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LANDSLIDE SENTINEL

A Life Saving Alert System

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Abstract: Landslides are a significant natural hazard in mountainous regions, posing threats to human life, infrastructure, and the environment. Traditional Landslide detection methods often rely on manual observations and post-event analysis, which are insufficient for real-time alerts. The Landslide Sentinel system addresses this gap by offering a real-time, automated, auditory and visual alert mechanism using a combination of Impact sub-sensors, Gyroscope sub-sensors, Proximity Ultrasonic sub-sensors, Navigation trackers and IoT technology.

Index Terms – Impact sub-sensors, Resistive heating, Gyroscope sub-sensors, Proximity Ultrasound sub-sensors and NavIC Trackers.

1) INTRODUCTION

Landslides have always perished the lives of living beings since ancient times, but are occurring more frequently now due to a variety of reasons listed below-

1. Soil Liquefaction- A cohesionless, water logged soil loses strength and thus behaves more like a liquid than like a solid.
This is called the Janssen effect, where a pile of rocks that seem solid at a moment, transition into more like a liquid phase when they are slightly shaken or their force chains are broken. [1][2]
2. Seismic Zones - Mountainous regions are generally seismically active. Any earthquake can shake the rocks who don't have enough binding, to loosen and fall apart, causing a landslide.
3. Tunneling - Increasing tunneling activities inside the mountains cause a major portion of the mountain to be hollowed out. This causes a large mass of the mountain to redistribute among the remaining portion, causing instability.
4. Freezing - High rainfall, especially at Northeastern India causes water to seep deep into the cracks and crevices of some rocks. When this water freezes, it expands, so it either breaks the rock or increases the cracks.
Breaking off of rocks from their places causes them to slide.
5. Global warming - When an ice sheet on a mountain melts, it causes sheet erosion which drags away with it, a huge

amount of soil. Deforestation and other anthropogenic activities in mountains, has also increased

chances of landslides.

This paper presents a solution which will detect, and alert the nearby citizens about the possible occurrences of a landslide. It cannot pre-detect a landslide, but will alert the potential victims as soon as landslide occurs. Sentinel means watchman or a guard, so this Landslide Sentinel will serve as a tool to alert the nearby citizens about the just occurred landslide.

Abbreviations, Meanings and Acronyms

IoT	- Internet of Things
LSS	- Landslide Sentinel System
S1	- A collection of Impact sub-sensor 1, Gyroscope sub-sensor 1, Proximity Ultrasound
sub-sensor 1 and	
	NavIC Tracker 1
S2	- A collection of Impact sub-sensor 2, Gyroscope sub-sensor 2, Proximity Ultrasound
sub-sensor 2 and	
	NavIC tracker 2
LED	- Light Emitting Diode
Threshold mass value	- Minimum mass value, which if put on the impact sub-sensor, will activate it
Threshold distance	- Minimum distance, which if travelled by sensor due to landslide, will activate it.
Threshold movement	- Minimum movement of surrounding things, which if captured by the proximity
ultrasound sub-sensor,	
	will activate it.
NavIC	- Navigation using Indian Constellation (India's own Navigation system that is made
available all over	India by NavIC Satellites) ^[3]

2) CONSTITUENT MATERIALS OF THE SYSTEM

- Relay Module
close the contacts of
- An electromechanical device that uses an electric current to open and a switch.
- YL-99 sub-sensors
usable signals. They
are used two times in this solution model, placed inside S1 and S2,
where S1 is placed
at higher altitude on the mountain than S2.
- Piezo Buzzer
- It provides an auditory alert with variable and controllable beeping rates.
- LEDs
- Offers visual alerts.
- Arduino Uno
- Central microcontroller for this LSS
- Batteries or power cables
- For power supply.
- Nichrome wire
- Used to ignite smoke bomb through resistive heating.
- Breadboard
- For connecting various components of the LSS.
- Jumper wires
- For connecting various components of the LSS.
- Resistors
- Control current flow and preventing the LEDs from burning out.
- NavIC Trackers
- Detects the original position and also the change in position.
- Gyroscope sub-sensor
or tilting movements.
- It measures angular velocity and any change in it, caused by shaking
- Proximity sub-sensor
emitting ultrasound
- It detects the presence, absence or any displacement in objects by waves and measuring the time taken for reflected waves to reach it back.
- Red Smoke Bomb
fumes when ignited.
- It is made up of red coloured ignitable material which will release red

3) CONSTRUCTION AND IMPLEMENTATION

1. Sensors (S1 and S2) sensors viz. Impact sub-proximity sub- sensor. They too deep nor too many sensors may be
 - One LSS sensor will be an interconnected combination of 4 sub-sensor, NavIC tracker, Gyroscope sub-sensor and Ultrasound sensor, will be implanted on the surface of landslide prone mountains, neither superficial. Here, S1 is placed at a higher altitude than S2, although Buzzers may be placed at the top of highway lights.
2. Network of Sensors Each sensor will have
 - The LSS will consist of a network of many interconnected sensors. 4 internal sub-sensors as mentioned above.
3. Main Controlling hub landslide prone control center may
 - The main controlling center will be placed at a safe location away from areas, because it must not get damaged during landslide. A suitable also have employees to monitor the proper functioning of this system.
4. Red smoke bomb contact with a
 - It will be placed on a tower at a place on a mountain. It will be in close nichrome wire, which will ignite the wick of this smoke bomb.

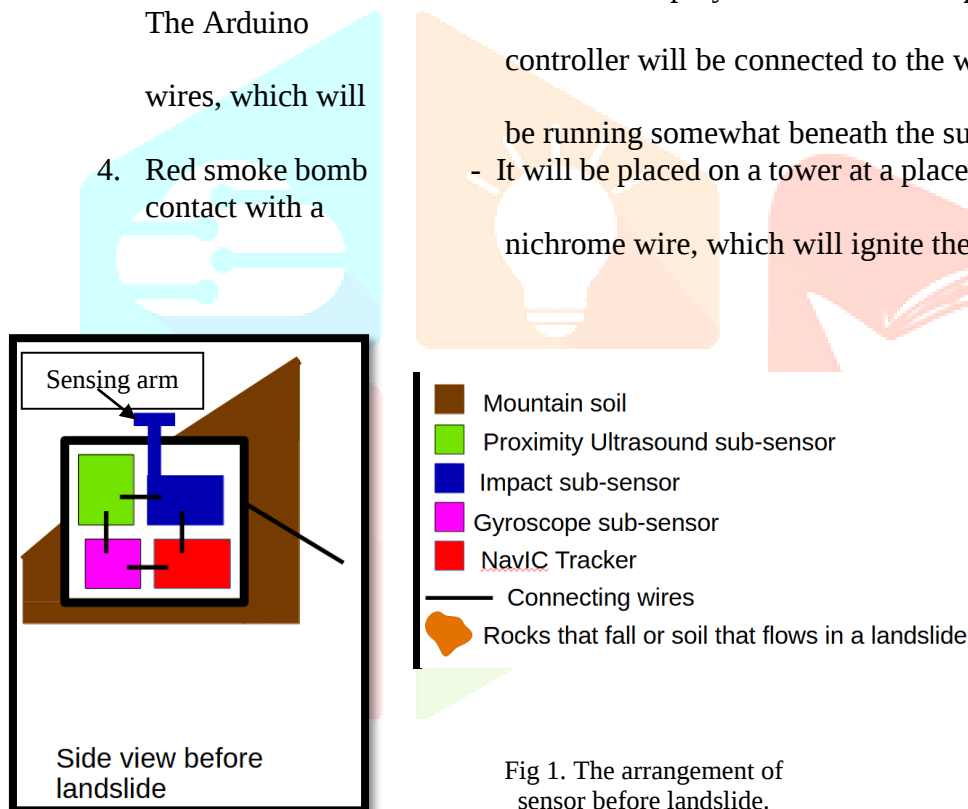


Fig 1. The arrangement of sensor before landslide.

4) WORKING MECHANISM

1. S1 Detection-
 - Huge masses, consisting of rocks and soil, fall on the sensing arm of the impact sub-sensor, triggering it if the mass that has fell exceeds the threshold mass value of the impact sub-sensor.

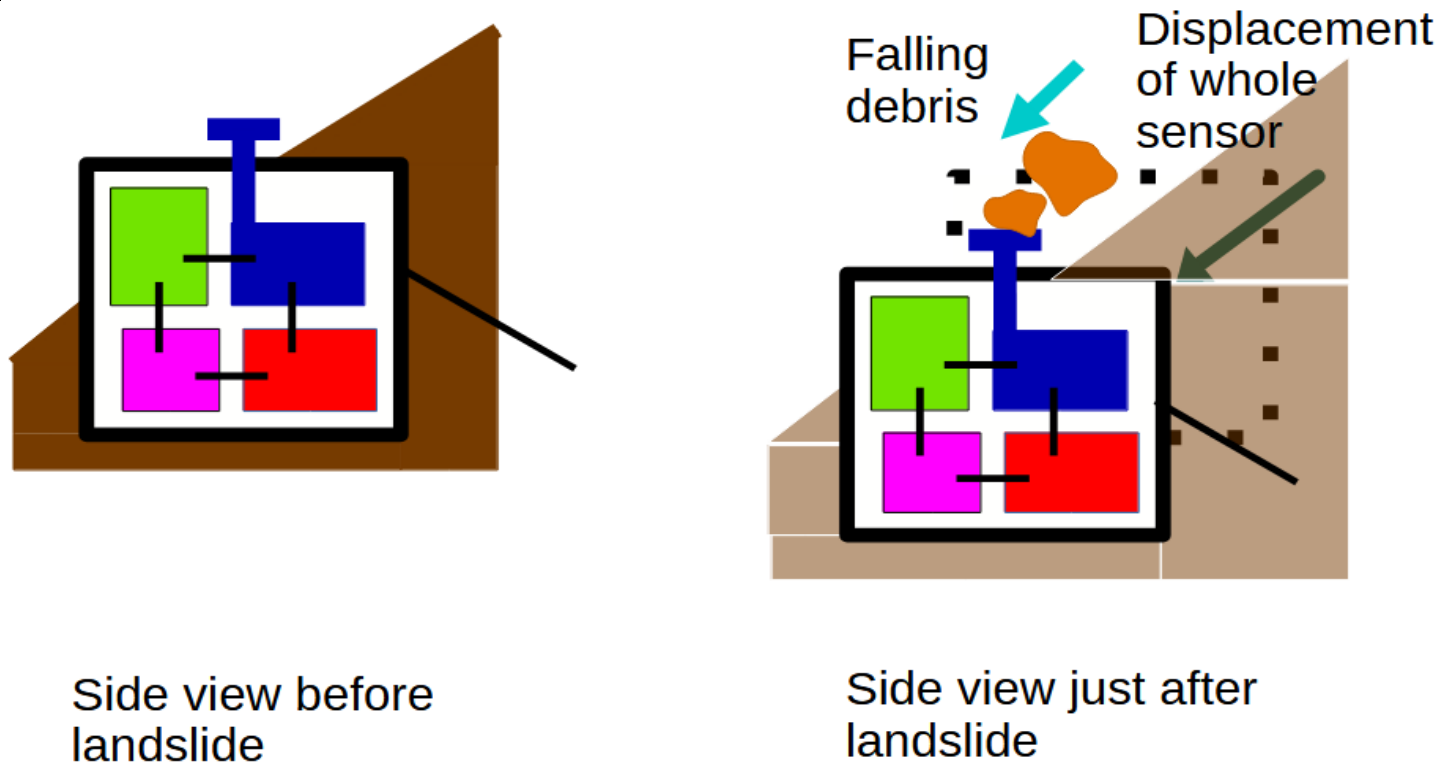


Fig 2. Shows how falling debris on sensing arm of impact sub-sensor will activate it.

- The landslide will carry away with it the whole sensor. In this case, the NavIC tracker will detect the change the position of the sensor. If the displacement is greater than the preset threshold distance, it will get activated.

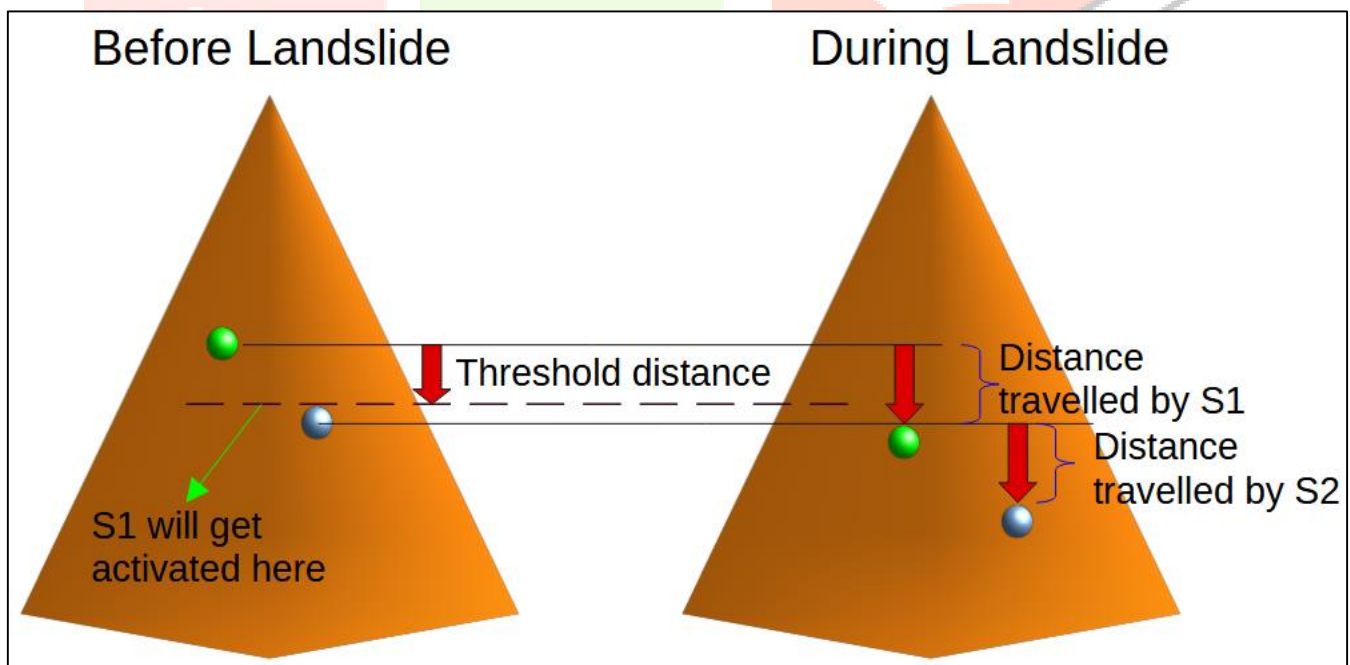


Fig 3. How changes in position of NavIC sensors installed inside sensors will help detect landslide Although it particularly mentions threshold distance for S1, the same is applicable for S2, and it too will get activated as soon as it exceeds its threshold value.

- The Gyroscope sub-sensor detects the shaking and tilting movements caused during a landslide, and gets activated.
- As landslide will carry away with it the whole sensor, relative positions of objects surrounding the sensor may change. This will be sensed by the proximity ultrasound sub-sensor, which will get activated, if the movement captured exceeds the threshold movement value. For example, before the landslide, any tree or boulder in front of the sub-sensor may

be set as a reference. Just during the landslide, both the whole tree or boulder and the sensor will begin to move. In this time, the tree may not be exactly at the same relative position as it was earlier. It may have shifted sideways. This change is detected because the time taken for reflected ultrasound rays to come back will be changed due to change in relative position.

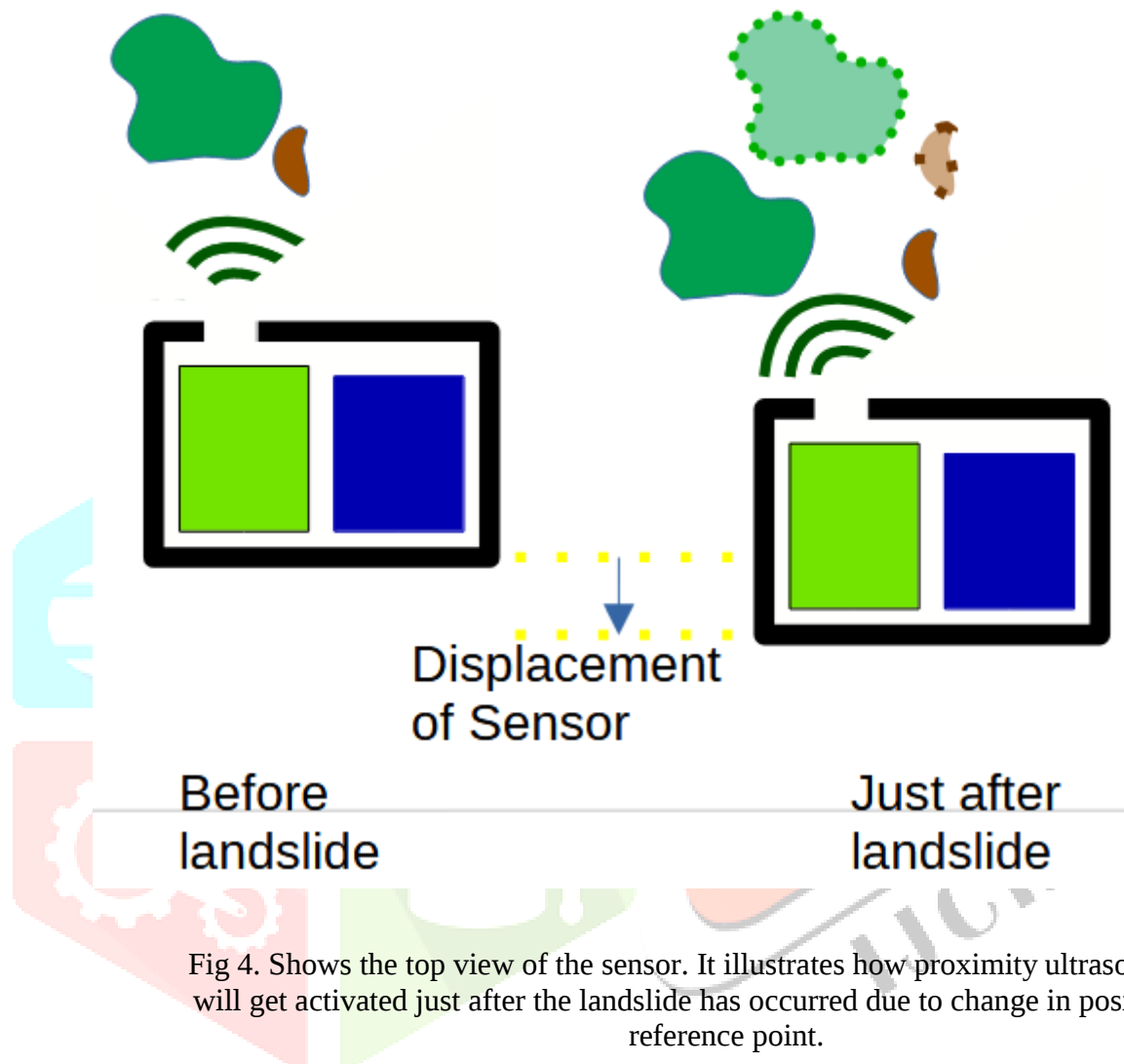


Fig 4. Shows the top view of the sensor. It illustrates how proximity ultrasound sensor will get activated just after the landslide has occurred due to change in position of the reference point.

- All these sub-sensors, as mentioned above, will get activated just after landslide has occurred. All the sub-sensors will initiate the following alert mechanism. However, leaving some room for technical malfunctions, it is guaranteed that at least one activation signal always and always reaches the Arduino board, even if rest all three stop working. This is the reason that our system relies not on one or two, but on four different sub-sensors to initiate an alert mechanism separately, because some may not work and due to their malfunction, system must not miss a deadly landslide.

2. Alert Mechanism for S1-

- As soon as any one of the 4 sub-sensors of S1 gets activated, following actions will take place.
- Activation of relay allows current to flow through the nichrome wire. Due to resistive heating, it heats up bright red and ignites the wick of red colored smoke bomb. The smoke bomb releases red fumes, which are noticeable in the sky from a considerable distance
- Buzzer starts beeping with a low frequency to indicate that the landslide is still in its initial phase
- A warning message is sent via a communication tower to all the registered mobile numbers of nearby citizens along with those who are driving their vehicles on the road or are present

on the road. They will have a small amount of time to evacuate themselves fast from the probable landslide.

- The toll plaza closes, preventing further entry of vehicles or persons onto the road

3. S2 Detection-

- As the landslide gains speed and continues to move downhill, it activates different sub-sensors present inside S2, with the same mechanism as described above.
- Impact sub-sensor will get activated.
- NavIC trackers will detect displacement of S2.
- Gyroscope sub-sensor will detect shaky movements.
- Proximity ultrasound sub-sensor will detect movement caused by landslide.
- However, till this time, the landslide has become more dangerous, it has collected much debris in its way and has gained more speed due to the slope of the hill. So, the alert mechanism is slightly different for S2, to indicate the severity of approaching landslide.

4. Alert Mechanism for S2-

- As soon as any one of the 4 sub-sensors of S2 gets activated, following actions will take place.
- Highway lights will begin to blink, to alert the people present on the road, indicating that the landslide is in close proximity and there are high chances for landslide to occur.
- The frequency of beeping of the buzzer increases to indicate increased severity of landslide.
- A Danger message is sent as done before.
- Emergency services will get activated, the LSS will send information regarding the high chances of landslide to helicopter bases, asking it to get prepared.

5) FLOWCHART OF WORKING MECHANISM AND EXAMPLE OF TEXT MESSAGE

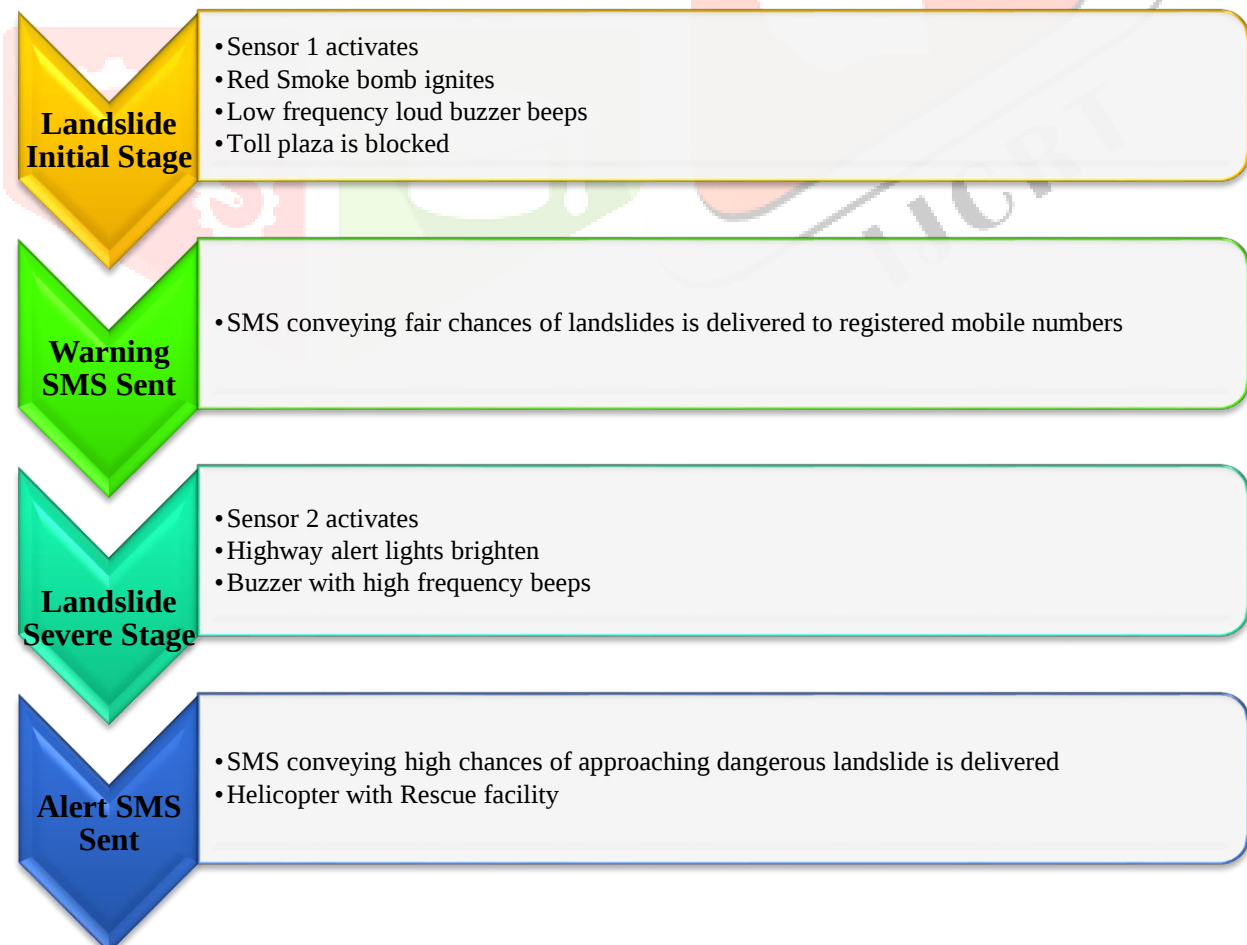


Fig 5. Flowchart of Working Mechanism

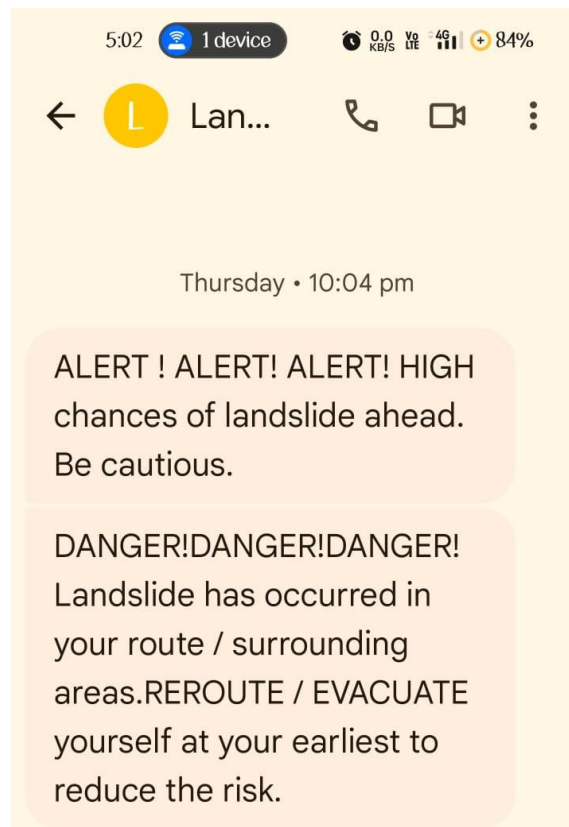


Fig 6. SMS alert on registered mobile numbers

6) DISCUSSIONS AND REASONS FOR CONSIDERATIONS

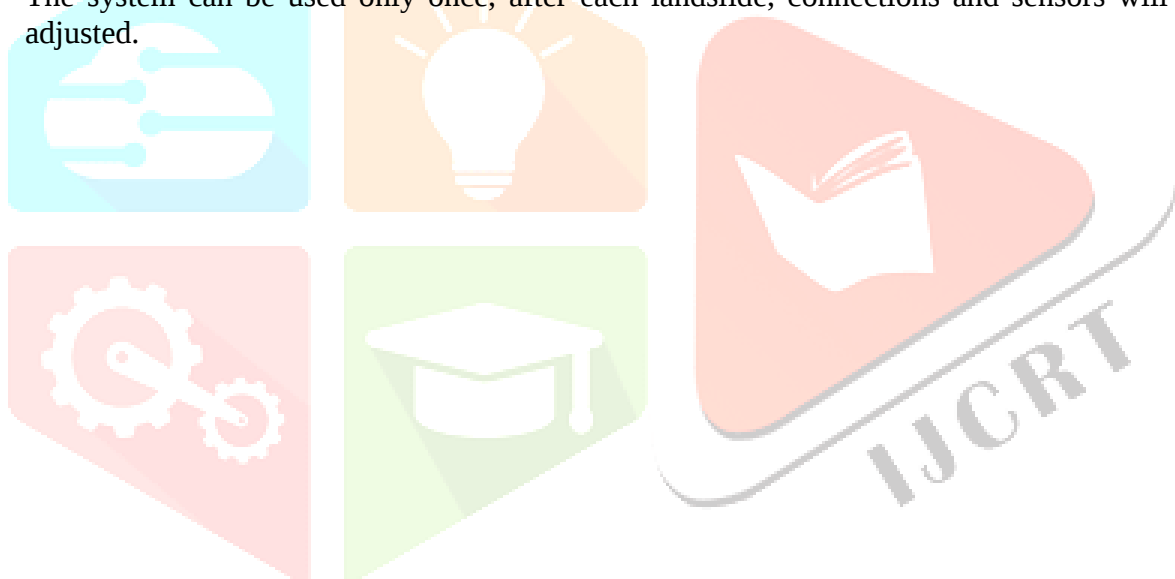
1. Red colored smoke bomb is used because red color scatters the least. According to Rayleigh Law of scattering, the color red, with the longest wavelength in the visible electromagnetic spectrum, scatters the least and thus is visible from a long distance.
2. Both the impact sub-sensors will have a threshold mass value of impact set into them. This means they will get activated only after a certain magnitude of force (due to weight of landslide) is applied on them. This prevents the sensors from unnecessary activation which may be caused if any small piece of rock or tree falls on them (No landslide has occurred). Since the mass of rocks or debris that flow in a landslide is huge, the threshold mass value is also set huge.
3. To receive the alert messages of the landslide, the citizens living in the landslide prone hilly areas may register their active phone numbers beforehand. Also, the text messages are sent to those numbers who will get registered when the citizens driving the vehicles cross the toll plaza. (The FASTag system)
4. Since the mountain ranges in India are too long, for example The Sahyadri, The Himalaya (2400 km), the sensors will be placed only in close proximity of human settlements and hilly roads, where landslides are likely to occur.
5. The only part of the sensor that will be above the mountain soil will be the arm of the impact sensor which will sense the impact of landslide rocks and the mouth of the proximity ultrasound sensor. This is done because the sensor can gather information about the change in relative positions of surrounding objects only if it is placed somewhat above the level of the mountain's surface.
6. Like the impact sub-sensors, threshold distance values and threshold movement values are set into the NavIC trackers and proximity ultrasound sub-sensors, respectively. This is done because we don't want our system to get unnecessarily activated by any small movement of the sensor or the reference point, caused due to normal winds (not a landslide). We will also have to code the proximity ultrasound sub-sensor in such a way that it won't get initiated even if any animal passes in front of it.

7) ADVANTAGES OF LSS

1. This system can be used to detect avalanches and alert the nearby citizens.
2. This system alerts not only normal humans but also the physically challenged ones. The buzzer alerts the blind and the dumb while the smoke bomb alerts the deaf and the dumb.
3. No human intervention in LSS erases chances of human errors.
4. Decreases human casualties to a great extent by alerting them just a few seconds before landslide hits the area.
5. Backup plan helps in case the main plan fails to initiate the LSS.
6. SMS alerts are sent to a large number of people at the same time, reducing the time.
7. Even if one or two or three of the sub-sensors malfunction, the system stays responsive. Atleast one signal is guaranteed to reach the Arduino board, if detected by the sub-sensors.

8) DISADVANTAGES OF LSS

1. The efficiency of sending SMS alerts to mobile numbers depends on the local weather conditions. Usually bad and extreme weather conditions at hilly areas prevent fast communication.
2. The system detects landslide just as they have occurred, but is unable to detect or predict landslides in advance, which may further help to save more lives.
3. Mild air pollution may occur as soon as the red colored smoke bomb is ignited.
4. Sometimes, signal may not reach from a particular sensor to the Arduino board if the connecting wires break. However, if rest all connecting wires are intact, their signals will initiate the alert mechanism.
5. The system can be used only once, after each landslide, connections and sensors will have to be adjusted.



9) REAL LIFE MODEL DEMONSTRATION



Fig 7. Arduino Board with all the connections

1. Red ellipse - SIM GSM Module (although this model sends SMS to only one mobile number, in practical and wider implementation, many SMS may be sent to the potential victims simultaneously)
2. Green ellipse - Piezo Buzzers
3. Yellow ellipse - Programmed Arduino Microcontroller
4. Pink ellipse - Relay module



Fig 8. Smoke bomb tower, not ignited

- | | |
|----------------------|--------------------------|
| 1. Sky blue ellipse | - Red colored smoke bomb |
| 2. Navy blue ellipse | - Nichrome wire |



Fig 9. Ignited red smoke bomb



Fig 10. Sensors

10) FUTURE SCOPE AND UPGRADATIONS

1. A Mobile application may be developed for better real time alerts.
2. Ingredients of the red colored smoke bomb may be made eco-friendly so as not to cause air pollution.
3. System may be made wireless.

11) WHY THIS LSS IS REQUIRED?

To prevent social, economic and environmental damages caused by landslide.

12) REFERENCES AND COURTESY

1. [1] https://en.wikipedia.org/wiki/Soil_liquefaction
2. [2] <https://youtu.be/F2M2aRXI8lc?si=6ge47FnoT9PnuIJb>
3. [3] https://en.m.wikipedia.org/wiki/Indian_Regional_Navigation_Satellite_System

Courtesy of all images to Yatharth Janaikar

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