fast or early detection of forest fires is a vital element for controlling such phenomenon. Forests fire is one of the most common hazards in forests. Forests fires are as old as forests themselves. They put in danger not only the forest wealth but also the entire regime to fauna and flora, critically disturbing the bio-diversity and the ecology and environment of a region. During summer, when there is no rain for months, the forests become littered with dry leaves and twinges, which could burst into flames ignited by the slightest spark. The Himalayan forests, particularly, Garhwal Himalayas have been burning often during the last few summers, with colossal loss of vegetation cover of that region.

2.1 Causes of Forest Fires

For a long time, forest fires have been a source of trouble. Fires have notable influence over the ecological and economic utilities of the forest, being a prime constituent in a great number of forest ecosystems. Past has witnessed multiple instances of forest and wild land fires. Fires play a remarkable role in determining landscape structure, pattern and eventually the species composition of ecosystems. The integral part of the ecological role of the forest fires is formed by the controlling factors like the plant community development, soil nutrient availability and biological diversity. Fires are considered as a significant environmental issue because they cause prominent economical and ecological damage despite endangering the human lives. Due to the forest fires, several hundred million hectares (ha) of forest and other vegetation are destroyed every year [24].

Lightning, volcanic eruption, sparks from rock falls, and spontaneous combustion are the four major natural causes of forest fire ignitions. However, many forest fires are caused because of human sources such as discarded cigarettes, arson, power line arcs , and sparks from equipment. In India, where land is cleared quickly and farmed before the soil looses its fertility, burning the leftover crop is often considered the cheapest way to prepare land for future use. Forested areas cleared by logging cause the existence of flammable grasses, and abandoned logging paths having overgrown vegetation may act as fire grounds. [9]

Forest fires may be caused by many different types of factors.[8] These factors are mentioned below-

1. Accidental causes- fires that are caused by spark from wheels of trains or certain locomotives, and other causes

2. Natural causes- fires that are caused by lightening, and fires caused by volcanic eruption

3. Negligence – These causes include –

i. Fires that are caused by agricultural and forestry activities- for the clearing of uncultivated land, for the forestry and agricultural processing, for the renewal of pastures, for the burning of leftover crops and vegetation, and - for the clearing of road and railway embankments
ii. Fires that are caused by cigarette stubs or matches in wooded areas
iii. Fires that are caused by other forms of negligence such as recreational and tourist activities, the firing of fire-crackers and rockets, blasting of landmines or explosive, the use of motor, flame, electric or mechanical devices, military manoeuvres or shooting exercises, the burning of waste in illegal dumps, bad maintenance of electrical lines or by the breakage or falling of wires, and negligence not otherwise defined.

4. Fires that are caused for gaining profits -Examples of these causes include - fires caused by the creation or renewal of pastures by eliminating forests; fires caused with the intention to regain agricultural terrain at the expense of forests for cultivation or to activate funding from European Union; fires caused with the intent of earning from the removal of vegetation for the purpose of agricultural cultivation ; fires caused with the intent of earning from the removal of vegetation for the purpose of building speculation; fires caused by occupational questions related to labourers hired by local administrations; fires caused with the intent of destroying by fire badly executed forestry operations; fires caused by inappropriate activity referable to poaching; fires caused to obtain products deriving from fire passage ,fires caused by organized crime.

5. Fires that are caused for the purpose of protests, resentment or insensitivity toward forests- fires caused as revenge or retaliation against public administration ,fires caused by conflicts between or revenge against owners, fires caused as protest against limitations imposed in conservation areas, fires caused for fun or games by minors, fires caused with the intent of destroying tourist areas, fires caused by matters relating to political contrast, fires caused by terrorist acts, fires caused by dissatisfaction, social dissent, behavioural disturbances (pyromania and mythomania).

6. Fires due to dubious causes- fires caused by arson not otherwise defined.

In a nutshell, fires cause

- Loss of costly timber resources and depletion of carbon sinks.

- Degradation of water storage areas which result in loss of water.
- Loss of biodiversity and extinction of animals and plants.
- Loss of wild life surroundings and depletion of wild life.
- Loss of natural regeneration and a decrease in forest cover and production.
- Global warming resulting in an increase in temperature.
- Loss of carbon resources and increase in percentage of CO_2 in the atmosphere.
- Change in climate of the area accounting for unhealthy living conditions
- Soil erosion that affects the productivity of soil and production
- Depletion of ozone layer
- Health problems leading to diseases
- Indirect affect on agricultural production: Loss of livelihood for the tribals as approximately 65 million people are classified as tribals who directly depend upon collection of non-timber forest products from the forest areas for their livelihood.

Fire regimes can be used as indicators to help conclude appropriate strategies for wildfire protection and prescribed fire use. A fire regime refers to the nature of fire occurring over long time periods and the immediate effects of fire that generally characterize ecosystems. Descriptions of fire regimes are general and broad because of the enormous unpredictability of fire in time and space. The fire regime concept brings a degree of order to a complex body of fire behaviour and fire ecology knowledge; and provides a simplifying means of communicating about the role of fire among technical and non-technical audiences.

The fire regimes can be described as follows:

- Under storey fire (applies to forests and woodlands)—forest fires are generally non-lethal to the dominant vegetation and do not substantially change the structure of the dominant vegetation.

- Stand replacement fire (that applies to forests, woodlands, shrub lands, and grasslands)—forest fires kill aboveground parts of the foremost vegetation, changing the aboveground structure substantially. Around 80 percent or more of the aboveground dominant vegetation is either consumed or dies as a consequence of fires.

- Mixed severity fire (applies to forests and woodlands)--severity of forest fire either causes selective mortality in dominant vegetation, depending on various tree species' susceptibility to fire, or varies between under storey and stand replacement.

- Non-fire regime--little or no incidence of natural forest fire.

2.2 Detection of forest fires

Early and effective detection is the key factor in fighting forest fires. Early detection efforts were accounted for early response, accurate results in both daytime and night time, and the ability to prioritize dangers of fire. Fire lookout towers were used in the US in the early 20th century and forest fires were reported using telephones and heliographs. Aerial and ground photography using instant cameras were used in the 1950s until infrared scanning was developed for forest fire detection in the 1960s.**[**13**]** However, data analysis and delivery was often delayed by limitations in the communication technology. Early satellite-derived forest fire analyses were hand-drawn on maps at a distant site and sent via overnight mail to the fire manager. During the Yellowstone fires of 1988, a remote data station was set up in West Yellowstone, permitting the delivery of satellite-based forest fire information in approximately four hours.

Currently, public hotlines, fire lookouts in towers, and land and aerial patrols are used as a means of early detection of forest fires. However, accurate human observation is limited by operator fatigue, time of day, time of year, and geographic position. Electronic systems have gained popularity recently as a possible solution to human operator error. These systems today may be semi- or fully automated and employ systems based on the risk area and the degree of human occurrence, as suggested by GIS data analyses. An integrated advancement of multiple systems can be used to merge satellite information, aerial imagery, and personnel position via Global Positioning System (GPS) into a collective whole for near-real time use by wireless Incident Command Centres.**[**2**]**

A small area with high risk that features thick vegetation, a strong human existence, or is close to an important urban area can be monitored using a local sensor network. Detection systems may contain wireless sensor networks that act as automated weather systems and are used for detecting temperature, humidity, and smoke. These may be battery-powered, solar-powered, or tree-rechargeable that is able to recharge their battery systems using the little electrical currents in plant material. Big, medium-risk areas can be monitored by scanning towers that incorporate fixed cameras or sensors to detect smoke or additional factors like the infrared signature of carbon dioxide produced by fires. Additional capabilities such as night vision, brightness detection, and colour change finding may also be incorporated into sensor arrays.

Satellite and aerial monitoring with the use of planes, helicopter, or UAVs can offer a wider view and may be enough to monitor very large, low risk areas. These more sophisticated systems employ GPS and aircraft-mounted infrared or high-resolution visible cameras to identify and target forest fires.**[4]**Satellite-mounted sensors such as Envisat's Advanced Along Track Scanning Radiometer and European Remote-Sensing Satellite's Along-Track Scanning Radiometer can calculate infrared radiation emitted by fires, identifying hot spots greater than 39 °C (102 °F). The National Oceanic and Atmospheric Administration's Hazard Mapping System combines remote-sensing information from satellite sources such as Geostationary Operational Environmental Satellite (GOES), Moderate-Resolution Imaging Spectroradiometer (MODIS), and Advanced Very High Resolution Radiometer (AVHRR) for detection of fire and smoke plume sites. However, satellite detection is prone to offset mistakes, anywhere from 2 to 3 kilometres (1 to 2 mi) for MODIS and AVHRR data and up to 12 kilometres (7.5 mi) for GOES data. Satellites in geostationary orbits might become disabled, and satellites in polar orbits are often limited by their small window of observation time. Cloud cover and picture resolution and may also limit the success of satellite imagery.

2.3 Prevention of forest fires

Forest fire prevention refers to the pre-emptive methods of reducing the risk of fires as well as lessening its effects and spread. Effective avoidance techniques allow supervising agencies to manage air quality, maintain ecological balances, protect resources, and to limit the effects of future uncontrolled fires. North American fire fighting policies may permit naturally caused fires to burn to continue their ecological role, so long as the risks of escape into high-value regions are mitigated. However, prevention policies have to consider the role that humans play in forest fires, since, for example, 95% of forest fires in Europe are linked to human involvement. Sources of human-caused wildfire may include arson, accidental ignition, or the unrestrained use of fire in land-clearing and agriculture like the slash-and-burn farming in Southeast Asia. A recent and ecologically evolutionary practice, termed "Hydro-Pyrogeography", promises and claims to bound forest fire from passing through any such wildland-urban boundary anywhere on earth that the practice is put into position, and thereby diminishing, even eliminating the above-referred oppositions and fears to traditional fuel management techniques.**[**3**]**

Fire affects the functioning of ecosystems in numerous ways:

• Regulating plant succession

• Regulating fuel accumulations.

• Controlling age, structure and species composition of vegetation.

• Affecting insect and disease populations.

• Influencing nutrient cycles and energy flows.

• Regulating biotic productivity, diversity and stability.

• Determining habitats for wildlife.

In the mid-19th century, explorers from the HMS Beagle observed Australian Aborigines by means of fire for ground clearing, hunting, and revival of plant food in a method later named fire-stick farming. Such cautious use of fire has been employed for centuries in the region protected by Kakadu National Park to encourage biodiversity. In 1937, the President of US, Franklin D. Roosevelt initiated a nationwide wildfire prevention campaign, highlighting the role of human negligence in forest fires. Later posters of this program featured Uncle Sam, administrators of the Axis powers of World War II, characters from Disney movie Bambi, and the official symbol of the U.S. Forest Service, Smokey Bear. **[**13**]**

Forest fires are caused by a combination of natural factors such as topography, fuels, and climate. Other than reducing individual infractions, only fuels may be altered to affect future fire risk and behaviour. Forest fire prevention programs around the world may employ techniques such as forest fire use and prescribed or controlled fires. Wildland forest fire use refers to any fire of natural causes that is checked but allowed to burn. Controlled burns are forest fires ignited by government authorities under less dangerous weather conditions.

Vegetation may be burned periodically to uphold high species diversity, and everyday burning of surface fuels limits fuel increase, thereby reducing the risk of crown fires. Using tactical cuts of trees, fuels may also be removed by hand crews in order to clean and clear the forest, prevent fuel build-up, and create entrance into forested areas. Chain saws and large tools can be used to thin out ladder fuels and shred trees and plants to a much. Multiple fuel treatments are regularly needed to influence future fire risks, and forest fire models may be used to predict and compare the benefits of different fuel treatments on future forest fire spread.**[**8**]**

However, controlled burns are supposedly "the most effective treatment for reducing a fire’s rate of spread, fire line intensity, flame length, and heat per unit of area" according to Jan Van Wagtendonk, a biologist at the Yellowstone Field Station. In addition to this, while fuel treatments are typically limited to smaller areas, effective fire management needs the administration of fuels across large landscapes in order to prevent future fire size and severity.

Building codes in fire-prone areas requires that structures be built of flame-resistant materials and a secure space be maintained by clearing flammable materials within a certain distance from the structure. Communities in the Philippines maintain fire lines 5 to 10 meters (16 to 33 ft) wide among the forest and their village, and patrol these lines during summer season or seasons of dry weather. Fuel build-up can result in costly, devastating fires as new homes, ranches, and other development are built nearby to wilderness areas. Continued expansion in fire-prone areas and rebuilding structures shattered by fires has been met with criticism.

However, the population increase along the wildland-urban interface discourages the use of current fuel management practices. Smoke is an irritant and tries to thin out the fuel load is met with resistance due to desirability of forested areas, in addition to other wilderness objectives like endangered species protection and habitat prevention. The ecological profits of fire are often overridden by the monetary and safety benefits of protecting structures and human life. For example, while fuel treatments lower the risk of crown fires, these methods destroy the habitats of various plant and animal species. Additionally, government policies that cover the wilderness usually differ from local and state policies that administer urban lands.

2.4 Areas affected around the World

Comprehensive national, regional or global statistics on forest fires are not available that would allow a reliable and precise comparison of the global fire occurrence in the 1980s and 1990s. However, some common remarks can be made. Both decades experienced high inter-annual regional and national variability of fire incidence and fire impacts. El Niño episodes such as in 1982-1983 and 1997-1998 were the most significant climatic oscillations affecting area burned and fire impacts in both decades. In these years, most of tropical Asia, Africa, the Americas and Oceania regions experienced enormously extended wildfire situations. During 1997-1998, the amount of land-clearing fires and other escaped fire situations have amplified in the equatorial forest regions of Southeast Asia and South America.

The northern temperate/boreal forest region also experienced extremely dry years in both decades. Central-Eastern Asia was affected most severely in 1987, particularly Central-Eastern Siberia and the northeast of China. The Far East of Russia also was severely affected by forest fires during the 1998 drought.

The most general cause of forest fires varies throughout the world. In the United States, Canada, and China, for example, lightning is the major cause of ignition. In other parts of the world, human involvement is a key contributor. In Mexico, Central America, South America, Africa, Southeast Asia, Fiji, and New Zealand, forest fires can be credited to human behaviour such as animal husbandry, agriculture, and land-conversion burning. Human negligence is a major cause of forest fires in China and in the Mediterranean Basin. In Australia, the source of forest fires can be traced to both lightning strikes and human activities such as machinery sparks and discarded cigarette butts."

Summers in Australia are notable for two things: barbecues and bush fires. Australia is currently facing its most horrible drought in a century, which for the last few years has lead to more frequent and serious bush fires. In January 2003, a forest fire in New South Wales and the Australian Capital Territory burst into flames through an area almost the size of the U.S. state of Texas, damaged 500 homes and killing four people, to say nothing of the thousands of sheep and cattle killed in the conflagration. And from late 2006 to early 2007, fire-fighters in Australia’s southern state of Victoria fought some of the worst bush fires in Australia’s history for 50 rainless days in a row and had to call for help from New Zealand and U.S. smoke jumpers. Meanwhile, humidity levels in Australia hit all-time lows of between 3 and 5 percent (20 percent humidity is considered a serious fire threat). **[**12**]**

In 2006, forest fires caused by lightning ravaged the Halkidiki peninsula in the north, a summer holiday spot especially popular with Britons. More than 1,000 travellers had to be evacuated. Then in 2007, Greece witnessed its worst forest fires in recorded history when inferno raged from the north of the country to the south. More than 60 people were killed, and hundreds of homes and an area of wildland about the size of Rhode Island were destroyed. Even the archaeological remains in Olympia, the birthplace of the Olympics, were in danger.

For the past five years, Portugal has witnessed some of the most dangerous forest fires in Europe. In 2003, unusually hot, dry air and strong winds effected almost 6 percent of the country’s forests, burned more than 350,000 hectares of land, and caused enormous soil erosion that affected water supplies and agriculture. Fifteen people died, and the damage summed up to an approximate 1 billion euros. Then in 2005, during a serious drought, five major fires spread across Portugal. The largest struck a region north of Lisbon and extended for more than 13 miles.**[**11**]** Again, more than 300,000 hectares of wildland was burned and at least 18 people died, including a number of fire-fighters.

Summer can be a cruel time of year for Siberia. The regions fragile boreal forests the worlds largest and a vital piece of the planets ecosystem have seen a 10-fold increase in forest fires during the past 20 years, Russian scientists evaluate. Russia lost 11.7 million hectares to forest fires in 2002 and other 23.7 million hectares in 2003 an area about the size of Britain. Since the beginning of the 2007 fire season, more than 140,000 wildfires covering a million hectares have been recorded. Fires are frequently ignited by lightning and are frequently so remote that it becomes difficult to tackle them effectively. This year, Russia's uphill battle against forest fires has sucked in more than 8,000 people and approximately 1,500 units of equipment, including 72 helicopters and planes.

There have been numerous global fire issues identified:

- Decrease in forest health
- Forest/urban interface: loss of many homes
- Fire damage to tropical forests
- Forest damage from unregulated burning for agricultural and forest clearing intention
- Global health impacts from forest fire smoke
- Numerous fatalities to fire fighters and others as a consequence of forest fires
- Forest fire disorder of air and sea transportation due to reduced visibility
- Escalating expenses of fire suppression and resource damage
- Bigger role of combustion gases to global climate change
- Need to link sustainable land use policies and practices with emergency preparedness actions to reduce negative impacts of forest fires
- Need for community involvement and private sector involvement in developing prolonged land use practices and fire management programmes
- Requirement for a quantitative fire database in fire-prone countries
- Role of fire in supervision of fire-adapted ecosystems

The South Asia region extends from the tropical evergreen forests of Sri Lanka and India in the South to the mountain forests up to the tree line, or alpine forests, in the Himalayas in the North. As in continental and insular Southeast Asia, a large range of biogeographic features and climatic conditions within the region have shaped a high diversity of forest ecosystems and other wooded land with different fire regimes and vulnerabilities. In addition, land preparation for agricultural, horticultural and shifting cultivation objectives is done during or at the end of the winter months.

Fire is used as the cheapest measure for cleaning such land by the villagers and shifting cultivators. Therefore, uncontrolled use of fire in or neighbouring to the forest occurs frequently. Frequently such fires escape to the forest accidentally. In some cases, fires are set wilfully by the cattle grazers to get hold of a new flush of good grasses.

2.5 Steps taken by Governments all over the World

This assessment of the global forest fire condition revealed strengths and weaknesses associated with sustaining the health and productivity of the world's forests when threatened by drought, forest fires and an increasing demand for natural resources. Before describing some of the positive outcomes in more detail, it may be instructive to compute the current state of fire management practices throughout the different regions:

- Forest fires during drought years continue to cause serious impacts to natural resources, public health, transportation, navigation and air quality over large areas. Tropical rain forests and cloud forests that usually do not burn on a large scale have been devastated by forest fires during the 1990s.
- Many countries, and regions, have a well-developed system for documenting, reporting and evaluating forest fires statistics in an orderly manner. However, many fire statistics do not offer sufficient information on the damaging and beneficial effects of forest fires.
- Satellite systems have been used effectively to map active fires and burned areas, especially in inaccessible areas where other damage assessment capabilities are not available.
- Some countries still do not have a system in place to annually report number of fires and area burned in a well-maintained database, often because other issues like food security and poverty are more important.
- Even those countries supporting highly financed fire supervision organizations are not exempt from the ravages of forest fires in drought years. When forest fires fuels have accumulated to high levels, no amount of fire fighting resources can make much of a difference until the weather moderates (as observed in the United States in the 2000 fire season).
- Uncontrolled use of fire for forest conversion, agricultural and pastoral purposes continues to cause a severe loss of forest resources, especially in tropical areas.

- Some countries are beginning to realize that inter-sectoral coordination of land use policies and practices is a vital element in reducing forest fire losses.
- Examples exist where sustainable land use practices and the participation of local communities in integrated forest fire management systems are being employed to restrict resource losses from forest fires.
- In some countries, volunteer rural fire brigades are successful in responding quickly and efficiently to forest fires within their local range ; and residents are taking more responsibility to ensure that homes will keep a check on forest fires.
- Although prescribed burning is being used in many countries to decrease wildfire hazards and achieve resource benefits, other countries have prohibitions against the use of prescribed fire.
- Fire ecology principles and fire regime classification systems are being used effectively as an essential part of resource management and fire management planning.
- Fire research scientists have been conducting cooperative research projects on a global scale to improve understanding of fire activities, fire effects, fire emissions, climate change and public health.
- Numerous examples were present in the 1990s of unprecedented levels of inter-regional and international cooperation in helping to lessen the impact of forest fires on people, property and natural resources.
- Institutions like the Global Fire Monitoring Centre have been influential in bringing the world's fire situation to the attention of a global audience via the Internet.

According to the Constitution of India, the central and state governments in the country are enabled to legislate on forestry subject. The implementation part of the forest policies/programmes lies with the state government. Thus, fire prevention, detection, and suppression activities are the responsibility of the state governments' forestry departments. The policies, planning, and financing are the primary responsibility of the Central Government. There is usually no separate department for carrying out forest fire management in the states. The regular staffs of the forest departments in the states carries out various activities of forest fire management. During forest fire seasons in some of the regions, fire watchers are recruited by the state governments as a special provision. At the central level, the Ministry of Environment and Forests is the ministry that is responsible for forest conservation and protection. Forest fire management is managed by the "Forest Protection Division" of the Ministry, which is headed by a Deputy Inspector General of Forests. The Ministry is implementing a plan called "Modern Forest Fire Control Methods" in India below which state governments are provided financial assistance for fire prevention and control. This assistance is being used by the state governments for procuring hand equipment, fire resistant clothes, firefighting tools, radios, fire watch towers, fire finders, creation of fire lines, research, training, and publicity on fire-fighting. This project is to be carried out in fourteen states and covers more than 70 percent of the forest area of the country. **[**3**]**

According to the GR, 25% of the total fund will be diverted to wildfires - to create mechanisms to help prevent such incidents. From this year joint forest management committees (JFMC) and eco development committees (EDC) would get funds for developing defensive mechanisms in the village. They will spend the fund for various activities of forest development.

Modern Forest Fire Control Project is being implemented in FDCM Ltd. as a part to the growth program of United Nations. The main object is to protect hyper sensitive and valuable forest area in Chandrapur District. Forest area of an Ongoing Project is 1,62,834 hectare out of which area with Forest Department is 1,11,227 hectare and FDCM Ltd. area is 51,607 hectare. During the first year i.e. 1985 of the Project, a percentage of area burnt from fire was 14.82%. It is reduced substantially to 2.91% in the year 2000. Due to forest fire protection, the humus content of the forest area is increased, thereby increasing the productivity. The project has also generated substantial employment to the rural population in the District.**[**15**][**16**]**

Phase II extension scheme on the additional area of 30,000 hectare of Forest Department in Chandrapur District is also under functioning with financial assistance from Central Government & State Government from 1994-95.

Similarly Centrally Sponsored Scheme of Modern Forest Fire Control Project (Master Plan) a new scheme for a period of 10 years from 2001-02 costing Rs. 84.22 crores over an area of 484200 hectare under the charge of FDCM Ltd. is to be put into practice with the financial assistance from Central & State Government.**[**17**]**

In case of forest fires, wildfire management stands at three unique levels i.e. pre-fire (preparatory planning for fire control), during fire (fire detection, spread and control planning) and post fire (damage assessment and mitigation planning). The role of various technical organizations and forest departments is very significant. The pre-fire phase needs inputs on effective preparations and planning for supervising and combating the fire. This process might stands at understanding of fire proneness / vulnerability and forest fire spread potential. These two parameters together reflect in the Fire Danger Rating (FDR).

The spatially explicit fire danger rating of the forests will assist to prioritize the areas for detailed fire control planning. Fire proneness / vulnerability could be measured based on long term history of fire events, location characteristics in relation to vegetation coat and type, climate, topography and biotic pressure. This kind of data needs to be integrated through the databases accessible with different organizations. A variety of advanced spatial modelling and analytical tools are being analysed to characterize spatial and temporal trends to grasp local and local level processes and develop fire proneness / vulnerability zones. The fire-spread simulation is one of the decisive process helps to assess the scale and direction of the fire spread. It depends on built-in substrate flammability properties and extrinsic factors catalyzing the fire extent. The intrinsic substrate properties lie on vegetation type, phonological patterns, and forest desiccation and fuel stick values.

Fire detection, spread and control preparation are the important issues for the 'During Fire 'scenario. Considering the large amount of area of operations and huge number of fire occurrences simultaneously occurring in a day, the identification and combating becomes difficult. Conventional methods of detection of active fire locations need to be augmented with advanced technologies like satellite remote sensing. The distant sensing system should have the capability to provide 3-4 signals on a daily basis backed up with robust process algorithms, data dissemination and reception systems. The Indian Forest Fire Response and Assessment System (INFFRAS) is established with a capacity to incorporate process and disseminate various types of data bases related to pre fire, during fire and post fire scenarios.

The post-fire phase involves ecological damage evaluation and mitigation planning .The ecological harm evaluation is complex in terms of Indian context as the fires mostly belong to ground creeping fire category. In such state the impacts are mainly in the shape of effects on biodiversity, productivity, regeneration and soil erosion etc., which are intangible in nature. These impacts could only be understood based on long term monitoring and measurements over gradients of fire uncovered areas across the country. Experiments on trace gas emissions from forest fires were carried out Indian area combining satellite derived information on burnt areas and emission factors anticipated from ground based measurements.

It is clear from the many initiatives cited above that significant results have been achieved at local, national and international levels to improve methods, technologies and skills in fire management. In the last decade, encouraging knowledge has been gained in international collaboration in forest fire science. The development of fire management systems is increasingly based on ideology of fire ecology, the participation of indigenous knowledge and the integration of local communities.

However, increasing demographic and land-use forces linked with fragile national economies in developing countries, and new problems arising as a consequence of global environmental changes, have led to the unprecedented occurrence of human-caused forest fires with destructive socio-economic and environmental implications. These developments call for further actions to halt a widespread degradation of forests and other natural resources.

In reviewing the global fire situation it is clear that a continued stress on the emergency response side of the wildfire problem will only result in future large and damaging fires. The way out of the emergency response problem is to pair emergency preparedness and response programmes with more sustainable land use policies and practices. There are a growing number of instances where countries are working strongly with local communities and revising resource management policies. Effectively working towards more sustainable forestry practices all the way through community outreach and policy revisions are vital parts of the strategy in better conserving natural resources for the betterment of society. Policy makers and the community need to understand that a strategy that only focuses on the emergency preparedness and response side will not be enough in the end. Only when sustainable land use practices and emergency preparedness measures complement each other do long-term natural resource profits accrue for society.

2.7 Markov Chain Approach

A **Markov chain**, named after Andrey Markov, is a mathematical system that undergoes a change from one state to another, between a finite or countable amount of possible states. It is the random procedure characterized as memory-less: the next state depends only on the current state and not on the sequence of events that preceded it. This specific kind of "memorylessness" is called the Markov property. Markov chains have many uses as statistical models of real-world processes.

A Markov chain is a series of random variables X_1, X_2, X_3, ... with the Markov property, namely that, given the current state, the future and past states are independent. Formally,

$$\Pr(X_{n+1} = x | X_1 = x_1, X_2 = x_2, \ldots, X_n = x_n) = \Pr(X_{n+1} = x | X_n = x_n).$$

The likely values of X_i form a countable set S called the **state space** of the chain.

Markov chains are frequently described by a directed graph, where the edges are categorized by the probabilities of going from one state to the other states.

Variations

- Continuous-time Markov processes have a continuous index.
- **Time-homogeneous Markov chains** (or **stationary Markov chains**) are processes where

$$\Pr(X_{n+1} = x | X_n = y) = \Pr(X_n = x | X_{n-1} = y)$$

  for all n. The probability of the transition is independent of n.

- A **Markov chain of order m** (or a Markov chain with memory m), where m is finite, is a process satisfying

$$\Pr(X_n = x_n | X_{n-1} = x_{n-1}, X_{n-2} = x_{n-2}, \dots, X_1 = x_1)$$
$$= \Pr(X_n = x_n | X_{n-1} = x_{n-1}, X_{n-2} = x_{n-2}, \dots, X_{n-m} = x_{n-m}) \text{ for } n > m$$

  In other words, the future state depends on the past m states. It is possible to construct a chain (Y_n) from (X_n) which has the 'classical' Markov property by taking as state space the ordered m-tuples of X values, i.e. $Y_n = (X_n, X_{n-1}, ..., X_{n-m+1})$.

- An additive Markov chain of order m is determined by an additive conditional probability,

$$\Pr(X_n = x_n | X_{n-1} = x_{n-1}, X_{n-2} = x_{n-2}, \dots, X_{n-m} = x_{n-m}) = \sum_{r=1}^{m} f(x_n, x_{n-r}, r).$$

The value $f(x_n, xn_{-r}, r)$ is the additive contribution of the variable x_{n-r} to the conditional probability.

2.8 Markov Chain Usage

➢ Board Games played with dice

A game of snakes and ladders or any other game in which moves are determined entirely by dice is a Markov chain, indeed, an absorbing Markov chain. This is in dissimilarity to card games such as blackjack, where the cards represent a 'memory' of the past moves. To see the difference, consider the probability for a positive event in the game. In the above mentioned dice games, the only thing that matters is the present state of the board. The next state of the board depends on the present state, and the next roll of the dice. It doesn't depend on how things got to their existing state. In a game such as blackjack, a player can gain an benefit by remembering which cards have already been shown (and hence which cards are no longer in the deck), so the next state (or hand) of the game is not independent of the past states.

- A centre biased random walk

Consider a random walk on the number line in which, at each step, the position (call it x) may change by +1 (to the right) or -1 (to the left) with probabilities:

$$P_{move\ left} = \frac{1}{2} + \frac{1}{2}\left(\frac{x}{c+|x|}\right)$$

$$P_{move\ right} = 1 - P_{move\ left}$$

(where c is a constant greater than 0)

For example if the constant, c, equals 1, the probabilities of a move to the left at positions x = -2,-1,0,1,2 are given by $\frac{1}{6}, \frac{1}{4}, \frac{1}{2}, \frac{3}{4}, \frac{5}{6}$respectively. The random walk has a centering effect that weakens as c increases.

Since the probabilities depend only on the current position (value of x) and not on any prior positions, this biased random walk satisfies the definition of a Markov chain.

Chapter 3

3. Planning and Design

In this project we have focussed on one of the major natural disasters i.e. forest fires. Forest fires lead to enormous damage to human life as well as property. Our project is based on a model that uses sensors to collect and send data to the main system where this data is analysed based o several parameters using Markov chain Monte Carlo approach to alert the concerned authorities that is forest department and fire department about the fires and also the probability of a fire to occur on a particular day. Here we have used the information based on the data for past few years to tell us about the particular period in which forest fires occur in a particular region. Also in our project we use 3 parameters i.e. temperature, smoke detection and previous day results. This data helps us to find out the probability of fire to occur on the next day.

3.1 Data Flow diagram

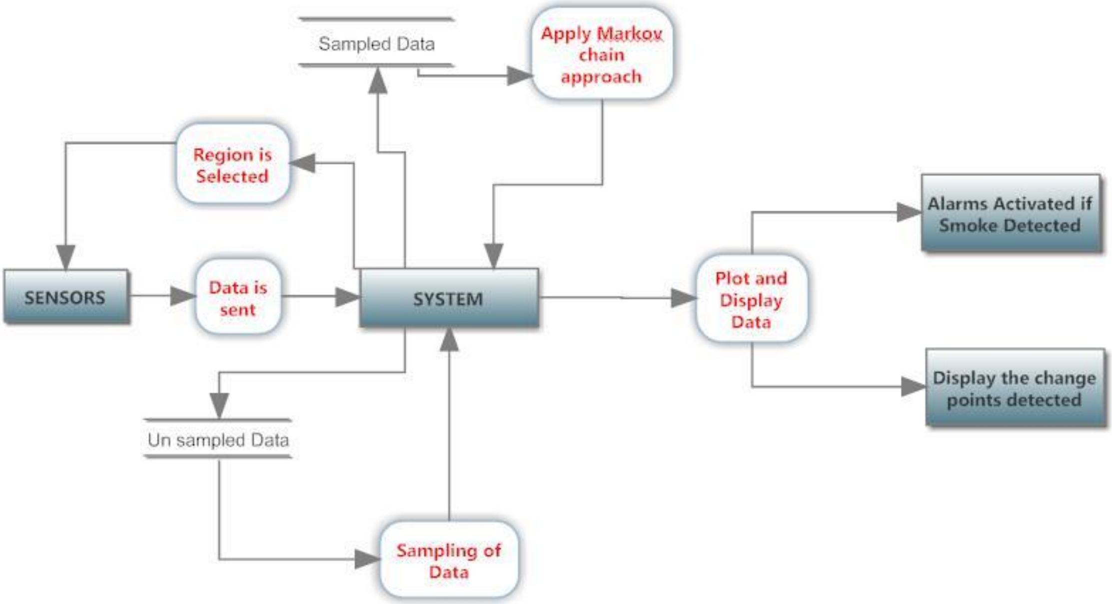

Figure 3.1: Data Flow Diagram

3.2 Flow Chart

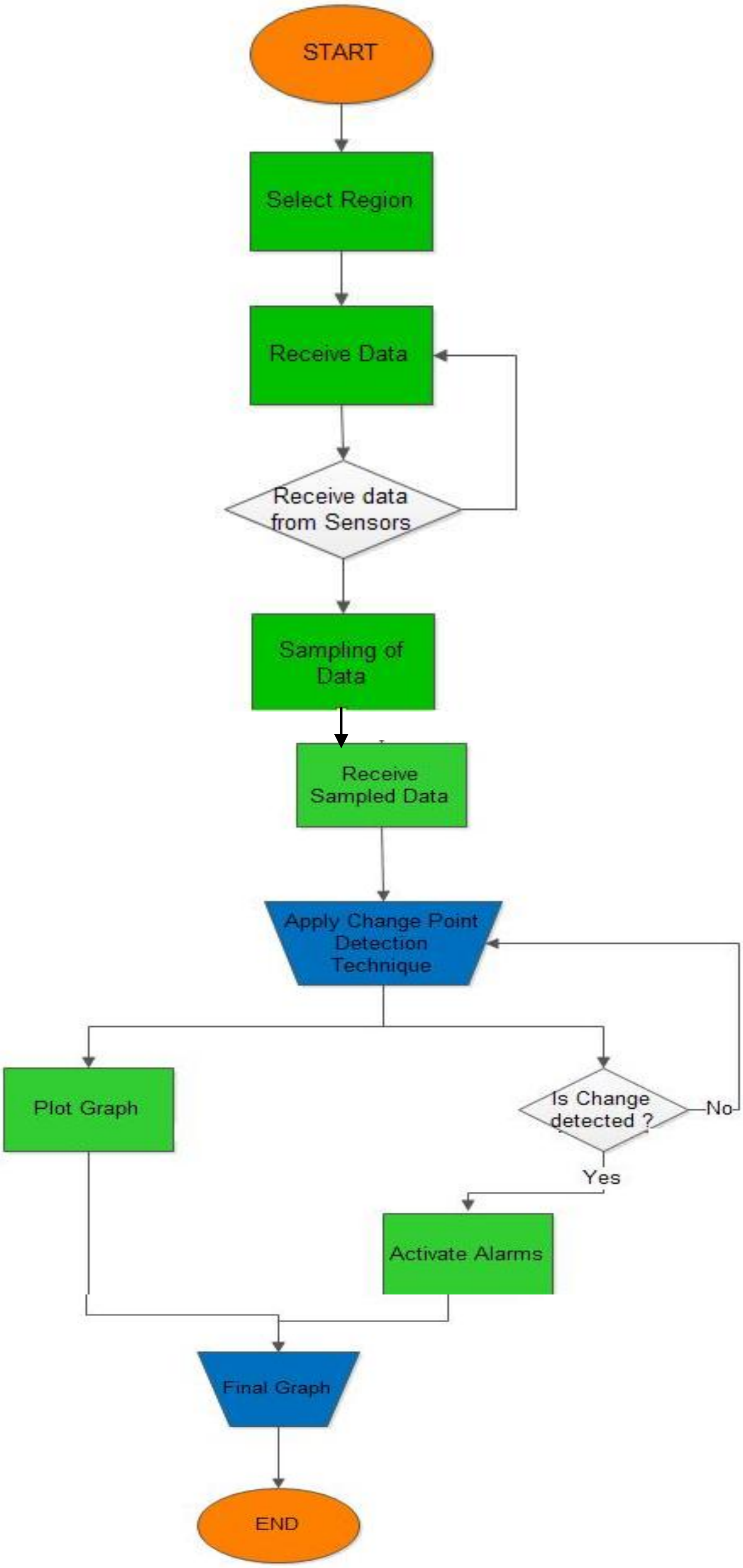

Figure 3.2: Flow chart

3.3 Parameters

Forest fires occur when all of the necessary elements of the fire triangle come together in a susceptible area: an ignition source is brought into touch with a combustible material such as vegetation that is subjected to enough heat and has a sufficient supply of oxygen from the ambient air. High moisture content usually prevents ignition and slows propagation, since higher temperatures are essential to evaporate any water within the material and heat the substance to its fire point. Dense forests usually provide more shade, which results in lower ambient temperatures and greater humidity, and are therefore less susceptible to forest fires. A few dense material such as grasses and leaves are simpler to catch fire because they contain less water than denser material like branches and trunks. Plants continuously lose water by transpiration, but water loss is usually balanced by water captivated from the soil, humidity, or rain. If this balance is not maintained, plants dry out and are thus more flammable, often a consequence of droughts.

3.3.1 Physical Properties

A forest fire front is the portion sustaining continuous flaming combustion, where unburned material meets active flames, or the smouldering transition between unburned and burned material. As the front approaches, the fire heats both the nearby air and woody material by convection and thermal radiation. High-temperature and long-duration exterior forest fires may encourage flashover or torching: the drying of tree canopies and their subsequent ignition from below.

Forest fires have a rapid forward rate of spread (FROS) when burning all the way through dense, uninterrupted fuels. They can move as quickly as 10.8 kilometres per hour (6.7 mph) in forests and 22 kilometres per hour (14 mph) in grasslands. Forest fires can move on tangential to the main front to structure a flanking front, or burn in the reverse direction of the main front by backing. They may also broaden by jumping or spotting as winds and vertical convection columns hold firebrands (hot wood embers) and other burning substances through the air over roads, rivers, and other barriers which may otherwise act as firebreaks. Torching and fires in tree canopies support spotting, and dry ground fuels that surround a forest fire are especially vulnerable to ignition from firebrands. Spotting can make spot fires as hot embers and firebrands ignite fuels downwind from the fire. In Australian bushfires, spot fires are known to happen as far as 10 kilometres (6 mi) from the fire front.

Especially large forest fires may affect air currents in their immediate vicinities by the stack effect: air goes up as it is heated, and large forest fires create powerful updrafts that will fetch in new, cooler air from surrounding areas in thermal columns. Great vertical differences in heat and humidity encourage pyrocumulus clouds, strong winds, and fire whirls with the force of tornadoes at speeds of more than 80 kilometres per hour (50 mph). Rapid rates of stretch, prolific crowning or spotting, the presence of fire whirls, and strong convection columns signify extreme conditions.

3.3.2 Effect of Weather

Heat waves, droughts, cyclical climate changes like El Niño, and regional weather patterns such as high-pressure ridges can increase the risk and alter the behaviour of forest fires dramatically. Years of precipitation followed by hot periods can encourage more widespread fires and longer fire seasons. Since the mid 1980s, earlier snowmelt and linked warming has also been associated with an increase in length and severity of the forest fire season in the Western United States. However, one individual element does not always cause a raise in forest fire activity. For example, forest fires will not occur during a drought unless accompanied by other things, such as lightning (ignition source) and strong winds (mechanism for rapid spread).

Fire intensity also increases during daytime hours. Burn rates of smouldering logs are up to five times more during the day due to lower humidity, increased temperatures, and increased wind speeds. Sunlight warms the ground during the day which creates air currents to travel uphill. At night the land cools, creating air currents that travel downhill. Forest fires are fanned by these winds and often follow the air currents over hills and all the way through valleys.

3.3.3 Atmospheric Effects

Most of the Earth's weather and air pollution resides in the troposphere, the part of the atmosphere that extends from the surface of the planet to a height of about 10 kilometres (6 mi). The vertical lift of a severe thunderstorm or pyrocumulonimbus can be enhanced in the area of a large forest fire, which can propel smoke, soot, and other particulate matter as high as the lower stratosphere. Previously, prevailing scientific theory held that most particles in the stratosphere came from volcanoes, but smoke and other forest fire emissions have been detected from the lower stratosphere. Pyrocumulus clouds can reach 6,100 meters (20,000 ft) over forest fires. Increased fire by-products in the stratosphere can increase ozone concentration beyond safe levels. Satellite observation of smoke plumes from forest fires revealed that the plumes could be traced intact for distances exceeding 1,600 kilometres (1,000 mi). Computer-aided models such as CALPUFF may help predict the size and direction of forest fire-generated smoke plumes by using atmospheric dispersion modelling.

Forest fires can affect climate and weather and have major impacts on atmospheric pollution. Forest fire emissions contain fine particulate matter which can cause cardiovascular and respiratory problems. Forest fires in Indonesia in 1997 were estimated to have released between 0.81 and 2.57 gigatonnes (0.89 and 2.83 billion short tons) of CO_2 into the atmosphere, which is between 13%–40% of the annual carbon dioxide emissions from burning fossil fuels. Atmospheric models suggest that these concentrations of sooty particles could increase absorption of incoming solar radiation during winter months by as much as 15%.

3.4 Use Case

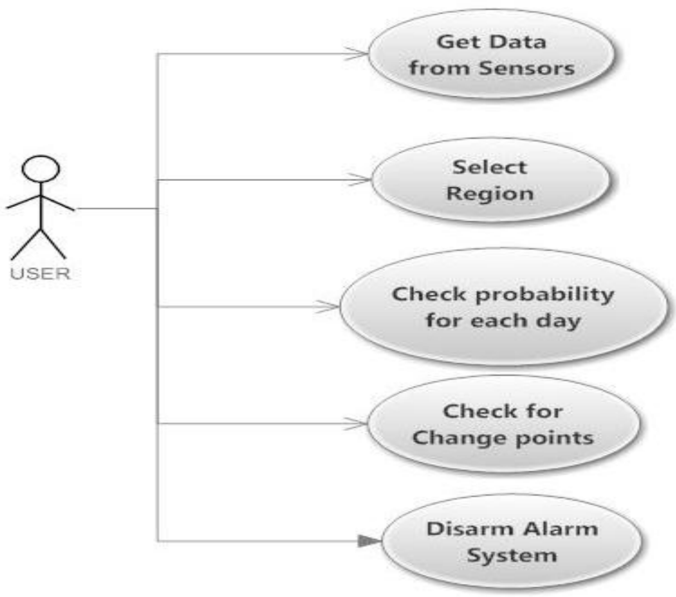

Figure 3.3: Use Case Diagram

Chapter 4

4. Implementation

4.1 Markov Chain Formula and Implementation

The probabilities of forest fire (modelled on various parameters), given the forest fire and smoke detection on the preceding day, can be represented by a transition matrix:

$$P = \begin{bmatrix} 0.9 & 0.1 \\ 0.5 & 0.5 \end{bmatrix}$$

The matrix *P* represents the forest fire model in which a day when fire won't be there is 90% likely to be followed by another day without fire, and a day on which fire is detected is 50% likely to be followed by another day on which there was fire. The columns can be labelled "fire detected" and "fire not detected" respectively, and the rows can be labelled in the same order.**[**18**][**19**]**

$(P)_{ij}$ is the probability that, if a given day is of type *i*, it will be followed by a day of type *j*.

Notice that the rows of *P* sum to 1: this is because *P* is a stochastic matrix.

Predicting the forest fire

The detection on day 0 is known to be "fire not detected". This is represented by a vector in which the "fire not detected" entry is 100%, and the "fire detected" entry is 0%:

$$\mathbf{x}^{(0)} = \begin{bmatrix} 1 & 0 \end{bmatrix}$$

The fire detection on day 1 can be predicted by:

$$\mathbf{x}^{(1)} = \mathbf{x}^{(0)} P = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} 0.9 & 0.1 \\ 0.5 & 0.5 \end{bmatrix} = \begin{bmatrix} 0.9 & 0.1 \end{bmatrix}$$

Thus, there is a 90% chance that day 1 will also be without any forest fire.**[**20**]**

The results on day 2 can be predicted in the same way:

$$\mathbf{x}^{(2)} = \mathbf{x}^{(1)} P = \mathbf{x}^{(0)} P^2 = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} 0.9 & 0.1 \\ 0.5 & 0.5 \end{bmatrix}^2 = \begin{bmatrix} 0.86 & 0.14 \end{bmatrix}$$

Or

$$\mathbf{x}^{(2)} = \mathbf{x}^{(1)} P = \begin{bmatrix} 0.9 & 0.1 \end{bmatrix} \begin{bmatrix} 0.9 & 0.1 \\ 0.5 & 0.5 \end{bmatrix} = \begin{bmatrix} 0.86 & 0.14 \end{bmatrix}$$

General rules for day *n* are:

$$\mathbf{x}^{(n)} = \mathbf{x}^{(n-1)} P$$

$$\mathbf{x}^{(n)} = \mathbf{x}^{(0)} P^n$$

4.2 Areas affected in India

In India there are no comprehensive data to indicate the loss to forests in terms of area burned, values, and volume and regeneration damaged by fire. The available forest fire statistics are not reliable because they under estimate fire numbers and area burned. The reason behind this is attributed to the fear of accountability. However, Forest Survey of India in a country-wide study in 1995 estimated that about 1.45 million hectares of forest are affected by fire annually. According to an assessment of the Forest Protection Division of the Ministry of Environment and Forests, Government of India, 3.73 million hectares of forests are affected by fires, annually in India.**[**15**]**

State/ District	Forest Area	Sample Plots	Extent of fire incidents						Total
			Very Heavy	Heavy	Frequent	Occasional	No Fire	Unrec	
Andhra Pradesh	14826.71	2037	60.58	5.75	521.99	3335.27	10016.34	886.78	14826.71
Assam	15427.88	2482	70.91	0	590.25	4551.13	10176.68	38.01	15427.88
Bihar	5317.01	296	57.718	0	452.6223	3330.7426	1505.927	0	5317.01
Himachal Pradesh	10269.40	4878	163.7	0	671.45	3811.38	5054.92	567.98	10269.40
Jammu & Kashmir	3331.75	428	7.5	0	60.98	1089.58	2088.05	85.64	3331.75
Haryana & Punjab	1180.72	45	0	0	41.54	332.48	807.7	0	1180.72
Karnataka	13223.30	1780	59.71	30.33	470.64	3342.94	9309.79	9.89	13223.30
Manipur	15154.00	1880	0	151.54	454.62	5758.52	8789.32	0	15154.00
Madhya Pradesh	1962591	1947	136.53	23.07	1838.83	10644.29	6983.19	0	19625.91
Maharashtra	8165.54	1355	0	0	186.83	4222.57	3756.94	0	8165.54
Meghalaya	9905.00	1659	26.75	0	269.12	3347.25	5230.91	1031.6	9905.66
Nagaland	14954.91	1128	0	0	1084.231	12038.703	1831.976	0	14954.91
Orissa	20143.38	2972	204.42	78.5	923.19	11345.345	5258.182	333.52	20143.38
Rajasthan	20178.79	2446	71.39	0	99.03	4348.12	14763.26	896.99	20178.79
Sikkim	1707.77	401	47.12	0	18.14	544.84	1097.67	0	1707.77
Tripura	6445.36	555	34.59	0	361.75	5293.65	755.37	0	6445.36
Uttar Pradesh	23164.09	2825	871.43	0	2092.51	11124.1	907605	0	23164.09
West Bengal	5764.81	1471	4.77397	0	656.4338	1356.5246	3444.318	302.76	5764.81
Dadra & Nagar	186.49	62	0	0	0	180.8953	5.5947	0	186.49
Grand Total	**208973.48**	**307.47**	**1817.122**	**289.19**	**10794.16**	**89998.3305**	**101952.188**	**4154.07**	**208973.48**
Percentage			**0.87**	**0.14**	**5.16**	**43.06**	**48.79**	**1.99**	**100.00**

Table 4.1: Extent of fire incidence in forest areas in the country

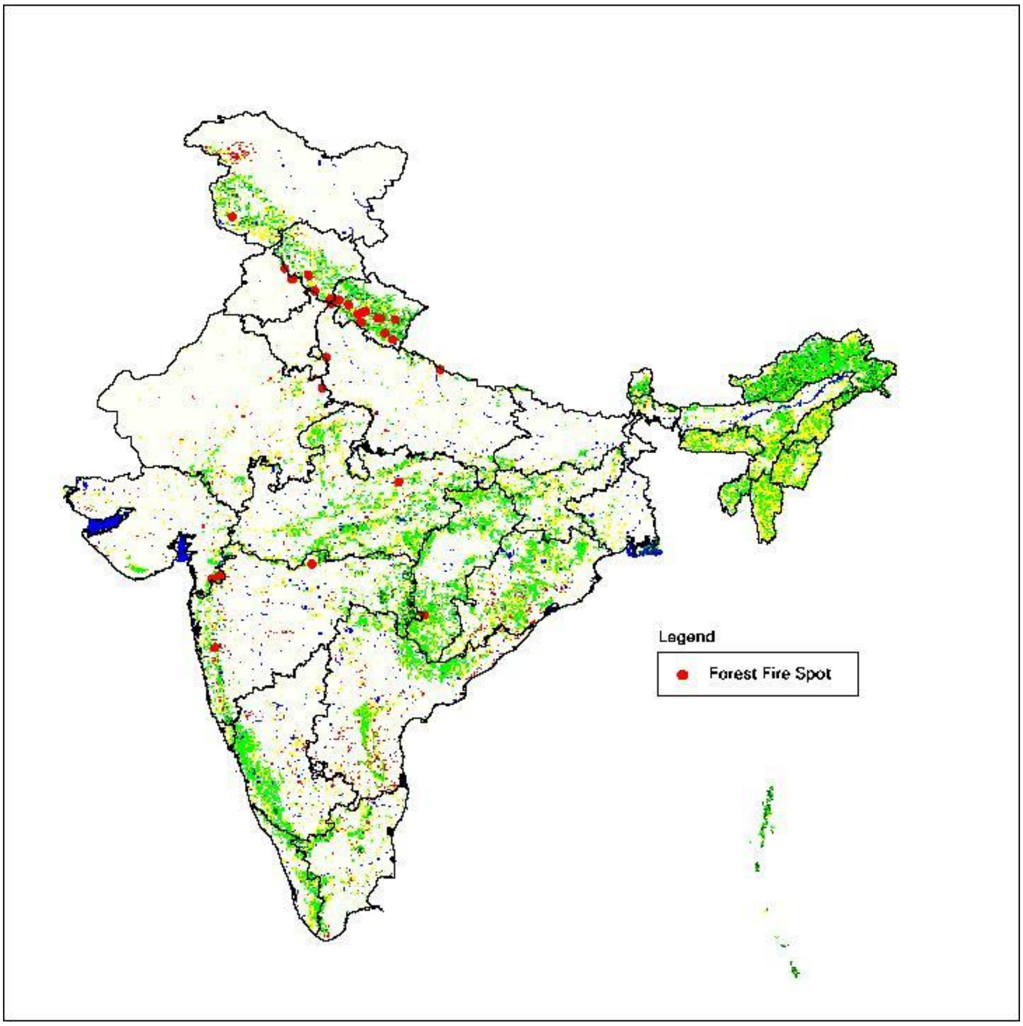

Figure 4.1: Forest Fire Spots in India

4.2.1 Forest Fires in Andhra Pradesh

The State of Andhra Pradesh has 63814 Sq.km of forest area which is 23% of geographical area of State. Planning, Monitoring & Decision making for managing this huge natural resource in conventional method is a difficult task.

As is well known due to natural causes and human activity forest has been demeaning. One of the major causes responsible for forest degradation is forest fires. Huge areas of forests and grasslands are burnt every year. Andhra Pradesh Forests has a wide variety of forest types with different species composition. With species like Teak, Terminalia, Anogeissus, Bamboo, Dalbergia, Lannea, Red Sanders etc., the leaf fall begins towards the end of the December and this along with dry grass forms a highly combustible material for forest fires. It is important to have a appropriate forest fire management and information on forest fire prone areas.

For evolving a decision making process based on Geomatics, the issues influencing forest fire were categorized into fuel index i.e. combustible Bio-mass from Forest Type, topography (slope and aspect) and proximity (Roads and Settlements). The inter connection for these factors was established and finally integrated for identification and zonation of fire prone areas from lowest to highest risk. The forest of entire AP has been categorized based on the degree of hazard. As an example the map prepared for Bhadrachalam South Division is shown below.

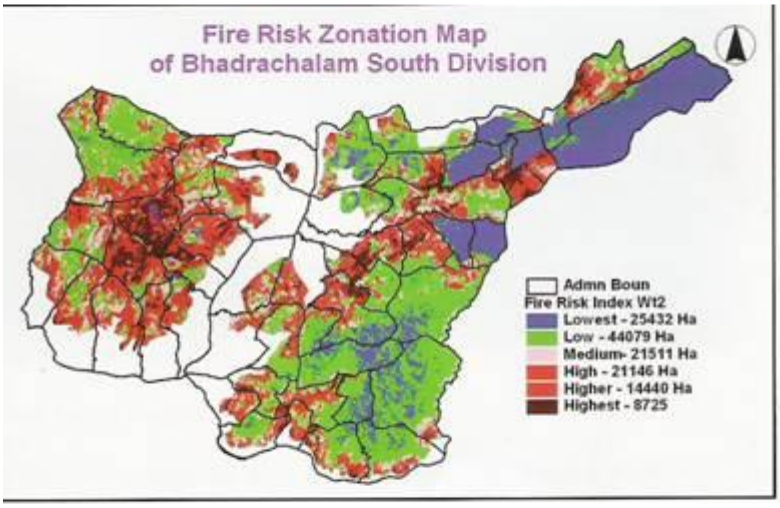

Figure 4.2: Fire Risk Map for a region in Andhra Pradesh

The Output maps from the process were sent to field officers to make use of in planning in preparation of Fire Management Plans. These maps assist by indicating locations for erection of fire watch towers, execution of fire lines and construction of fire walls. With the help of Global Positioning System (GPS) locations are verified and established for execution works. This technology has helped in designing forest fire lines and rationalized utilization of funds for forest management. Thus the management of forest fire in AP is no other matter of experience only.

This Forest fire risk zonation maps have been supplied to the field level functionaries and this has helped in keeping stronger vigil in the further vulnerable areas. This combined with the cooperation of the local communities (VSS) has reduced incidence of Forest fire to some extent.

Incidentally the entry sent by AP Forest Dept. on Forest Fire Mapping under “Trail Blazing Application of the year 2004” was adjudged by the Govt. of India as the second best in the category and was awarded Silver Icon in e-Governance.

4.2.2 Forest fires in Garhwal Himalaya Forests

Uttaranchal is highly vulnerable to a variety of natural disasters. Forest fire is very common in Uttaranchal hills. Forest fires have caused significant harm to the forest ecosystem. The Forest fires occur between April to June annually when the weather is hot and dry in Uttaranchal hills. Forest fires are caused by natural and man made causes. In Uttranchal 8 hill districts mainly Chamoli, Pithoragarh, Almora, Nainital, Uttarkashi, Dehradun, Tehri, and Pouri, are highly vulnerable regions of forest fire. Every year one third of all forests are affected by the forest fire in Uttranchal. In the recent years a very big part of the forest has been destroyed in Uttranchal in the name of development. During the British period, the wildfire was prevented in the summer through removal of forest litter all along the forest boundary this was called “forest fire line”. In the recent years satellite remote sensing techniques have genuinely helped to assess forest fire. It is very essential to mitigate forest fire for protecting our flora and fauna and our ecology. A strategy needs to be evolved to reduce the damage Caused by forest fire.

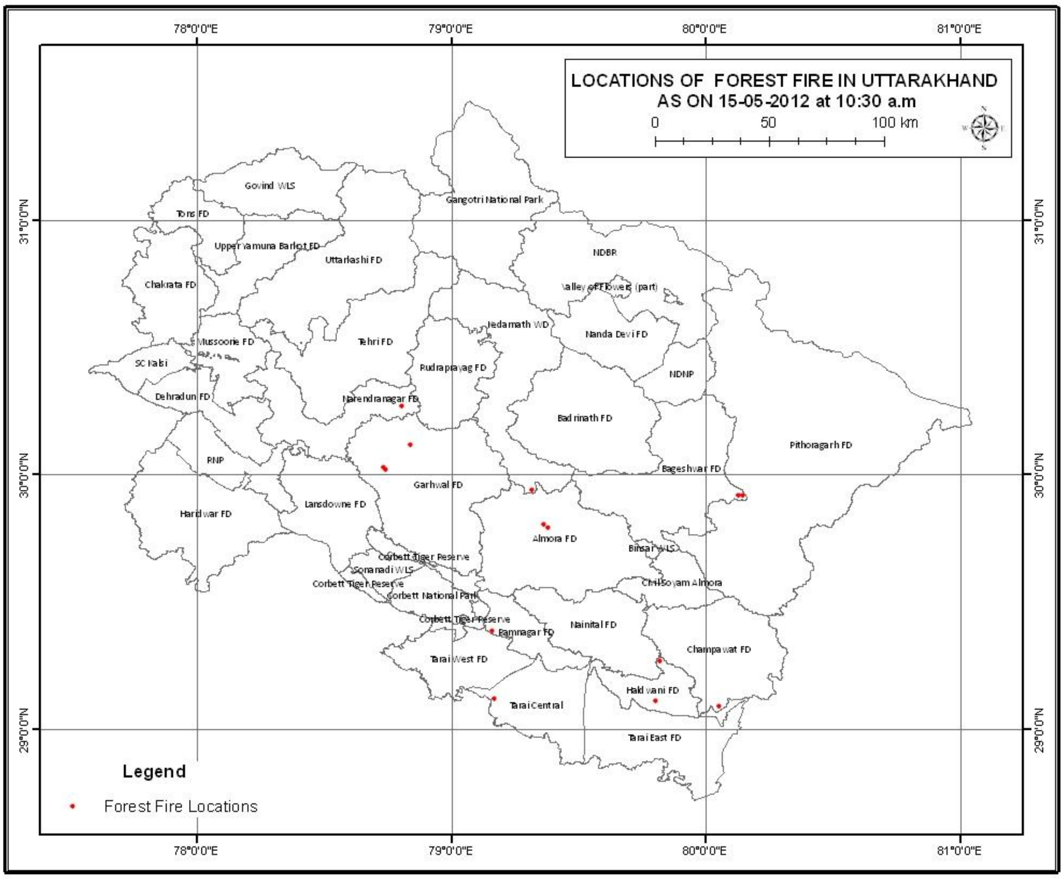

Figure 4.3: Forest Fire locations in Uttarakhand

The state has experienced heavy fire episodes for the period of May-June 2005 and daily datasets of Defence Meteorological Satellite Program-Operational Line Scan system (DMSP-OLS) and selected cloud-free Moderate Resolution Imaging Spectroradiometer (MODIS) datasets were used in mapping active fire locations. DMSP-OLS collects information in visible (0.5 to 0.9 μm) and thermal (10.5 to 12.5 μm) bands and detects dim sources of lighting on the earth's exterior, including fires. Fire sites derived from DMSP-OLS and MODIS data were validated with limited ground data as of forest subdivision and media reports. Results of the study point out that the state experienced deep fire episodes, most of them taking place during night-time rather than daytime. Validation of satellite-derived fires with ground information showed a high quantity of spatial correlation. [24]

4.2.3 Forest Fires in Maharashtra

Large swathes of forests in Maharashtra risk being shattered by forest fires allegedly started by tendu contractors. Large forest areas have been devastated in fires at different places in Vidarbha over the past fortnight. Sources in the forest department say these are not natural forest fires, a frequent phenomenon during summer. The tussle between state forest department and tendu leaf contractors is said to be the root cause of the wildfires.

The state forest department, while issuing tenders for tendu leaf plucking in forests, imposed an order which makes contractors liable for forest fires in the areas of their operation. When the deadlock between the department and tendu contractors stayed unresolved, the forest department officials imposed a much milder condition, which said contractors would immediately inform the officials about forest fire in their area of operation.

Forest department sources said this did not advance matters and suddenly there were a spate of forest fires, which claimed huge tracts of dense forests. The latest incident was at the Tadoba-Andhari Tiger Reserve that singed 3,000 hectares of forest cover.

According to the conditions, villagers will not be allowed to pluck tendu leaves; they will not be paid the wages and bonus if there is incident of wildfire in more than one hectare land around the forest.

4.3 Softwares

- **C++**

C++ (pronounced "cee plus plus") is a statically type, free-form, multi-paradigm, compiled, general-purpose programming language. It is considered as an intermediate-level language, as it comprises a combination of both high-level and low-level language features.

C++ is one of the most popular programming languages with use domains including systems software, application software, device drivers, embedded software, high-performance server and client applications.

C++ is also used for hardware design, where the design is at first described in C++, then analyzed, architecturally constrained, and scheduled to create a register-transfer level hardware description language via high-level synthesis

- **MATLAB**

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use atmosphere where problems and solutions are expressed in familiar mathematical notation. Typical uses include Math and computation Algorithm development Data acquisition Modelling, simulation, and prototyping Data analysis, exploration, and visualization Scientific and engineering graphics Application growth, including graphical user interface building MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many practical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

4.4 Code

- **C++**

```
#include<iostream.h>
#include<fstream.h>
#include<dos.h>
#include<stdio.h>
#include<process.h>
#include<stdlib.h>
#include<conio.h>
void values(float& a1, float& b1, float& c1, float& d1)
```

```
{
float m1,n1,o1,p1;int q1,r1,s1,t1;
m1=((a1*a1)+(b1*b1))*100  ;  n1=((a1*b1)+(b1*d1))*100   ;
o1=((a1*c1)+(c1*d1))*100    ;  p1=((b1*c1)+(d1*d1))*100     ;
q1=(int)m1; r1=(int)n1; s1=(int)o1; t1=(int)p1;
a1=(float)q1/100; b1=(float)r1/100;
c1=(float)s1/100; d1=(float)t1/100;
}
void main()
{
clrscr();
int ans,q,r,s,t,e,f,k,z,x,y,f1,mon,temp,temp2,temp1,f2,f3,f4,i,j,w[20];
float m,n,o,p,a,b,c,d,zz[365]; sleep(2);
while(ans!=5)
{int day=1; clrscr();
cout<<"Enter the place";
cout<<"\nEnter 1 to get results for Andhra Pradesh Forests";
cout<<"\nEnter 2 to get results for Garhwal Himalayan Forests";
cout<<"\nEnter 3 to get results for South Tropical Deciduous Maharashtra Forests";
cout<<"\nEnter 4 to get Change Point Values";
cout<<"\nEnter 5 to exit";
cin>>ans;
switch(ans)
{
case 1: clrscr();
        cout<<"Andhra Pradesh Forests"; cout<<endl;
        k=0; f1=81; f2=19; f3=72; f4=28; x=1 ;
                for(i=1;i<=6;i++)
                {e=(f1+f2); a=(float)f1/e;
                b=(float)f2/e;   f=(f3+f4);
                c=(float)f3/f; d=(float)f4/f;
                 for(j=1;j<=5;j++)
                 {      k++;
                        values(a,b,c,d);
                        y=x;
```

```
            temp = rand () % 13; temp2 = temp + 15; temp1= temp2 - 17;
            if(temp1 > 5) z=1;
            x = rand() % 15;
            if(x>1) x=0;
            if((x==1) && (z==1))
            {if(y==1)
            {f3++; zz[k]=c;
            }else
            {f1++; zz[k]=a;
            }}else
            {if(y==1)
            {f4++; zz[k]=d;
            }else
            {f2++; zz[k]=b;
            }}delay(500);
            ofstream out("pr3.txt",ios::beg); out<<zz[k];
            cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
            day++; out.close();
     }}
//       cout<<"\nFeb";
       f1=52; f2=48; f3=56; f4=44; x=0 ;
       for(i=1;i<=6;i++)
       {e=(f1+f2); a=(float)f1/e; b=(float)f2/e; f=(f3+f4);
         c=(float)f3/f;d=(float)f4/f;
        for(j=1;j<=5;j++)
        {   k++;
            values(a,b,c,d);
            y=x;
            temp = rand () % 17; temp2= temp + 16; temp1= temp2 - 25;
            if(temp1 > 5) z=1;
            x = rand() % 15;
            if(x>1) x=1;
            if((x==1) && (z==1))
            {if(y==1)
            {f3++; zz[k]=c;
```

```
}else
{f1++;zz[k]=a;
}}else
{if(y==1)
{f4++;zz[k]=d;
}else
{f2++; zz[k]=b;
}}delay(500);
ofstream out("pr3.txt",ios::beg); out<<zz[k];
cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
day++; out.close();
}}
//          cout<<"\nMarch";
f1=79; f2=21; f3=78; f4=22;x=0 ;
for(i=1;i<=6;i++)
{e=(f1+f2);a=(float)f1/e;b=(float)f2/e;
  f=(f3+f4); c=(float)f3/f; d=(float)f4/f;
 for(j=1;j<=5;j++)
 {       k++;
values(a,b,c,d);
y=x;
temp = rand () % 20; temp2 = temp + 16; temp1= temp2 - 18;
if(temp1 > 5) z=1;
x = rand() % 15;
if(x>1)       x=0;
if((x==1) && (z==1))
{if(y==1)
{f3++; zz[k]=c;
}else
{f1++; zz[k]=a;
}}else
{ if(y==1)
{f4++; zz[k]=d;
}else
{f2++; zz[k]=b;
```

```
}}delay(500);
ofstream out("pr3.txt",ios::beg); out<<zz[k];
cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
day++; out.close();
}}
//    cout<<"\nApril";
f1=68; f2=32; f3=80; f4=20; x=0 ;
for(i=1;i<=6;i++)
{e=(f1+f2); a=(float)f1/e; b=(float)f2/e;
  f=(f3+f4); c=(float)f3/f; d=(float)f4/f;
 for(j=1;j<=5;j++)
 {     k++;
    values(a,b,c,d);
    y=x;
    temp = rand () % 24; temp2 = temp + 15; temp1= temp2 - 20;
    if(temp1 > 5) z=1;
    x = rand() % 15 ;
    if(x>1)      x=0;
    if((x==1) && (z==1))
    {if(y==1)
    {f3++; zz[k]=c;
    }else
    {f1++; zz[k]=a;
    }}else
    {if(y==1)
    {f4++; zz[k]=d;
    }else
    {f2++; zz[k]=b;
    }}delay(500);
    ofstream out("pr3.txt",ios::beg); out<<zz[k];
    cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
    day++;      out.close();
 }}
//    cout<<"\nMay";
f1=54; f2=46; f3=52; f4=48; x=0 ;
```

```
for(i=1;i<=6;i++)
{e=(f1+f2); a=(float)f1/e; b=(float)f2/e;
  f=(f3+f4); c=(float)f3/f; d=(float)f4/f;
 for(j=1;j<=5;j++)
 {          k++;
            values(a,b,c,d);
            y=x;
            temp = rand () % 26; temp2= temp + 13; temp1 = temp2 - 25;
            if(temp1 > 5) z=1;
            x = rand() % 15;
            if(x>1)            x=1;
            if((x==1) && (z==1))
            {if(y==1)
            {f3++;zz[k]=c;
            }else
            {f1++; zz[k]=a;
            }}else
            {if(y==1)
            {f4++; zz[k]=d;
            }else
            {f2++; zz[k]=b;
            }}delay(500);
            ofstream out("pr3.txt",ios::beg); out<<zz[k];
            cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
            day++; out.close();
 }}
//                  cout<<"\nJune";
f1=72; f2=28; f3=79; f4=21; x=0 ;
for(i=1;i<=6;i++)
{e=(f1+f2); a=(float)f1/e; b=(float)f2/e;
   f=(f3+f4); c=(float)f3/f; d=(float)f4/f;
 for(j=1;j<=5;j++)
 {          k++;
            values(a,b,c,d);
            y=x;
```

```
            temp = rand () % 24; temp2 = temp + 10; temp1= temp2 - 17;
            if(temp1 > 5)z=1;
            x = rand() % 15;
            if(x>0)         x=1;
            if((x==1) && (z==1))
            {if(y==1)
            {f3++; zz[k]=c;
            }else
            {f1++; zz[k]=a;
            }}else
            {if(y==1)
            {f4++; zz[k]=d;
            }else
            {f2++;zz[k]=b;
            }}delay(500);
            ofstream out("pr3.txt",ios::beg); out<<zz[k];
            cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
            day++;          out.close();
        }}
//          cout<<"\nJuly";
        f1=72; f2=28; f3=74;  f4=26; x=0 ;
        for(i=1;i<=6;i++)
        {e=(f1+f2); a=(float)f1/e; b=(float)f2/e;
          f=(f3+f4); c=(float)f3/f; d=(float)f4/f;
         for(j=1;j<=5;j++)
         {          k++;
            values(a,b,c,d);
            y=x;
            temp = rand () % 8; temp2 = temp + 22 ; temp1= temp2 - 17;
            if(temp1 > 5) z=1;
            x = rand() % 15;
            if(x>1)         x=0;
            if((x==1) && (z==1))
            {if(y==1)
            {f3++; zz[k]=c;
```

```
            }else
            {f1++; zz[k]=a;
            }}else
            {if(y==1)
            {f4++; zz[k]=d;
            }else
            {f2++; zz[k]=b;
            }}delay(500);
            ofstream out("pr3.txt",ios::beg); out<<zz[k];
            cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
            day++; out.close();
        }}
//      cout<<"\nAugust";
        f1=70; f2=30; f3=80; f4=20; x=0 ;
        for(i=1;i<=6;i++)
        {e=(f1+f2); a=(float)f1/e; b=(float)f2/e;
          f=(f3+f4); c=(float)f3/f; d=(float)f4/f;
         for(j=1;j<=5;j++)
         {      k++;
            values(a,b,c,d);
            y=x;
            temp = rand () % 22; temp2 = temp + 7; temp1= temp2 - 15;
            if(temp1 > 5)   z=1;
            x = rand() % 15;
            if(x>1)         x=0;
            if((x==1) && (z==1))
            {if(y==1)
            {f3++; zz[k]=c;
            }else
            {f1++; zz[k]=a;
            }}else
            {if(y==1)
            {f4++; zz[k]=d;
            }else
            {f2++; zz[k]=b;
```

```
            }}delay(500);
            ofstream out("pr3.txt",ios::beg); out<<zz[k];
            cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
            day++; out.close();
        }}
//      cout<<"\nSept";
        f1=79; f2=21; f3=81;  f4=19; x=0 ;
        for(i=1;i<=6;i++)
        {e=(f1+f2); a=(float)f1/e; b=(float)f2/e;
          f=(f3+f4); c=(float)f3/f; d=(float)f4/f;
         for(j=1;j<=5;j++)
         {      k++;
            values(a,b,c,d);
            y=x;
            temp = rand () % 22; temp2 = temp + 8; temp1= temp2 - 15;
            if(temp1 > 5) z=1;
            x = rand() % 15;
            if(x>1) x=0;
            if((x==1) && (z==1))
            {if(y==1)
            {f3++; zz[k]=c;
            }else
            {f1++; zz[k]=a;
            }}else
            {if(y==1)
            {f4++; zz[k]=d;
            }else
            {f2++; zz[k]=b;
            }}delay(500);
            ofstream out("pr3.txt",ios::beg); out<<zz[k];
            cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
            day++; out.close();
        }}
//  cout<<"\nOct";
        f1=70; f2=30; f3=82; f4=18; x=0 ;
```

```
for(i=1;i<=6;i++)
{e=(f1+f2); a=(float)f1/e; b=(float)f2/e;
  f=(f3+f4); c=(float)f3/f; d=(float)f4/f;
 for(j=1;j<=5;j++)
 {          k++;
            values(a,b,c,d);
            y=x;
            temp = rand () % 20; temp2 = temp + 10 ;temp1= temp2 - 15;
            if(temp1 > 5)   z=1;
            x = rand() % 15;
            if(x>1)             x=0;
            if((x==1) && (z==1))
            {if(y==1)
            {f3++; zz[k]=c;
            }else
            {f1++; zz[k]=a;
            }}else
            {if(y==1)
            {f4++; zz[k]=d;
            }else
            {f2++; zz[k]=b;
            }}delay(500);
            ofstream out("pr3.txt",ios::beg); out<<zz[k];
            cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
            day++; out.close();
 }}
//                cout<<"\nNov";
f1=81; f2=19; f3=82; f4=18; x=0 ;
for(i=1;i<=6;i++)
{e=(f1+f2); a=(float)f1/e;b=(float)f2/e;
  f=(f3+f4); c=(float)f3/f;d=(float)f4/f;
 for(j=1;j<=5;j++)
 {          k++;
            values(a,b,c,d);
            y=x;
```

```
temp = rand () % 16; temp2 = temp + 13; temp1= temp2 - 15;
if(temp1 > 5)   z=1;
x = rand() % 15;
if(x>1) x=0;
if((x==1) && (z==1))
{
if(y==1)
{
f3++; zz[k]=c;
}
else
{
f1++; zz[k]=a;
}}
else
{
if(y==1)
{
f4++; zz[k]=d;
}
else
{
f2++; zz[k]=b;
}}
delay(500);
ofstream out("pr3.txt",ios::beg);
out<<zz[k];
cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
day++;
out.close();
}}
//    cout<<"\nDec";
f1=78; f2=22; f3=73; f4=27; x=0 ;
for(i=1;i<=7;i++)
{e=(f1+f2); a=(float)f1/e; b=(float)f2/e;
```

```
 f=(f3+f4); c=(float)f3/f; d=(float)f4/f;
for(j=1;j<=5;j++)
{         k++;
          values(a,b,c,d);
          y=x;
          temp = rand () % 15; temp2 = temp + 13; temp1= temp2 - 14;
          if(temp1 > 5) z=1;
          x = rand() % 15;
          if(x>1) x=0;
          if((x==1) && (z==1))
          {if(y==1)
          {f3++; zz[k]=c;
          }else
          {
          f1++; zz[k]=a;
          }}
          else
          {
          if(y==1)
          {
          f4++; zz[k]=d;
          }else
          {
          f2++; zz[k]=b;
          }}
          delay(500);
          ofstream out("pr3.txt",ios::beg);
          out<<zz[k];
          cout<<"Day = "<<day<<"  Probability for tomorrow = "<<zz[k]<<endl;
          day++;
          out.close();
}}
break;
```

case 2 and 3 have a similar application of markov chain approach to find probability of forest fire in those particular regions.

```
case 4 : clrscr();
         cout<<endl;
         cout<<"Change Point Detection"<<endl<<endl<<endl;
         int ab=0;
         float sum,mean;
         for(i=1;i<362;i++)
         {
                 if(ab==0)
                 {
                 sum = zz[i] + zz[i+1] + zz[i+2] + zz[i+3] + zz[i+4] + zz[i+5];
                 mean =  sum/6;
                 if(mean > 0.4)
                 {
                         cout<<"Change Point at "<<i<<" Day"<<endl;
                         ab=1;
                 }}
                 else
                 if(ab==1)
                 {
                 sum = zz[i] + zz[i+1] + zz[i+2] + zz[i+3] + zz[i+4] + zz[i+5];
                 mean =  sum/6;
                 if(mean < 0.25)
                 {
                 cout<<"Change Point at "<<i<<" Day"<<endl;
                 ab=0;
                 }}
         }
         getch();
         break;

case 5 : exit(0);
}
```

```
}
getch();
}
```

- **MATLAB code**

```
clc;
clear all;
b=zeros(360,1);
for i = 1 : 1 : 360
    fid = fopen('PR3.txt','r');
    a=fscanf(fid,'%f');
    if(a>0.5)
        stem(i,a,'r');
    else
    stem(i,a);
    end
    b(i,1)=a;
    hold on;
    pause(0.4);
    status=fclose(fid);
end;
figure ;
plot(b,'g');
```

4.5 Working

In this project we use randomized sampling approach to get data. First we select the region from whose data we wish to see and plot on the graph. Next Markov chain Monte Carlo approach is applied on the various parameters used in the program to get the value of probability for forest fire to happen on the next day. These values are simultaneously plotted on the graph. At the end we get the change points for the entire year for a particular region and also another graph used to analyse those change points. These change points along with the graph help us find out particular periods in a year in which different regions are prone to forest fires. The change points as well as the period for forest fires to occur for each region varies depending on the parameters.

Figure 4.4: Starting of the program

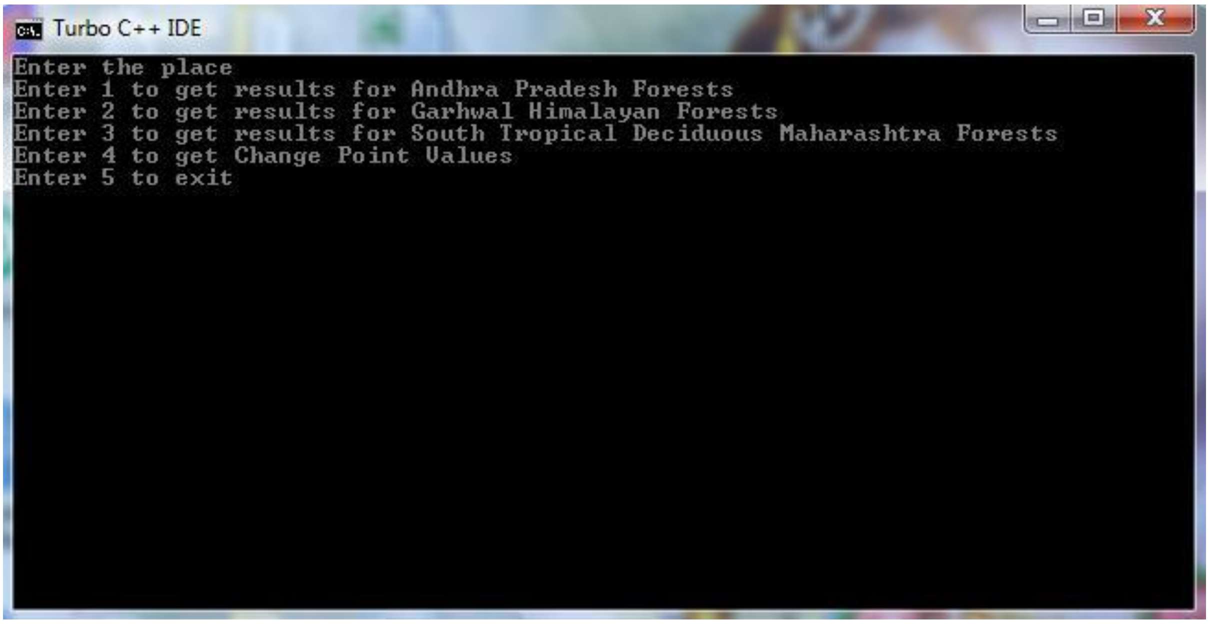

Figure 4.5: Options

Here the program gives the user the option to choose to get results from the given 3 places i.e. Andhra Pradesh Forests, Garhwal Himalayas and the South Tropical Deciduous Maharashtra Forests. After we select a place from the given options we start getting the probability of fire for each day.

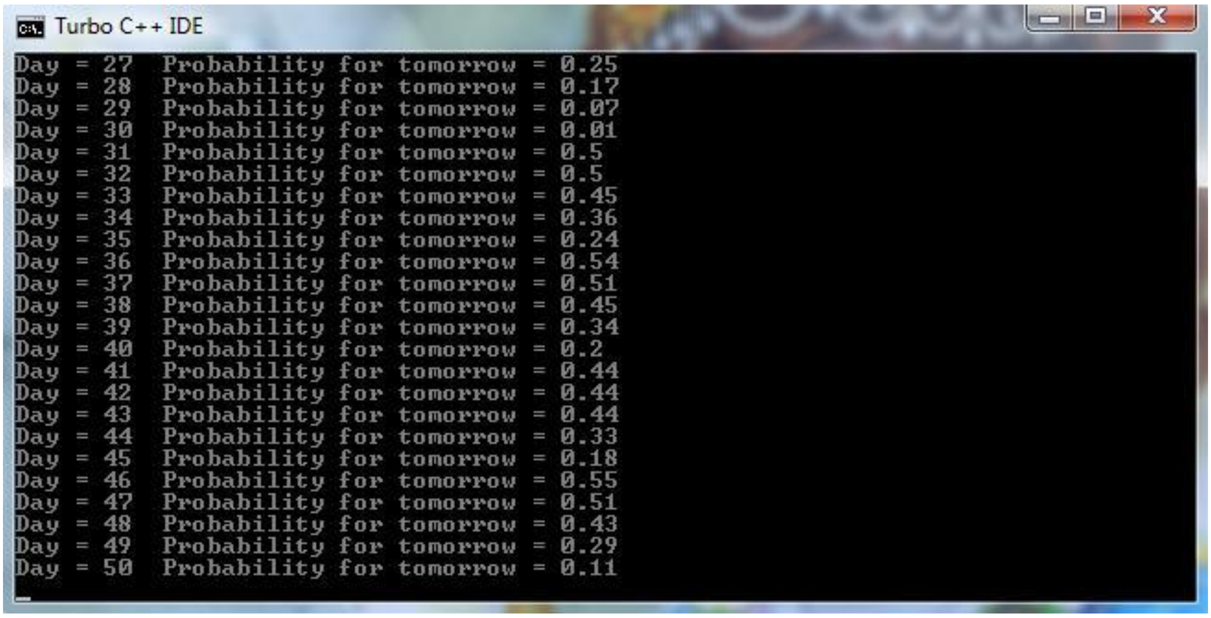

Figure 4.6: Probability results

Once we choose an option we start getting probability for each day which is calculated using Markov chain Monte Carlo approach. The probability helps us find out whether a fire will be there on the next day or not. The calculation of this probability is based on parameters like temperature, smoke detection and previous day results.

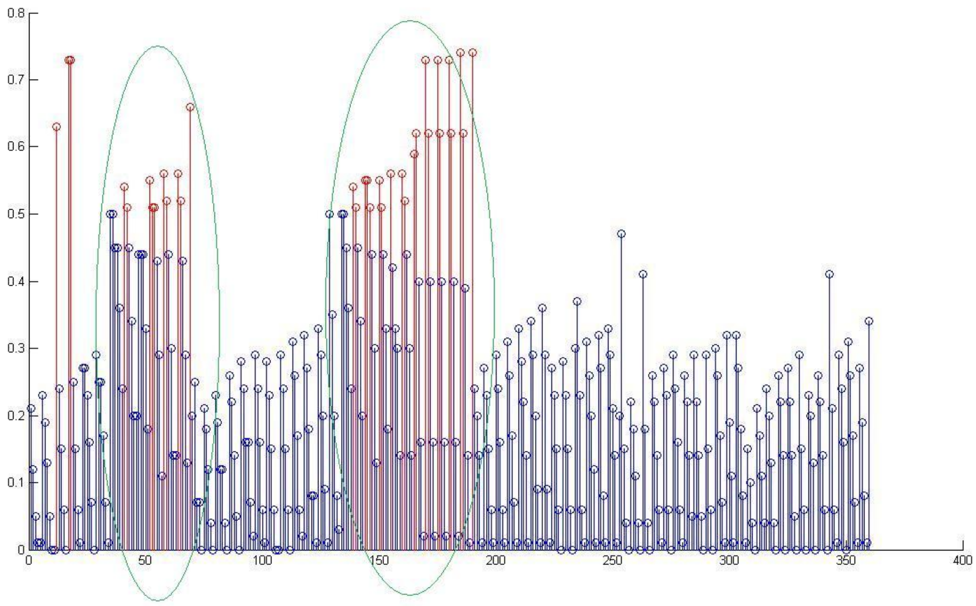

Figure 4.7: Graph for probability of each day

The graph here is produced in MATLAB simultaneously. The graph has days on the x-axis and probability that is calculated on y-axis. Each stem represents the probability of fire on the next day. The lines represented by red display an alert signal as the probability of fire as calculated by Markov chain Monte Carlo approach is very high. Also continuous red lines tell us that in which months the probability of forest fire to happen is the highest. These months are encircled in the above figure. According to the above figure in the given region the months February (red lines around 30-61 days) and May and June (red lines around 125-170 days) are the months when the probability is very high.

4.6 Change Point Detection

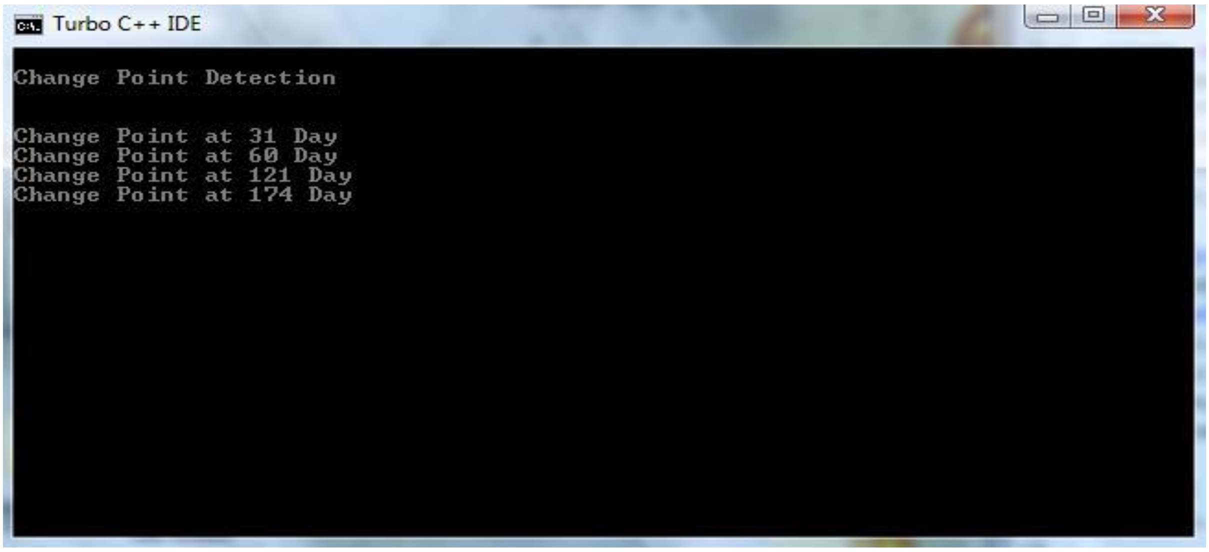

Figure 4.8: Change Points

After getting the probability for forest fire to happen for each day and getting the desired graph now we select the change points detection option to get the change points represented in the graph. These change points represent the positions in the graph where change took place.

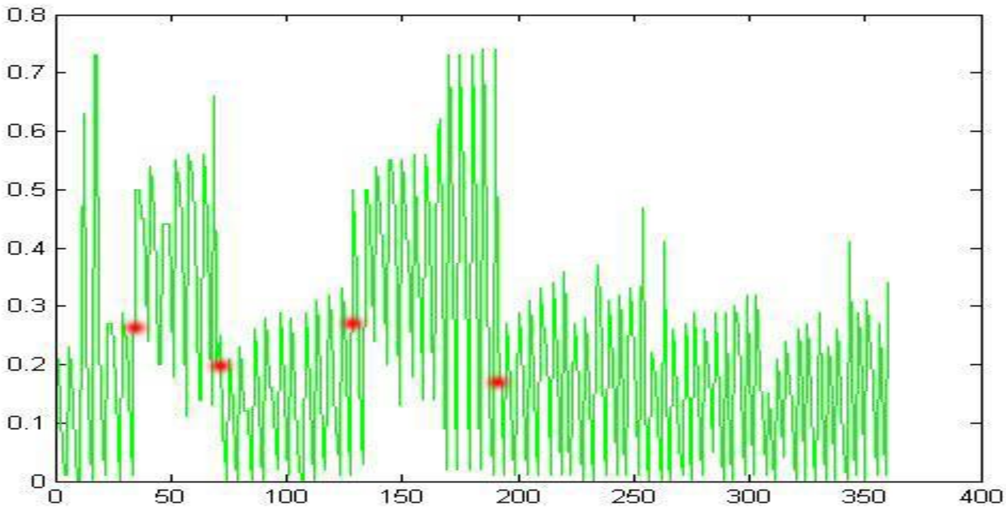

Figure 4.9: change points graph

In this graph change points are represented by the red dots. These are the points of days which marked the change in the graph. The value of probability after these change points either increased or decreased. The area of graph between the change points is used to represent the time of the year in which the probability of forest fire was very high.

The change points we get from our program using the Markov chain Monte Carlo approach are close to the ones mentioned by previous data of the forest fires that is considered in the program. Also the months in which a change is depicted in the graph is similar to the change observed according to the given data.

Chapter 5

5. Conclusion and Future Scope

This system can be used to prevent enormous damage from one of the major natural disasters i.e. forest fires. In this system, a wireless sensor network is utilized as a weather station network, sending weather information and disasters' alerts. The weather information is analysed by using various techniques to announce the disasters' alerts. This system can be further combined with a geographic information system or GIS. A geographic information system is a system designed to capture, store, manipulate, analyse, manage, and present all types of geographical data.

Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred into a digital medium through the use of a computer-aided design (CAD) program, and geo-referencing capabilities. With the wide availability of ortho-rectified imagery (both from satellite and aerial sources), heads-up digitizing is becoming the main avenue through which geographic data is extracted. Heads-up digitizing involves the tracing of geographic data directly on top of the aerial imagery instead of by the traditional method of tracing the geographic form on a separate digitizing tablet (heads-down digitizing).

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