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Design Of Smart Shoe System To Avoid Human Fall

Prabhakar Dorge[1], Bharati B. Sayankar[2], Prerana Wankhede[3], Sachin Nagmote[4], Dinesh Wankhede[5]
[1]Department of Electronics & Telecommunication Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, India
[2]Department of Electronics and Communication Engineering, Tulsiramji Gaikwad - Patil College of Engineering & Technology, Nagpur, India
[3]Department of Electronics & Telecommunication Engineering, G. H. Raisoni College of Engineering and Management Nagpur, India
[4,5]Department of Electrical Engineering, St. Vincent Pallotti College of Engineering and Technology, Nagpur, India

Abstract *:To enhance the quality of life for elderly and physically challenged individuals and reduce the risk of falls, this research proposes a novel machine learning-based approach. Our system prototype includes a smartphone and a smart shoe with four pressure sensors and a Wi-Fi communication module. Fall detection is achieved through a decision tree algorithm, which segregates normal and cautious gait values and issues alerts via messages, emails, or calls when cautious gait is detected. This innovative system has the potential to significantly decrease the likelihood of falls among elderly individuals, enabling them to live more independently while safeguarding their well-being. Because of the quick response, this system provides more peaceful to working individuals for their parents.*
Keywords:*Prediction, Gait, Wi-Fi communication, Decision Tree Method, Arduino*

1. INTRODUCTION

Gait abnormality causes huge health problems in the people all over the world this injury can result in physical inactivity, poor quality of life and sometimes death [1]. Many research projects have already been taken place on the human gait analysis which says that by the end of 2050 one in five in worldwide will be age 65 or over can definitely face this problem. Falls are common in elderly approximately 30-50% of elderly population faces it every year. In the age group of 70 to 75 year's its 30% per year. Increase in age results in unintentional falls which is a matter of concern[2]. Falls causes both physical and mental injury in elderly people that they need to be depends on someone else. Once fall happen it is necessary to provide immediate medical assistant in a golden hour before injury become severe so this system will provide immediate alert to the caregiver and family members so that medical care should be provided as soon as possible [3].

Falls results in social as well as economic impacts and it has been estimated that it will be 15% of total population worldwide at the end of 2050 and the percentage of fall accident is more in the people who leave at home with 40 percentages more than one. Most of the falls occur during the activities of daily leaving which involves small loss of balance while walking and standing [4]. Falls can result in severe injuries that are leading to the inactivity of whole body which may result in increased isolation and health deterioration. These incidences may cause significant economic expenses hence we build a mobile system which uses smart shoe sensors to predict falls and smartphone to alert the user of a fall before it happens. Automatic fall detections currently are classified into 3 types on the basis of sensors; they are video- based, wearable sensor based and acoustic based methods. Also, many sensors depend upon significant installations and trainings which lack to give appropriate outcome and hence contribute to a poor system. Nowadays, we can use smartphone-based fall detection systems as they are portable anywhere. This system detects cautious gait patterns and whenever needed warns the user by giving audio messages or vibrations and calls the caretaker if the user falls with the exact location of him. Video based methods uses high frequencies to detect cautious gait, also expert calculations are not cost recommended whereas wearable sensors-based methods require extra sensors for motion sensing on foot, waist and wrist which includes gyroscopes, strain gauges, accelerometers etc. They measure various attributes of human walking patterns [5]. These produce various outcomes which are used for classification of gait pattern. In this paper we are considering smart phone-based fall risk detection with shoe-worn sensors. As smart phones are very much portable and have the ability to work anywhere. With the help of growing mobile technology, the smart phone-based fall risk detection can be used anywhere. These systems have become more popular because of the development of computational abilities. Hypothetically, the forces sensor-shoes can also analyses cautious patterns. Hence to develop it practically, we are focusing to make smart shoe for fall risk prediction, detection and for analysing gait. Hence, we put forward this system which alerts the user also gives appropriate information like location, cautious walking patterns to the caretakers [6].

1.1 Theory of Walking

Knowing the standards for normal walking is necessary to comprehend or identify abnormal gait patterns. Normal walking is produced by balanced muscle contraction, joint movement, and sensory perception. People who are healthy can stand up straight and alter their position to find the balance and stability they want while walking on two legs[7]. The arm swing has an impact on the pelvis, causing it to rotate and inclination periodically. Additionally, the angles at the ankle, knee, and hip shift as you move to improve coordination. As a result, the regular gait is periodic and characterized by balance and coordination [8]. A set of parameter results from a quantitative investigation of gait stability and gait symmetry have been obtained when walking speed decreases with age and has an impact on comfortable walking pace. Based on this, we created an early warning system that predicts risk of fall while walking [9].

1.2 Fall Risk Factor

There are several factors in various categories which can result in falls according to some researcher it can be categorised into intrinsic and extrinsic factors some describe them in various general terms which are as given here. Biological characteristics include impaired vision, balance and gait issues, muscular imbalances, orthostatic posturing, and postural instability. Fear of falling, use of drugs, lack of sleep, poor cleanliness, inactivity, and mental health. Age, gender, and history of falls. Environmental factors: surface, damp flooring, barriers, and ascent.

1.3 Mechanisms of fall

For old and disabled people even, a small cause can result in fall. This cause can be any of these factors.

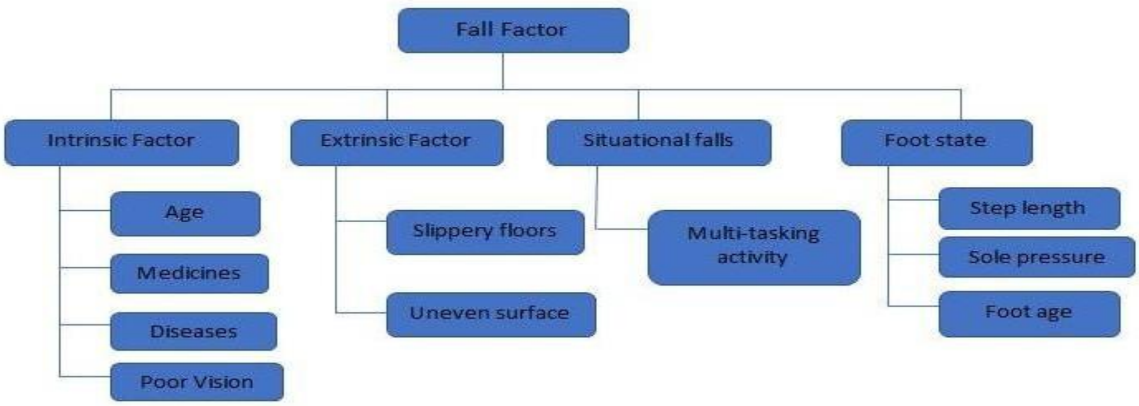

Fig. 1 Mechanisms of Fall

The nervous system which helps in balancing of a human body. These factors include the issues that weaken this nervous system, like- Growing age reduces the reaction time also while stepping it decreases the strength of muscle power. If the medicines are taken more than the prescribed quantities the risk of fall can increase much more. The usage of benzodiazepines results in hip fractures and night falls. Also, consumption of drugs like sedatives, dioxins etc. can be the reason.People who are suffering from vascular diseases like arthritis, thyroid disorders, diabetes, cardiac diseases etc. would be the reasons to fall.cataracts, age related muscular of eyes causes fall. E. Immobile people fall more than relatively active ones [10].Environmental and external factors which needs greater postural control like walking on uneven surfaces, slippery floors, in poor lighting and in unfamiliar environments like relocating to new houses. It also includes unexpected hitting to an object.Some multitasking activities like walking while talking and decisions like hasten to washrooms, lifting a phone call in hurry [11].The state of the foot represents the comportment of the foot in the walking pattern which helps to state the stability of the users. By identifying state of the foo We can figure-out the pre-fall condition and hence evaluate the risk of fall. Some papers focus on factors such as step length, sole pressure, foot age, single and double support time. But in our paper, we are mainly focusing on the sole pressure exerted on the foot [12].

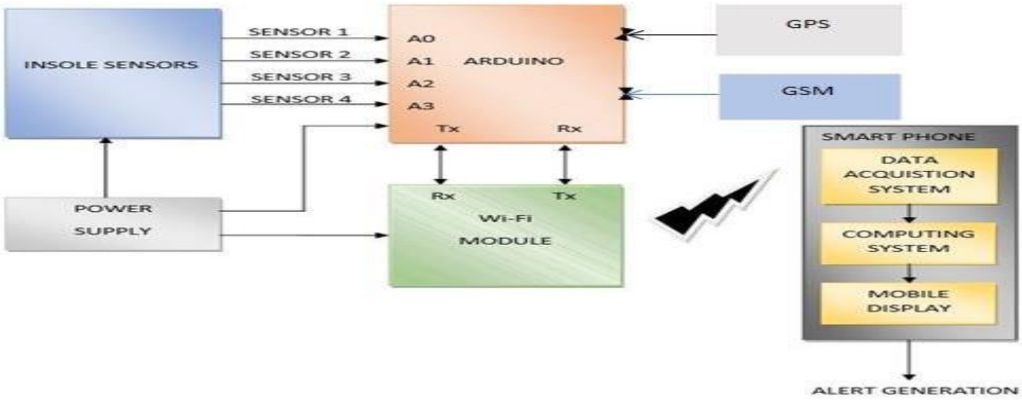

Fig. 2 Block Diagram of proposed system

2. METHODS

The design for a realistic smart shoe for human fall detection assessment tool must involve modules such as Smart Shoe, GPS, Smartphone, Pressure Sensors and Communication module, FSR402 Force Sensor, ESP8266 Wi-Fi module, Arduino UNO and Serial monitor, Decision Tree Method. In Smart Shoe, there is basically an insole application, a digital sensing insole with pressure sensors [13].

In (Fig. 2) there are two main parts of this framework, smart shoe and smart phone from which the smart shoe includes pressure sensors and communication module. Pressure sensors utilizes the pressure exerted on the foot while strolling. To survey the stress dissemination, here we have used four pressure sensors which are put on shoe innersole. From that four force sensors, two are inserted in the front side of the toe and the other two are in the back side of the toe. The communication module is composed of two components which are Arduino UNO and Wi-fi module with electric supply. The Arduino is an open-source platform with a simple input and output system. In this module the signal is first amplified and then transfers the amplified signal to the smart phone through the Wi-Fi communication module [14]. For processing the data, there are two different software tasks in the communication module, from which one is for Arduino and another is for android. We have programmed an Arduino to read signals from the pressure sensors whose values are in the form of analog signals and to form an envelope of the data that converts analog signals into digital form[15]. Eventually Arduino sends those envelopes of data to the smartphone. Smartphone collects pressure data to record different walking patterns for the same subject over a span of time to identify the abnormality in a strolling pattern. Hence to identify if the gait is cautious or not, we have used the Decision Tree Method. whenever an imminent fall occurs it gives the exact location of the user with the help of GPS and calls the caretaker.

3. RESULTS

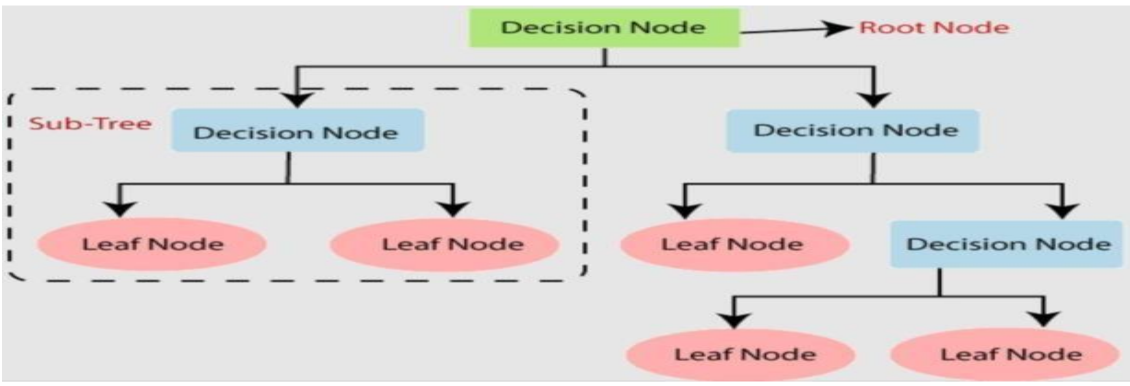

Fig. 3 Working of Decision Tree algorithm

In this paper, we have used the Decision Tree algorithm to classify the data. It is a popular machine learning algorithm as it takes less effort for data preparation, hence its time complexity is less as compared to all algorithms, also it gives a good accuracy of 91%. In this algorithm, it comprises branches and nodes. The nodes are connected by branches. The top nodes of the decision tree are known as root-nodes, which consists of all the training data. All these root-nodes are called decision nodes. These decision nodes are further split into two classes also called as sub-tree by comparing the normal and abnormal values. One, the leaf-nodes or terminal-nodes which are not further divided line and the other is decision-nodes which are then divided again as above [15, 16].The whole set-up of our prototype works according to the following flowchart as shown in Fig. 4.

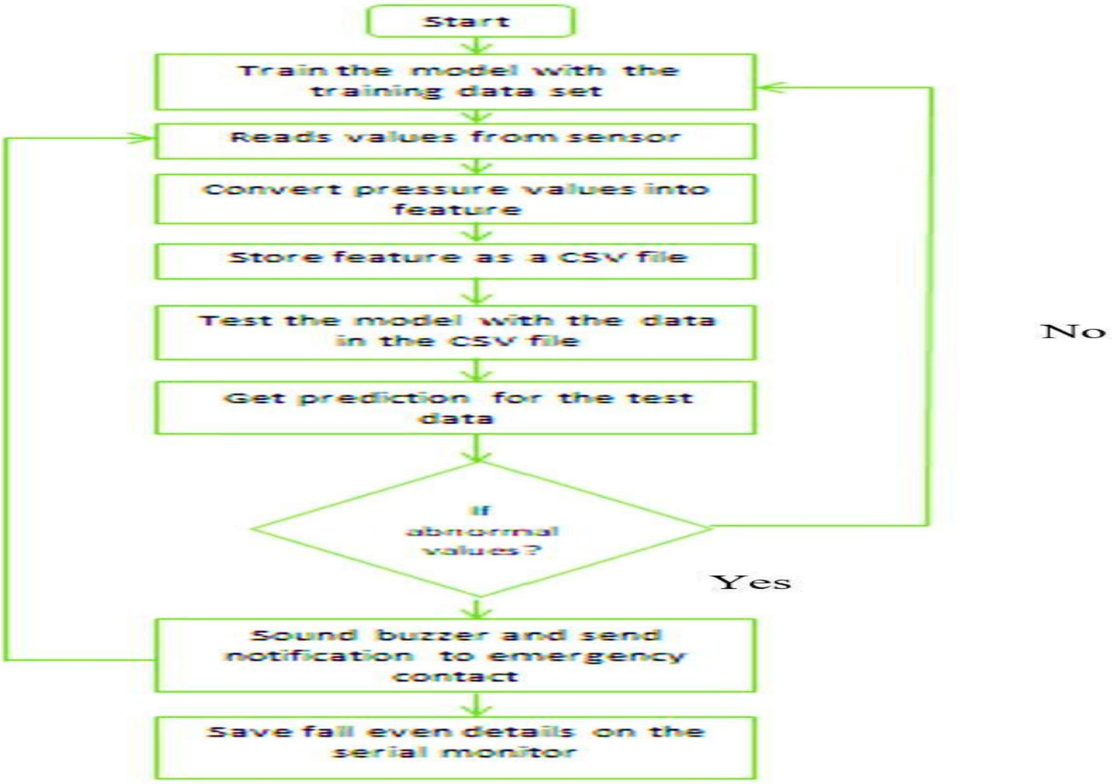

Fig. 4 Fall detection flowchart

4. DISCUSSION

As discussed earlier this paper is mainly focusing on the sole pressure which helps in predicting the fall in future. So, we need several pressure values at different points like Front- Foot (FF), Mid-foot (MF) and Rear- foot (RF) for predicting the fall.

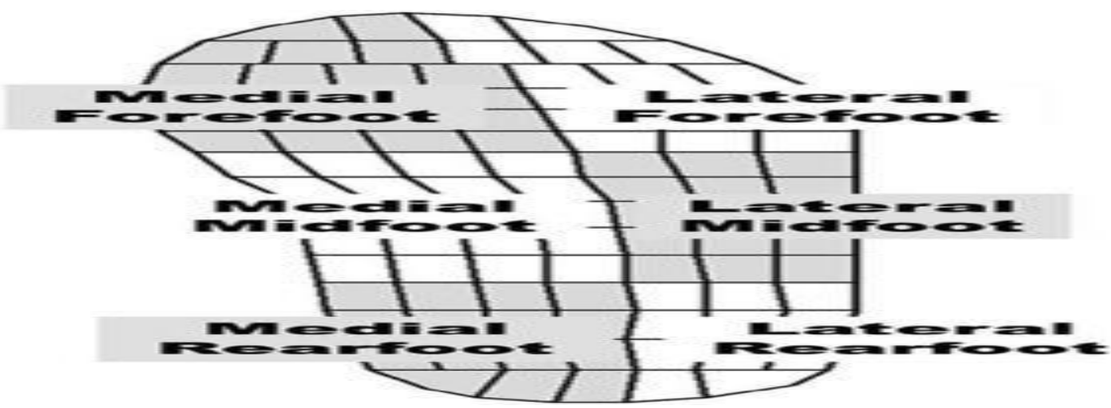

Fig. 5 Regions under pressure

When a person walks normally, pressure is distributed evenly on the foot, this is considered as normal gait pattern but when a person is about to, uneven pressures are exerted on the fore-foot and rear-foot. This is considered as abnormal gait pattern.

Fig. 6 FSR402 Force Sensor

FSR402 is attached to the shoe sole which is used for detecting the pressure values acting on foot.The force sensing resistor is made of polymer sheets. When a force is applied to a sensor film surface, particles hit the conducting electrodes, changing the film's resistance. When there is no pressure on the foot the resistance is infinite but whenever the pressure is applied at different points, it changes the resistor values according to the pressure exerted. [17].

We are interfacing our all other components such as FSR402, GPS, GSM and ESP 8266 with Arduino UNO. Basically with 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB port, on-board LEDs, a power jack, an ICSP header, and a reset button, the Arduino Uno microcontroller board is based on the ATmega328P. Either an external power jack or a USB cable can be used to power it. It requires an input voltage between 7 and 20 volts and operates at 5 volts [18], [19].

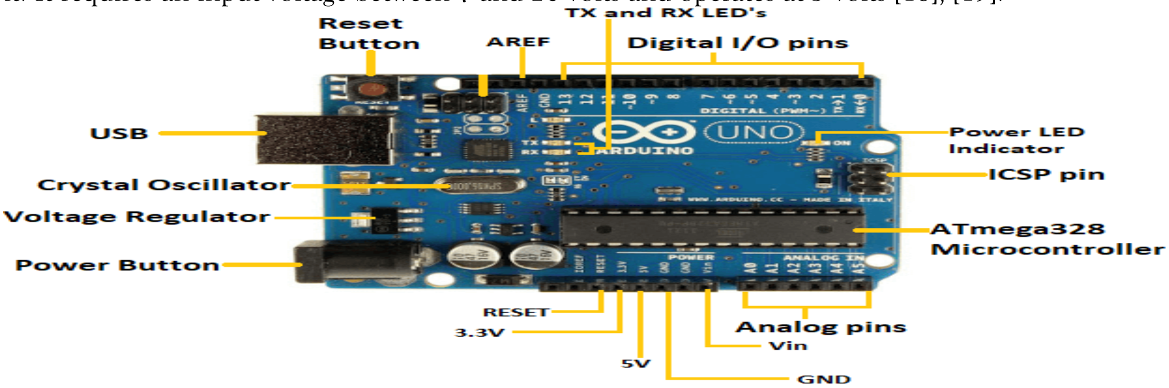

Fig. 7 Arduino UNO

WI-FI Module ESP 8266

An ESP8266 is a Wi-Fi module and IOT module. It is used to provide the internet connection to the components used in our prototype. We preferred this module as it is cheaper as compared to all other Wi-Fi modules. It operates at 3.3V. It consists of 8 pins. They are ground, transmitter(Tx), general purpose input output(GPIO2),channel enable(CH_EN), general purpose input output(GPIO- 0),reset, receiver(Rx),VCC(+3.3V) numbered from 1 to 8 respectively [20].

Fig. 8 ESP 8266 Wi-Fi module

It is used to obtain the exact location of the user, that is, the GPS location; the Arduino code was run to obtain it. GPS has two parts; one is the antenna which is used to connect to the satellite and the other part, i.e., NEO-6M acts as a circuit board which connects to the Arduino board to enable communication through it.It consists of 4 pins. They are Vcc, Tx, Rx, GND [21].

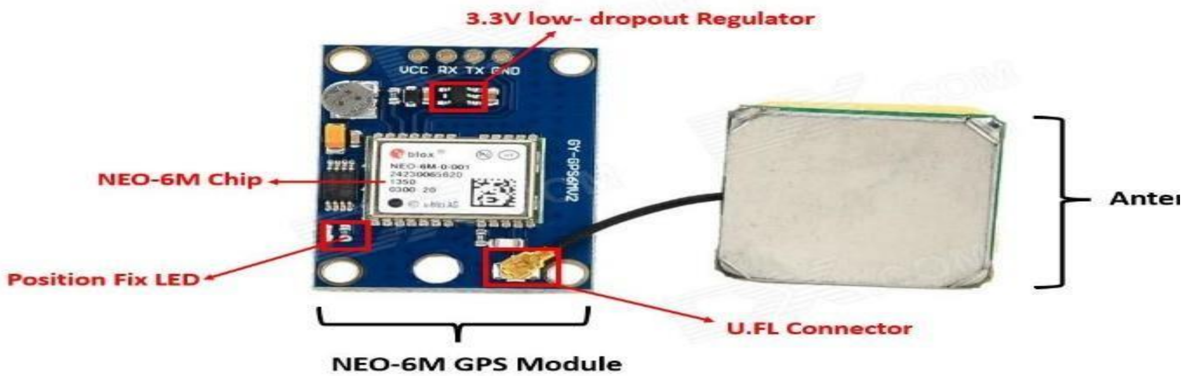

Fig. 9 GPS

Fig. 10 GSM

Global System for Mobile communication (GSM) Module and Fall Alert is here. We have used SIM 900A GSM module in our paper for sending SMS to the caretaker and for calling purpose. This module is made up of Dual Band GSM/GPRS based on SIM900A modem from SIMCOM. It works on frequencies 900/ 1800 MHz. The GSM/GPRS Modem has internal TCP/IP stack to enable us to connect with internet via GPRS. This GSM module is with a very powerful single-chip processor integrating AMR926EJ-S core, allowing you to benefit from small dimensions and cost-effective solutions.

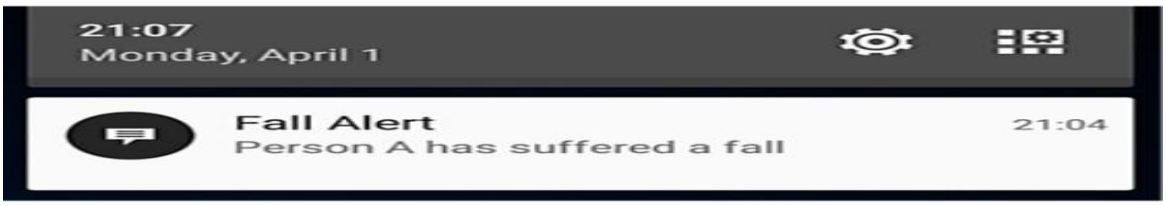

Fig. 11 Fall Alert received upon fall event

If an imminent fall occurs, the following SMS is sent to the caretaker whenever the cautious values are detected and an imminent fall occurs, the system alerts the caretaker by sending the messages (Fig. 11) and calls the caretaker.

Strengths of Innovations are given here. Predicting fall by detecting abnormal gait patterns. There is no need to wear special sensors. For informing and seeking help from caretakers. Compact and easy to use and handle. The users are in need to keep smartphones with them every time, which is quite difficult for older people. Phone battery discharge is more as compared to normal discharge

5. CONCLUSION

This paper seeks to address the issue of senior citizens' falling, which causes a serious threat to their health. As a result, it was crucial to suggest a smart system that anticipates falls before they happen, using devices that are installed on the elderly to alert caretakers of this so that he takes immediate action to avoid injuries. Hence a machine learning technique-based system to anticipate falls in elderly has been presented. To build this system, we use a decision tree making algorithm because it gives faster response as compared to other algorithms and gives accuracy of 91%. We plan to prioritise data design for better performance in the future in order to enhance the prototype.

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