Proposal and Off-Line Preliminary Analysis of a Wellness Sensor Network for Modelling Activity of Daily Livings

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Abstract

The adoption of a smart home system is mostly influenced by technological advancements rather than consumer desire. The impractical nature of this strategy has elicited disappointment among several customers, mostly due to concerns related to its practicality, affordability, and various other challenges. The contemporary era has introduced an advantageous smart home solution referred to as the wellness regimen. The primary objective of this study is to build upon the existing research on the smart home system of the wellness protocol. The focus is on implementing this system within the context of economical dense sensing, with the ultimate aim of practical utilisation by individuals and gaining insights into human activity patterns and lifestyle. The system utilises extensive sensory data for both training and testing purposes, with the earliest dataset dating back to 2013. The accuracy of detecting and anticipating behavioural patterns in smart ageing is directly proportional to the amount of information used.

Keywords: *Smart Home, Dense Sensing, Economic Sensing, Lifestyle, and Wellness Sensor Network.*

I. OVERVIEW AND CONNECTED WORKS

An increasing demographic, particularly including older adults and persons with physical disabilities, choose to live independently inside their own residences. The decision to forgo living with caretakers among elderly and physically challenged individuals is often motivated by concerns around privacy and the financial burden associated with hiring a home nurse. In addition to this, global data indicates a substantial increase in some pressing issues, such as the global phenomenon of population ageing [1] and the escalating prevalence of individuals affected by dementia [2]. The challenges mentioned above have contributed to the worldwide development of smart home initiatives, aimed at establishing an automated household and surveillance system to assist residents in managing their everyday living concerns.

Within the realm of smart home automation, the term "smart" refers to the ability of a residential dwelling to acquire knowledge of occupant behaviours and afterwards exhibit intelligent responses to anticipated events, therefore offering necessary and suitable aid to the resident. Sensors are strategically placed throughout the residential premises to monitor and record the routine activities of the tenants. The gathered data is then sent to a centralised computer system for thorough analysis and informed decision-making purposes. The central intelligent server infers the occupant's decision and executes the relevant information, which is then provided to the occupant. This process is carried out to ensure that the occupant receives the appropriate care [3].

During the first stages of their research on sensor-based smart home monitoring systems, they developed a novel home automation system using an experimental neural network. Subsequently, a number of adaptive programmes have used sensor-based methodologies to track the whereabouts of users [4]. The widespread use of wearable sensors in ubiquitous mobile computing may be attributed to its ease of deployment and mobility. The establishment of a novel sensing paradigm, referred to as "dense sensing," occurred in the late 2000s. In contrast to wearable sensors, which are directly affixed to the user's body, the dense sensing approach involves the attachment of sensors to various elements within the environment. Due to its unobtrusive nature, this specific approach has garnered significant popularity, especially within the assistive daily living (ADL) smart home industry [5]. The use of conventional methods including the use of a video camera for the purpose of home monitoring has elicited apprehensions over privacy among customers. Moreover, a significant number of individuals exhibit a preference for the dense sensing technique due to the potential challenges faced by older individuals and patients with cognitive impairment or dementia in consistently wearing the sensors.

Additionally, some individuals may see the act of carrying the sensors at all times as onerous [6]. Numerous previous advancements in applications and technological developments have facilitated extensive research endeavours in the field of smart homes on a global scale. Notable examples include House_n, CASAS, Gator-Tech, inHaus, AwareHome, DOMUS, iDorm, AgingMo at the University of Missouri, PlaceLab at MIT, and Smart Home Lab at Iowa State University [3-5].

Nevertheless, it is important to acknowledge that current smart home technology and research have some limitations. Smart home deployments are being implemented in impractical synthesis lab environments, exhibiting a high cost that is beyond the means of average users. These deployments involve a substantial number of sensors, with even a single activity detection requiring an average of five to six sensors. Furthermore, there is a lack of understanding regarding customers' requirements, and project developments are primarily driven by technological advancements rather than market demand [4]. In a similar vein, several smart home systems within the telehealth setting are grappling with challenges pertaining to privacy, confidentiality, legal considerations, and the nature of physician-patient interactions [7].

The existing body of research has identified these limitations as potential avenues for further investigation and areas where further understanding is needed. A team member inside our organisation has already developed a pioneering prototype for a smart home equipped with a wellness sensor network. [8] The implementation is grounded in the context of a real-world smart home ecosystem. The present endeavour aims to simulate the human way of life by using the wellness protocol within the framework of economic sensing. Moreover, it gives rise to a distinct behaviour style.

The objective of imitating human lifestyle is to enhance comprehension of human well-being. According to the notion, it is believed that prevention is superior than treatment. This study has the potential to provide valuable insights about the lifestyle patterns of individuals residing in order to enhance our comprehension of their lifestyle habits as a proactive strategy for potential chronic diseases. The concept and research objective of modelling lifestyle vary from telecare systems [9-13] that focus on treating patients, specifically aiming for their "cure". The intended audience include both those who are not currently receiving medical treatment and those who are.

The following section outlines the organisational structure of the article. Segment II provides a comprehensive description of the setup of our experimental system. Section III presents the results of our data analysis and provides preliminary conclusions. Section IV finishes the present research by emphasising the next efforts that we anticipate undertaking.

II. EXPERIMENTAL DESIGN CONFIGURATION

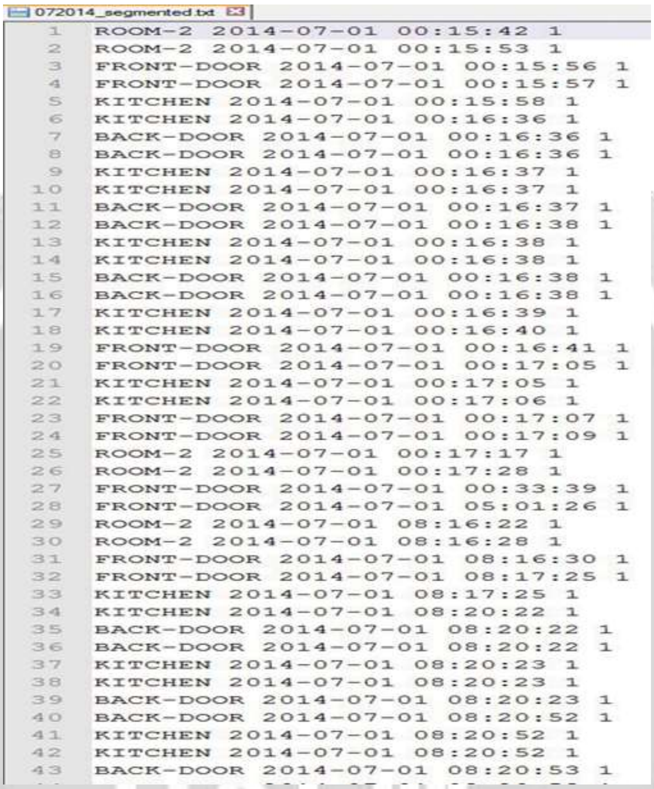
This section provides an overview of the implementation process of the Wellness System. The current system is functioning with a distinct configuration compared to the previous work cited in references [4] and [6]. The study focuses on the application of economic sensing techniques to get insights on the lifestyle of individuals inhabiting a certain area.

The residents of the establishment in question mostly consist of old individuals who have been there for an extended period of time, with few occurrences of visitors. The user has provided a numerical reference. Within domestic settings, two distinct types of sensors are often used. One of the primary components is a passive infrared (PIR) motion sensor, which is capable of detecting the movement of occupants and generating discrete digital values that represent this activity over a certain period. The second kind of sensors is known as Electrical and Electronic (E&E) appliance sensors. These sensors are designed to detect the functioning of appliances used by occupants by monitoring voltage variations. Over a period of time, the sensor consistently delivers an analogue current and voltage reading. A dispersed arrangement is being used to position a total of eight sensors. Each of the following areas in the house is equipped with a total of five motion sensors: the master bedroom, living room, kitchen, front entry, and back door. The personal computer, microwave, and refrigerator are equipped with electrical and electronic (E&E) appliance sensors.

The data collected from various sensors is consolidated and sent to a centralised server referred to as the local gateway server. Upon the arrival of data, it is then inserted into the designated MySQL database system via the use of a C# graphical user interface (GUI) application. Subsequently, the data is uploaded into the internet and presented to the end user through an online website.

In contrast to the conventional ZigBee protocol, there exist several advantages associated with the use of our wellness protocol sensor network. At the level of sensor nodes, the method successfully addressed significant challenges related to data storage and data collision. The event-based protocol only transmits sensory data upon user interaction with the sensor node. This occurs when an occupant triggers a motion sensor or utilises an electrical device.

Numerous numerical representations I provide a brief overview of the unprocessed dataset. The dataset consists of four basic columns, with the first column indicating the sensor ID or the location of the sensor node. The date and time of sensor activation are shown in the second and third columns, respectively. The display of the sensor activation state may be seen in the fourth column. The sensor is considered to be active when its status is shown as '1'.



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072014_segmented.txt
ROOM-2 2014-07-01 00:15:42 1
ROOM-2 2014-07-01 00:15:53 1
FRONT-DOOR 2014-07-01 00:15:56 1
FRONT-DOOR 2014-07-01 00:15:57 1
KITCHEN 2014-07-01 00:15:58 1
KITCHEN 2014-07-01 00:16:36 1
BACK-DOOR 2014-07-01 00:16:36 1
BACK-DOOR 2014-07-01 00:16:36 1
KITCHEN 2014-07-01 00:16:37 1
KITCHEN 2014-07-01 00:16:37 1
BACK-DOOR 2014-07-01 00:16:37 1
BACK-DOOR 2014-07-01 00:16:38 1
KITCHEN 2014-07-01 00:16:38 1
KITCHEN 2014-07-01 00:16:38 1
BACK-DOOR 2014-07-01 00:16:38 1
BACK-DOOR 2014-07-01 00:16:38 1
KITCHEN 2014-07-01 00:16:39 1
KITCHEN 2014-07-01 00:16:40 1
FRONT-DOOR 2014-07-01 00:16:41 1
FRONT-DOOR 2014-07-01 00:17:05 1
KITCHEN 2014-07-01 00:17:05 1
KITCHEN 2014-07-01 00:17:06 1
FRONT-DOOR 2014-07-01 00:17:07 1
FRONT-DOOR 2014-07-01 00:17:09 1
ROOM-2 2014-07-01 00:17:17 1
ROOM-2 2014-07-01 00:17:28 1
FRONT-DOOR 2014-07-01 00:33:39 1
FRONT-DOOR 2014-07-01 05:01:26 1
ROOM-2 2014-07-01 08:16:22 1
ROOM-2 2014-07-01 08:16:28 1
FRONT-DOOR 2014-07-01 08:16:30 1
FRONT-DOOR 2014-07-01 08:17:25 1
KITCHEN 2014-07-01 08:17:25 1
KITCHEN 2014-07-01 08:20:22 1
BACK-DOOR 2014-07-01 08:20:22 1
BACK-DOOR 2014-07-01 08:20:22 1
KITCHEN 2014-07-01 08:20:23 1
KITCHEN 2014-07-01 08:20:23 1
BACK-DOOR 2014-07-01 08:20:23 1
BACK-DOOR 2014-07-01 08:20:52 1
KITCHEN 2014-07-01 08:20:52 1
KITCHEN 2014-07-01 08:20:52 1
BACK-DOOR 2014-07-01 08:20:53 1
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Fig. 1 (A). The data created by the sensor

Fig. 1 (B). The building installed with the Smart Aging system

Fig. 1 (C). Placement of diverse sensing elements

III. ANALYSIS OF DATA AND INITIAL RESULTS

The current section also presents our preliminary discoveries on the characteristics of our datasets. One of the annotations on our raw dataset pertains to the period of time. The subsequent procedure involves identifying the tenant's whereabouts. The third chart presents the duration of utilisation for different rooms, while the fourth chart displays the frequency of use for both the front and back doors.

The first step is annotating the raw dataset in order to indicate the duration. The duration of an individual's presence inside a certain location is often referred to as the length of occupancy. This objective is achieved by the examination of the temporal duration of sensor activation in two distinct data entries. In Figure 1, the two data entries pertaining to the occupant's arrival time (Kitchen 2023-07-01 00:15:58) and departure time (Kitchen 2023-07-01 00:16:36) are computed, and the resultant duration is appended to the data in the fourth column. The annotated data is presented in the format of hours, minutes, and seconds, denoted as hh, mm, and ss, respectively. Please refer to Figure 2 for further details.

Furthermore, the system is capable of detecting the occupancy and locations of older individuals inside their residence during the course of the day. According to Figure 3, it is evident that the individual in question spent a significant amount of time in the vicinity of the master bedroom, front-door, back-door, and kitchen areas between the hours of 12:00 am and 9:30 am, as well as from 19:00 to 23:00. Notably, there was no recorded activity in the living room during this period.

```
062014_DURATION_removed_hms_zero.txt
1  ROOM-2 2014-06-01 00:10:09 0 0 6
2  FRONT-DOOR 2014-06-01 00:10:26 0 1 55
3  ROOM-2 2014-06-01 00:12:41 0 0 4
4  ROOM-3 2014-06-01 00:22:43 0 4 7
5  FRONT-DOOR 2014-06-01 00:26:52 0 0 20
6  ROOM-3 2014-06-01 00:27:18 1 19 3
7  FRONT-DOOR 2014-06-01 01:46:25 0 0 31
8  ROOM-3 2014-06-01 01:47:07 4 24 55
9  ROOM-2 2014-06-01 06:16:37 0 0 35
10 FRONT-DOOR 2014-06-01 06:17:17 0 19 19
11 ROOM-2 2014-06-01 06:36:53 0 1 9
12 FRONT-DOOR 2014-06-01 06:38:08 0 20 49
13 ROOM-2 2014-06-01 06:59:07 0 4 8
14 FRONT-DOOR 2014-06-01 07:03:21 0 0 2
15 BACK-DOOR 2014-06-01 07:03:25 0 0 1
16 KITCHEN 2014-06-01 07:03:27 0 0 1
17 KITCHEN 2014-06-01 07:03:30 0 0 32
18 FRONT-DOOR 2014-06-01 07:04:03 0 0 2
19 ROOM-2 2014-06-01 07:04:12 0 1 3
20 FRONT-DOOR 2014-06-01 07:05:16 0 0 1
21 FRONT-DOOR 2014-06-01 07:05:17 0 0 1
22 KITCHEN 2014-06-01 07:05:18 0 0 24
23 FRONT-DOOR 2014-06-01 07:05:43 0 0 1
24 ROOM-2 2014-06-01 07:05:52 0 19 26
25 FRONT-DOOR 2014-06-01 07:25:25 0 0 15
26 ROOM-2 2014-06-01 07:25:48 0 0 45
27 FRONT-DOOR 2014-06-01 07:26:41 0 0 3
28 KITCHEN 2014-06-01 07:26:45 0 0 4
29 FRONT-DOOR 2014-06-01 07:26:50 0 0 1
30 ROOM-2 2014-06-01 07:26:59 0 0 25
31 FRONT-DOOR 2014-06-01 07:27:35 0 0 2
32 KITCHEN 2014-06-01 07:27:37 0 4 11
33 FRONT-DOOR 2014-06-01 07:31:49 0 0 4
34 ROOM-2 2014-06-01 07:32:06 0 1 6
35 FRONT-DOOR 2014-06-01 07:33:17 0 0 3
36 KITCHEN 2014-06-01 07:33:20 0 0 33
37 BACK-DOOR 2014-06-01 07:33:53 0 0 2
38 KITCHEN 2014-06-01 07:33:57 0 0 1
39 FRONT-DOOR 2014-06-01 07:33:59 0 0 1
40 ROOM-2 2014-06-01 07:34:13 0 56 25
41 FRONT-DOOR 2014-06-01 08:30:40 0 0 2
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Fig. 2. The data treated and interpreted with duration (hour-minute-second format).

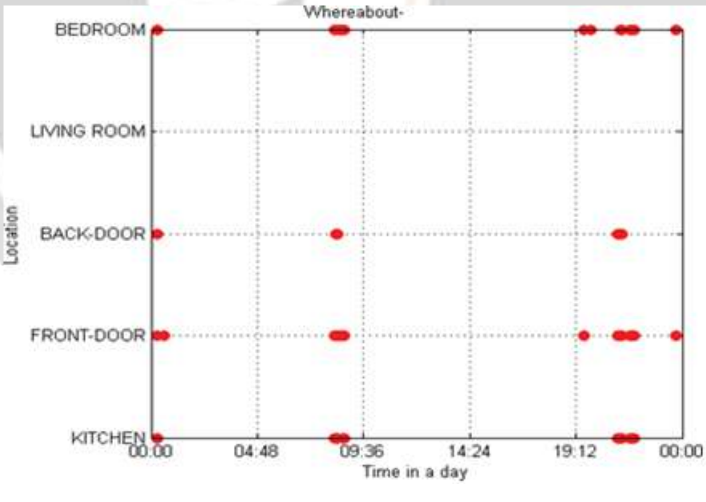

Fig. 3. The tenant is around what in the building

Additionally, the figures 4, 5, and 6 provide evidence of the duration of the occupant's presence, namely in the master bedroom, living room, and kitchen, respectively. It is noteworthy to observe that in early July 2023, the occupant of the premises dedicated a duration exceeding eight hours exclusively to the act of sleeping inside the confines of the master bedroom. Commencing on July 10th, 2023, the occupant of the designated area shown a progressive decrease in the amount of time spent sleeping inside the boundaries of such enclosure. One potential reason for this situation is that the occupant may designate a period of time for sleeping inside the confines of the common living area. The allusion to figure 5 implies that the occupant of the living room has, on average, allocated 8 hours per day in the room since July 10th, 2023. Based on the data shown in Figure 6, it is apparent that the average duration of time spent by the resident in the kitchen was 15 minutes, except for the timeframe spanning from July 5th, 2023 to July 8th, 2023, when the inhabitant's time spent in the kitchen surpassed one hour. The likely reason for this event might be linked to the occupant's involvement in food preparation for festive gatherings at that particular time.

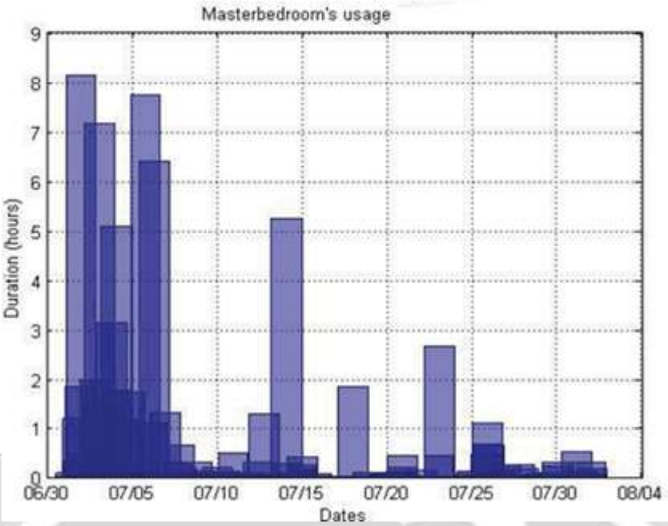

Fig. 4. Usages of Master bedroom

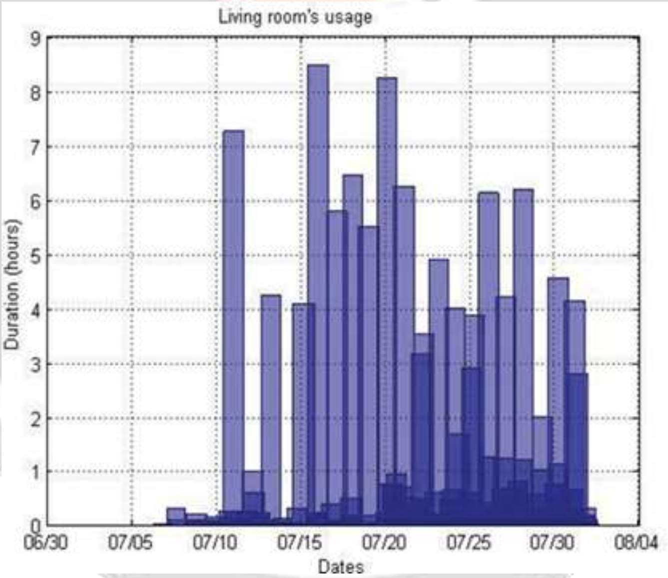

Fig. 5. Usages of living room

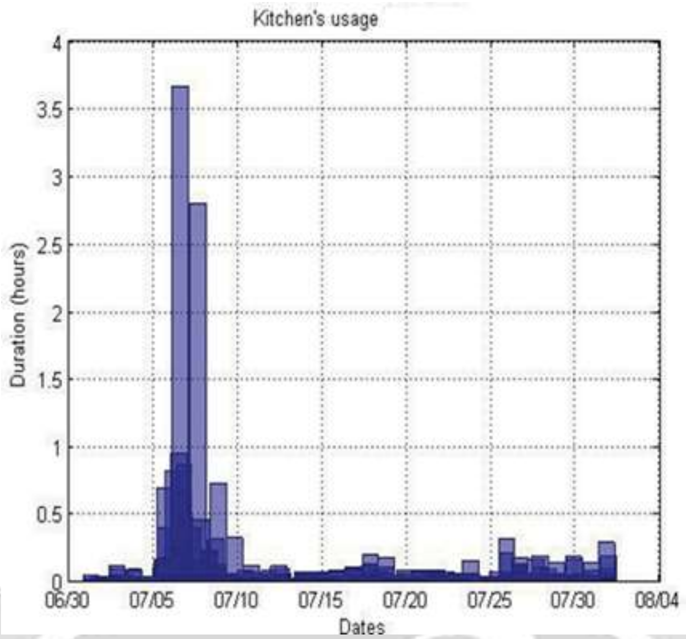

Fig. 6. Usages of Kitchen

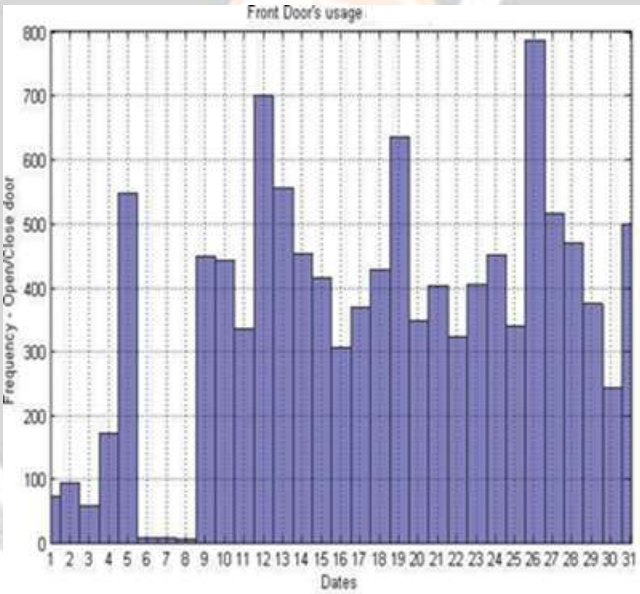

Fig. 7. Usage of front door's frequency

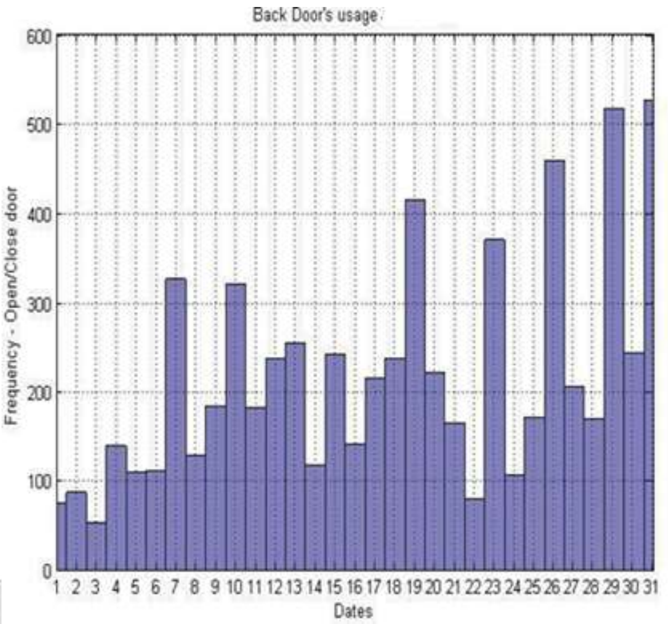

Fig. 8. Usages of Back door's frequency

Furthermore, Figure 7 presents the frequency of utilisation for the entry door, whilst Figure 8 portrays the frequency of utilisation for the back door. The data demonstrates that the use of doors was rather consistent throughout the month of July. Except for the time period spanning from July 6th to July 7th, the graph shows a decline in the frequency of using the front entrance. The observed decrease implies that the individual's level of participation in extracurricular pursuits was comparatively lower throughout this period. The primary function of the backdoor was to facilitate the disposal of waste materials and aid in the drying process of clothing. The analysis of the data shown in Figure 8 reveals a clear pattern indicating that the tenant consistently and equally favoured the back door for ingress and egress. The confidence level associated with the identification of the activity surpassed the threshold of 95% confidence.

IV. CONCLUSION AND FUTURE WORK

This research paper provides a first examination of the attributes of the Wellness System dataset. The data collected from the study show promise and indicate the potential to improve persons' capacity to engage in activities of daily living. The study found that the accuracy of activity detection was 97.5%. The observed occurrence is not consistent with the expected behavioural pattern. In order to effectively evaluate the behavioural pattern, a more sophisticated methodology is required, which entails integrating sensor data. The datasets including information about Electronic and Electrical (E&E) appliances will undergo further processing and annotation. This will include the addition of a time-stamp, which will aid in the integration of sensor data fusion methods. Furthermore, the primary objective of this project is to construct a suitable data mining model for a wellness dataset with the purpose of predicting trends and future values.

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