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Bluetooth Proximity Estimation on Android with Respect to Accuracy of GPS Values and Power Consumption

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Abstract: The availability of "always-on" communications has tremendous implications for how people interact socially. In particular, sociologists are interested in the question if such pervasive access increases or decreases face-to-face interactions. Unlike triangulation which seeks to precisely define position, the question of face-to-face interaction reduces to one of proximity, i.e. are the individuals within a certain distance? Moreover, the problem of proximity estimation is complicated by the fact that the measurement must be quite precise (1-1.5m) and can cover a wide variety of environments. Existing approaches such as GPS and Wi-Fi triangulation are insufficient to meet the requirements of accuracy and flexibility. In contrast, Bluetooth, which is commonly available on most smart phones, provides a compelling alternative for proximity estimation. In this paper, we demonstrate through experimental studies the efficacy of Bluetooth for this exact purpose. We propose a proximity estimation model to determine the distance based on the RSSI values of Bluetooth and light sensor data in different environments. We present several real world scenarios and explore Bluetooth proximity estimation on Android with respect to accuracy and power consumption.

Keywords: Bluetooth, RSSI, Proximity Estimation Model, Smart Phone, Face-To-Face Proximity.

I. INTRODUCTION

In recent years, the presence of portable devices ranging from the traditional laptop to fully fledged smart phones has introduced low-cost, always-on network connectivity to significant swaths of society. Network applications designed for communication and connectivity provide the facility for people to reach anywhere at any time in the mobile network fabric. Digital communication [3], such as texting and social networking, connect individuals and communities with ever expanding information flows, all the while becoming increasingly more interwoven. There are compelling research questions whether such digital social interactions are modifying the nature and frequency of human social interactions. A key metric for sociologists is whether these networks facilitate face-to-face interactions or whether these networks impede face-to-face interactions. Studies have shown that collecting occurrences of communications based on self-reporting, where subjects are asked about their social interaction proximity, is unreliable since the accuracy depends upon the recency and salience of the interactions [4]. With the increasing availability of data in logs generated by smart phones, there are tremendous opportunities for collecting data automatically [5]–[7]. The critical technical challenge is how to measure face-to-face interactions, i.e. are two or more individuals within a certain distance that could afford such interactions?

Interactions are not limited to any particular area and can take place at a wide variety of locations, ranging from sitting and chatting in a Starbucks coffee shop to walking and chatting across a college campus. As will be explored later in the paper, for most face-to-face interactions, the approximate distance between individuals in casual conversation is within 0.5 to 2.5 meters (Section 4 presents empirical evidence supporting this claim.). One of the solutions would seem to be location based calculation which relies on location technologies such as Wi-Fi triangulation [8], cell phone triangulation [9], GPS, or a combination of all three. However, none of these solutions are ideal or sufficient. Although Wi-Fi triangulation can present a reasonable degree of accuracy, its accuracy in all but the densest Wi-Fi deployments is insufficient, ranging on the order of 3 to 30 meters [8]. Similarly, cell phone triangulation suffers from an even worse accuracy [9]. Moreover, while Wi-Fi is reasonably pervasive, Wi-Fi tends to generally be sparser in green spaces, i.e. outdoor spaces. Notably, GPS suffers from both an accuracy shortcoming (5-50m) as well a lack of viability indoors [10].

However, it is important to note that face-to-face interaction does not demand an absolute position as offered by the previously mentioned schemes but rather requires a determination of proximity. With that important shift of the problem definition, Bluetooth emerges as a straightforward and plausible alternative, offering both accuracy (1-1.2m) [11] and ubiquity (most modern smart phones come with Bluetooth) [12]. Although some prior work has attempted to use the detection of Bluetooth to indicate nearness [4], it is not enough for the face-to-face proximity estimation. The question addressed by this paper is to what extent Bluetooth can be an accurate estimator of such proximity. To summarize, our work makes the following contributions:

- We demonstrate the viability of using Bluetooth for the purposes of face-to-face proximity estimation and propose a proximity estimation model with appropriate smoothing and consideration of a wide variety of typical environments.
- We study the relationship between the value of Bluetooth RSSI and distances based on empirical measurements and compare the results with the theoretical results using the radio propagation model.
- We explore the energy efficiency and accuracy of Bluetooth compared with Wi-Fi and GPS via real-life measurements.
- We deploy an application “Phone Monitor” which collects data such as Bluetooth RSSI values on 196 Android-based phones. Based on the data collection platform, we are able to use the proximity estimation model across several real-world cases to provide high accurate determination of face-to-face interaction distance.

The remainder of the paper is organized as follows. In SectionII, Existing System and Proposed Systems. Afterwards, in SectionIII Block Diagram Description. In SectionIV the Experimental results. Finally, we suggest ways to extend this work to future communication research in SectionV.

II. EXISTING SYSTEM AND PROPOSED SYSTEMS

A. Existing System

In recent years, the presence of portable devices ranging from the traditional laptop to fully fledged smart phones has introduced low-cost, always-on network connectivity to significant swaths of society. Network applications designed for communication and connectivity provide the facility for people to reach anywhere at any time in the mobile network fabric. Digital communication, such as texting and social networking, connect individuals and communities with ever expanding information flows, all the while becoming increasingly more interwoven. There are compelling research questions whether such digital social interactions are modifying the nature and frequency of human social interactions. A key metric for sociologists is whether these networks facilitate face-to-face interactions or whether these networks impede face-to-face interactions.

1. Disadvantages of Existing System

Where subjects are asked about their social interaction proximity, is unreliable. Interactions are not limited to any particular area and can take place at a wide variety of locations.

B. Proposed System

We demonstrate the viability of using Bluetooth for the purposes of face-to-face proximity estimation and propose a proximity estimation model with appropriate smoothing and consideration of a wide variety of typical environments. We study the relationship between the value of Bluetooth RSSI and distance based on empirical measurements and compares the results with the theoretical results using the radio propagation model. We explore the energy efficiency and accuracy of Bluetooth compared with Wi-Fi and GPS via real-life measurements. We deploy an application “Phone Monitor” which collects data such as Bluetooth RSSI values on 196 Android-based phones. Based on the data collection platform, we are able to use the proximity estimation model across several real-world cases to provide high accurate determination of face-to-face interaction distance.

1. Advantages of Proposed System

It provides adequate accuracy for detecting something like buddy proximity (e.g., median accuracy of 20-30 meters), Different from the above proximity detection method, our work is a fine grain Bluetooth-based proximity detection method which can provide adequate accuracy for face-to-face proximity estimation without environment limitations.

III. BLOCK DIAGRAM DESCRIPTION

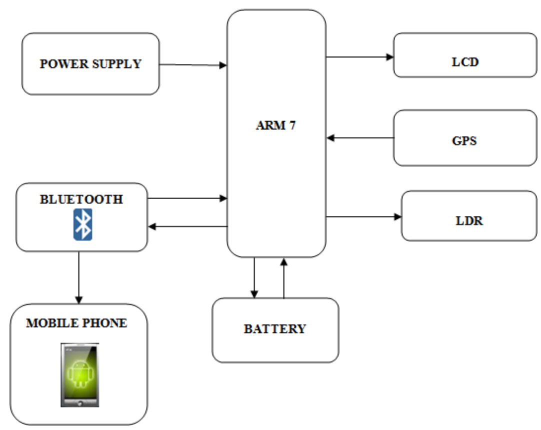

Fig.1. Block diagram.

A. ARM7 LPC2148 TDMI

Over the last few years, the ARM architecture has become the most pervasive 32-bitarchitecture in the world through wide range of ICs available from various IC manufacturers. The ARM processors are embedded in products ranging from cell/mobile phones to automotive braking systems. Worldwide community of ARM partners and third-party vendors has developed among semiconductor and product design companies including hardware engineers, software developers, and system designers. ARM7 is one of the widely used micro-controller family in embedded system application. This section is humble effort for explaining basic features of ARM-7. The ARM is a family of instruction set architectures for computer processors based on a reduced (RISC) architecture developed by British company ARM Holdings.

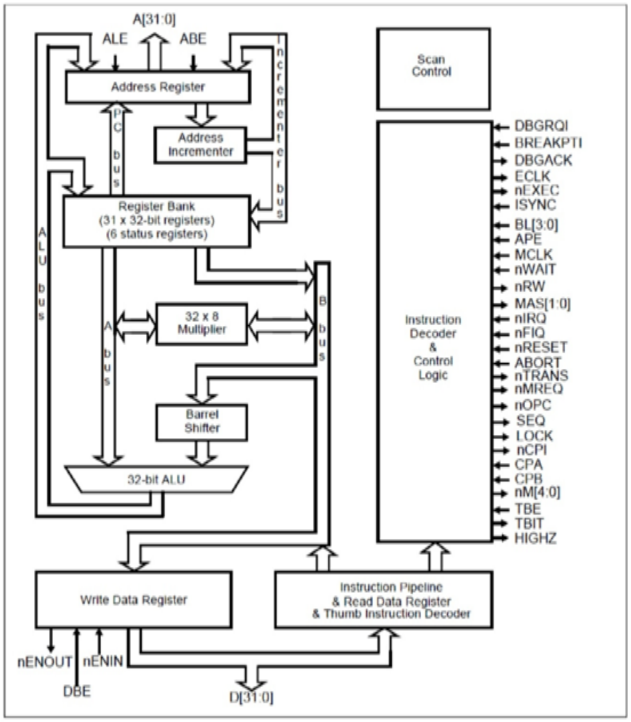

Fig.2. ARM7 TDMI Core Diagram.

A RISC-based computer design approach means ARM processors require significantly fewer transistors than typical processors in average computers. Here this approach reduces costs, heat and power use. These are desirable traits for portable, light, battery-powered devices including smart laptops, phones, and tablet. A simpler design facilitates more efficient multi-core CPUs and higher core counts at lower cost providing higher processing power and improved energy efficiency for servers and supercomputers. It Provides 8kB of on-chip RAM accessible to USB by DMA. One or two (LPC2141/2 vs. LPC2144/6/8) 10-bit A/D converters provide a total of 6/14analog inputs with conversion times as low as 2.44 us per channel.

- Single 10-bit D/A converter provide variable analog output.
- Two 32-bit timers/external events counter PWM unit and watchdog.
- Low power real-time clock with independent power and dedicated 32 kHz clock input.
- Multiple serial interfaces including two UARTs (16C550) two Fast I2C-bus, SPI and SSP with buffering and variable data length capabilities.
- Vectored interrupt controller with configurable priorities and vector addresses.
- 45 of 5 V tolerant fast general purpose I/O pins in a tiny LQFP64.
- Nine edge or level sensitive external interrupt pins available.

On-chip integrated oscillator operates with an external crystal in range from 1 MHz to30 MHz and with an external oscillator up to 50 MHz.

B. Power Supply

All electronic circuits works only in low DC voltage, so we need a power supply unit to provide the appropriate voltage supply for their proper functioning. This unit consists of transformer, rectifier, filter & regulator. AC voltage of typically 230volts rms is connected to a transformer voltage down to the level to the desired ac voltage. A diode rectifier that provides the full wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation. A regulator circuit can use this dc input to provide dc voltage that not only has much less ripple voltage but also remains the same dc value even the dc voltage varies somewhat, or the load connected to the output dc voltages changes.

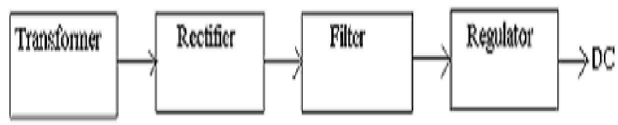

Fig.3. General Block of Power Supply Unit.

C. LCD Display

Liquid crystal displays (LCDs) have materials which combine the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal. An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle.

One each polarizer’s are pasted outside the two glass panels. This polarizer’s would rotate the light rays passing through them to a definite angle, in a particular direction. When the LCD is in the off state, light rays are rotated by the two polarizer’s and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent. When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction. The light rays passing through the LCD would be rotated by the polarizer’s, which would result in activating / highlighting the desired characters. The LCD’s are lightweight with only a few millimeters thickness. Since the LCD’s consume less power, they are compatible with low power electronic circuits, and can be powered for long durations.

The LCD does don’t generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCD’s have long life and a wide operating temperature range. Changing the display size or the layout size is relatively simple which makes the LCD's more customer friendly. The LCDs used exclusively in watches, calculators and measuring instruments are the simple seven-segment displays, having a limited amount of numeric data. The recent advances in technology have resulted in better legibility, more information displaying capability and a wider temperature range. These have resulted in the LCDs being extensively used in telecommunications and entertainment electronics. The LCDs have even started replacing the cathode ray tubes (CRTs) used for the display of text and graphics, and also in small TV applications.

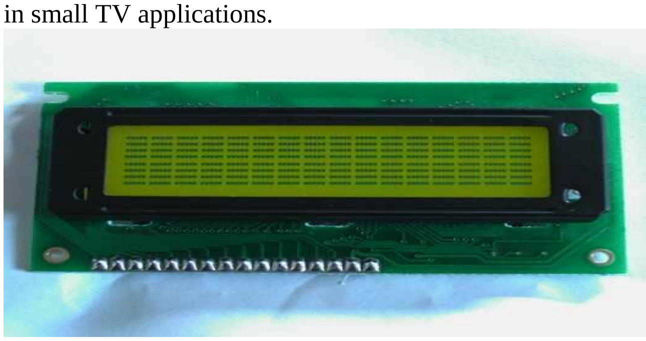

Fig.4. LCD Display.

1. LCD Module (2X16 CHARACTER)

Dot matrix LCD modules is used for display the parameters and fault condition.16 characters 2 lines display is used. It has controller which interface data's and LCD panel. Liquid crystal displays (LCD's) have materials, which combine the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal. An LCD consists of two glass panels, with the liquid crystal material sandwiched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal molecules to maintain a defined orientation angle.

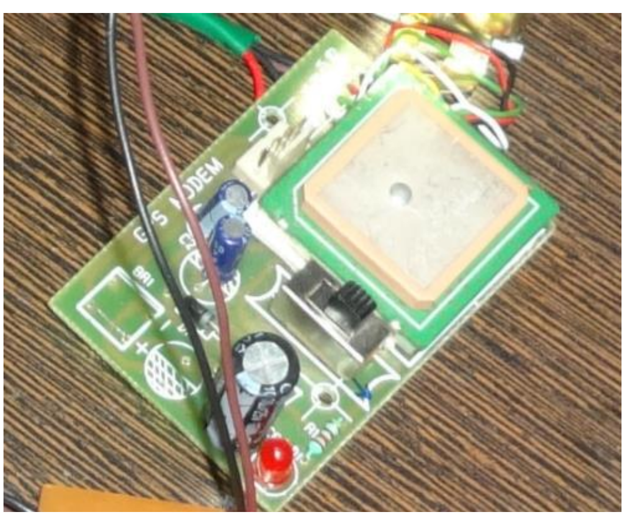

Fig.5. GPS module.

D. GPS Modem

LS20030~3 series products are complete GPS smart antenna receivers, including an embedded antenna and GPS receiver circuits, designed for a broad spectrum of OEM system applications. The product is based on the proven technology found in LOCOSYS 32 channel GPS SMD type receivers MC-1513 that use Media Tek chip solution. The GPS smart antenna will track up to 32 satellites at a time while providing fast time-to-first-fix, one-second navigation update and low power consumption. It can provide you with superior sensitivity and performance even in urban canyon and dense foliage environment. Its far-reaching capability meets the sensitivity requirements of car navigation as well as other location-based applications.

E. LDRs

Two LDRs (light dependent resistors) are used in place of temperature sensors to track the light and its units are sent to motor via microcontroller and LDRs are present on the solar panel shown in Fig.6.

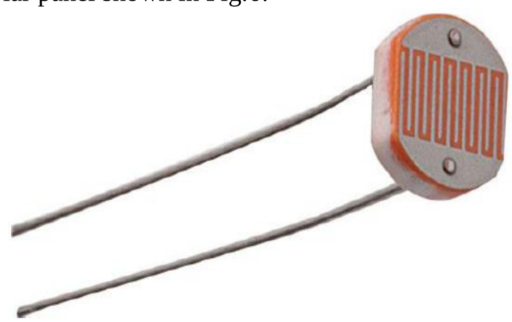

Fig.6. LDRs Module.

F. Battery charging circuit

Battery charging circuit consists of step down transformer, Bridge rectifier, filter and LM7812 IC as shown Fig.7. Step down transformers converts electrical voltage from one level or phase configuration usually down to a lower level. Bridge rectifier converts the alternating current to pulsating direct current; capacitor acting as filter is connected at the output of bridge rectifier to convert pulsating DC to pure DC. 7812 is a famous IC which is being widely used in 12V voltage regulator circuits. Two capacitors used one on the input side and other on the output of 7812 in order to achieve clean voltage output. Good heat sink plate mounted on a 7812 to achieve 12V, 1A current.

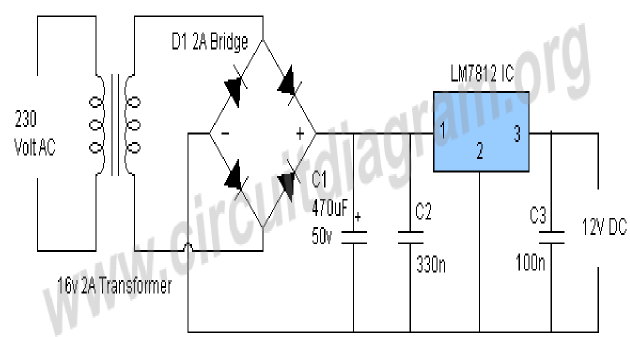

Fig.7. Battery charging circuit.

G. Bluetooth Module

Bluetooth File Transfer for the PC is a file transfer utility and client which makes it extremely easy to share files between devices with a better laid out user interface than Windows' built-in file transfer program. The included file and folder manager gives you the ability to browse your computer or remote device. It comes with full support for Android and Apple devices and basically any type of device with Bluetooth capabilities. From within the Bluetooth File Transfer explorer itself, you're able to upload and download files, perform file management operations such as deleting, renaming, copy paste files and more. Bluetooth File Transfer can also playback multimedia files, open text files and browse images. Although the program might be a little bit slow finding devices, that is not really a fault of the program but more no of Bluetooth protocols. This software certainly makes it a less daunting task of dealing with Bluetooth devices and file management.

IV. EXPERIMENTAL RESULTS

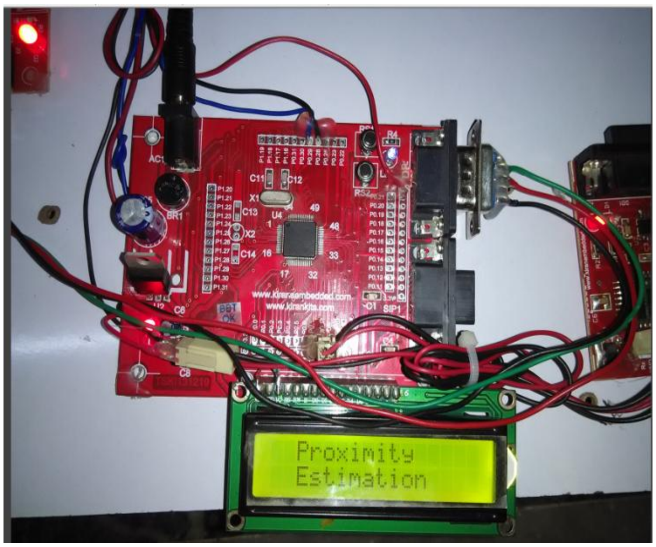

Fig.8 simulation result of proxy estimation.

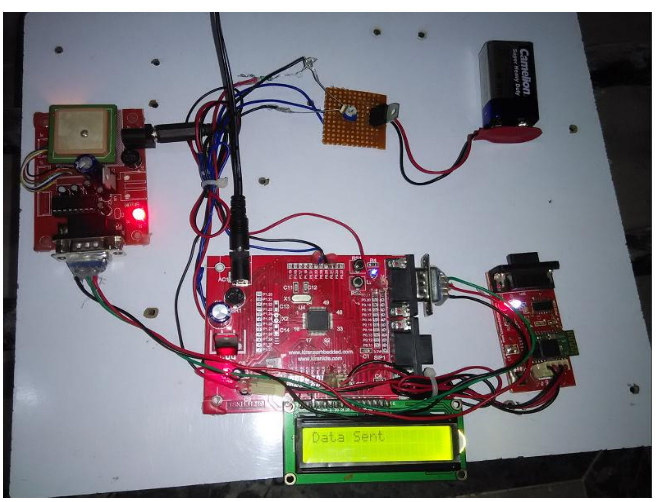

Fig.9 Simulation result of data sent proxy estimation.

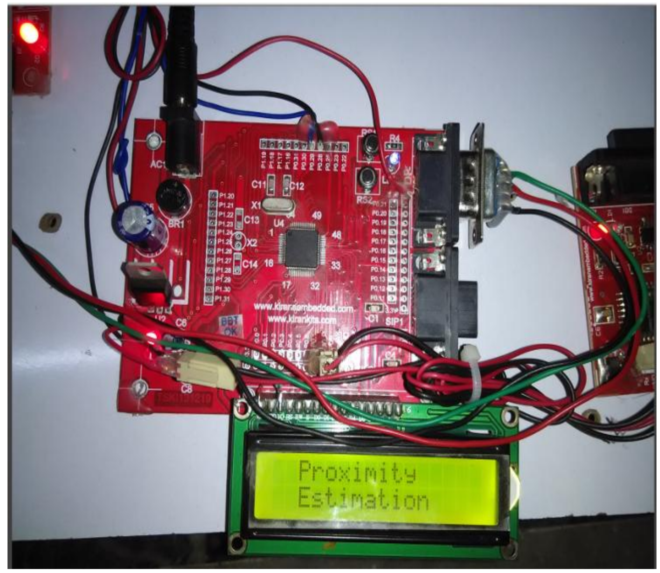

Fig.10 Simulation result of output proxy estimation.

V. CONCLUSION AND FUTURE WORK

In summary, our presented work validates the usage of Bluetooth as a tool for face-to-face proximity detection. We carefully explored the relationship between Bluetooth RSSI values and distances for indoors and outdoors settings. We also analyzed the impacts of different environment settings. Based on the experiment results, we summarized two methods to estimate proximity: single threshold and multiple thresholds. In the latter approach we showed how the light sensor and smoothing can be employed to yield reasonable approximations for proximity. Then we proposed the proximity estimation model by combining Bluetooth RSSI value, light sensor data as well as data smoothing together. By developing and deploying the application “Phone Monitor” on 196 phones, we recorded data reported from devices in different occasions. We applied the proximity estimation model on the realistic data and analyzed the proximity among the participants as well as the symmetry of proximity. Compared with the method of collecting all devices around, the accuracy of utilizing proximity estimation model to estimate whether two devices are in a direct communication distance is improved dramatically.

We also compared the battery usage and accuracy of our method with other different location methods such as Wi-Fi triangulation and GPS. The result demonstrates that Bluetooth offers an effective mechanism that is accurate and power-efficient for measuring face-to-face proximity. For our future work, we intend to improve our threshold algorithms with data mining. The thresholds used in the proximity estimation model are based on the experiment results on Nexus S 4G phones. For different phones, such thresholds may be different. Therefore, a more general method is necessary to determine the relationship between Bluetooth RSSI values and the face-to-face proximity. With more data reported in the next following two years, a more efficient data mining algorithm is needed to analyze the data. During the nighttime, only the data reported by light sensor is not reliable. One possible method to solve this problem is to take atmospheric pressure into consideration to determine whether the phone is indoor or outdoor.

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