Towards Hajj and Umrah Digital Transformation Using Smartwatches

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Abstract: Many of us now rely on smartwatches as an integral part of our lives. The smartwatch market has become one of the world's most popular and best-selling markets. They have been used in various fields like health and sports. They have valuable features that assist people in their daily lives. With Hajj and Umrah undergoing digital transformation, smartwatches can be used to enhance pilgrims' experience during sacred rituals. NUSK is a smartwatch launched by (SDAIA) in Hajj season 1442 AH (2021) to provide several services like displaying pilgrims' information and health status, monitoring their health data, and requesting emergency medical or security assistance. It is vital to develop similar projects and build upon the success of NUSK. Hence, this work uses "Bangle.js", an open-source (sw/hw) smartwatch, to present some Hajj and Umrah applications to enhance the pilgrim's experience in the sacred journey and to help achieve our country's ambitious vision towards Hajj and Umrah digital transformation. We also propose incorporating "Bangle.js" into the labs of microprocessor courses at Saudi Computer Colleges to allow students to broaden their skills, abilities, and thinking toward real-life applications facilitating digital transformation.

Keywords: Digital Transformation, Smartwatches, Smart Hajj, Smart Umrah, Auto Tawaf.

نحو التحول الرقمي للحج والعمرة باستخدام الساعات الذكية

الملخص: يعتمد الكثير منا الآن على الساعات الذكية كجزء لا يتجزأ من حياتنا. أصبح سوق الساعات الذكية أحد الأسواق الأكثر شهرة والأكثر مبيعًا في العالم. لقد تم استخدامها في مجالات مختلفة مثل الصحة والرياضة. لديهم ميزات قيمة تساعد الناس في حياتهم اليومية. مع خضوع الحج والعمرة للتحول الرقمي ، يمكن استخدام الساعات الذكية لتعزيز تجربة الحجاج خلال الشعائر المقدسة *NUSK* .هي ساعة ذكية أطلقتها *(SDAIA)* في موسم الحج 1442 هـ (2021) لتقديم العديد من الخدمات مثل عرض معلومات الحجاج وحالتهم الصحية ، ومراقبة بياناتهم الصحية ، وطلب المساعدة الطبية أو الأمنية الطارئة. من الضروري تطوير مشاريع مماثلة والبناء على نجاح *NUSK*. ومن ثم ، يستخدم هذا العمل *"Bangle.js"*، وهي ساعة ذكية مفتوحة المصدر *(sw / hw)* ، لتقديم بعض تطبيقات الحج والعمرة لتعزيز تجربة الحجاج في الرحلة المقدسة وللمساعدة في تحقيق رؤية بلدنا الطموحة تجاه الحج والعمرة. التحول الرقمي. نقترح أيضًا دمج *"Bangle.js"* في مختبرات دورات المعالجات الدقيقة في كليات الكمبيوتر السعودية للسماح للطلاب بتوسيع مهاراتهم وقدراتهم وتفكيرهم تجاه تطبيقات واقعية تسهل التحول الرقمي.

1. Introduction

As scientific and economic studies indicate, the smartwatch market is witnessing significant and remarkable development. The global smartwatch market was valued in 2019 at $20.64 billion and is expected to reach $96.31 billion by 2027. With a compound annual growth rate (CAGR) of 19.6%, the smartwatch market has become one of the world's most popular and best-selling markets [1]–[3]. These enormous numbers indicate the heavy reliance on smartwatches at present and the extent of their growth over the next few years to include a broader range of users than it is today. Smartwatches' applications and use cases vary in many fields due to the services and features they provide, starting from the fields of sports and health to more complex fields such as personal assistants and artificial intelligence applications [4], [5]. Undoubtedly, this diversity provides a wide range of applications that can be developed to improve the worshipper's experience in Hajj and Umrah.

The Kingdom of Saudi Arabia is moving towards a comprehensive digital transformation in all governmental fields and services. The numbers indicate that it has made great leaps and gains. The Kingdom is the seventh globally in financing technical development. Also, it is the ninth in the development of technology and digital transformation, as mentioned in the annual report on global competitiveness (IMD) [6]. Undoubtedly, the Hajj and Umrah sectors have always gained significant attention from the Saudi government. They are cornerstones in the process of digital transformation for the Kingdom, as it aims to employ digital transformation to maximize the services provided to the pilgrims [7]–[9].

Digital transformation in Hajj and Umrah requires a thorough procedure for updating the vision and strategy of all agencies working in the Hajj and Umrah sectors by replacing traditional procedures with digital and automated ones [10]. This paper uses "Bangle.js", an open-source (hardware/software) smartwatch, to provide applications and services to pilgrims. The Hajj and Umrah include many services that smartwatches can enhance and facilitate to expedite the desired digital transformation and enhance the pilgrims' experience. To the best of our knowledge, no previous work has explored and paved the way for using smartwatches in Hajj and Umrah digital transformation besides "NUSK" and this work.

2. Related Work

The smartwatch market is relatively new, as Microsoft launched the first smartwatch, "SPOT," in 2004 [11]. The Google Trends website also shows that the term "smartwatch" is relatively new and has gained much attention recently, as shown in Figure 1 [12].

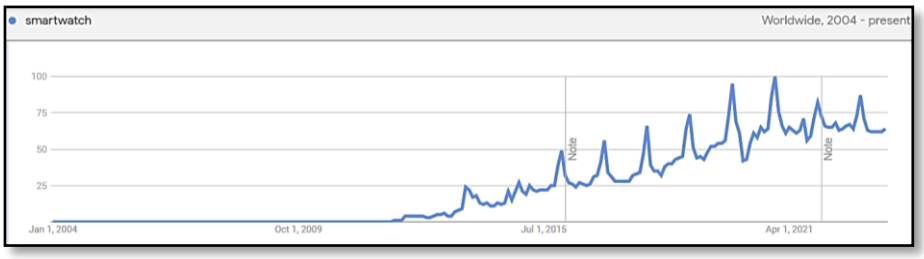

Figure 1. The trend of the keyword "Smartwatch" in Google Search over time [12].

Thus, the first real experience of using smartwatches in Hajj, as far as we know, was in the Hajj season of 1442 AH (2021) when the Saudi Authority for Data and Artificial Intelligence, in cooperation with the Doyof Al Rahman Program, and STC, launched the smartwatch "NUSK" in its trial version, with about 5,000 smartwatches distributed to pilgrims [13], [14]. "NUSK" provides various services, including the pilgrim's personal information, immunity status, and health data monitoring by measuring blood oxygen and heartbeat. Furthermore, it allows the pilgrim to request assistance from the camp supervisor and provide medical emergency or security assistance from official government agencies to accelerate access to their location and rescue operations. The smartwatch sends awareness messages and alerts to pilgrims [15]–[17]. This paper uses "Bangle.js" smartwatch to mimic "NUSK", build upon its success, and suggest new directions in Hajj and Umrah digital transformation using smartwatches.

3. Current Applications

As far as we know, this section shows all mobile applications used in Hajj and Umrah that can be implemented in smartwatches. These apps cover several fields, like health and navigation.1

a. Health Applications

"Aseifni" is a mobile application that provides multiple services, including reporting a health condition and making emergency calls. The application is capable of tracking emergency cases using the mobile's GPS. It also provides first aid instructions and other services, such as locating the nearest pharmacies or hospitals [18], [19].

b. Navigation Applications:

"Tarwiyah" is a mobile application that provides a map of Al-Mashaer (Holy sites) showing drinking water fountains, toilets, camps, and sacred locations. The map also shows the distributors of Zamzam water in Makkah, Madinah, and Jeddah [18].

c. Hybrid Applications:

This subsection presents various applications that provide miscellaneous services that cannot be categorized in one section like the abovementioned two. "Manasikana" is an official application introduced by the Ministry of Hajj and Umrah. The application provides many services in many languages, such as supplications, prayer timings, Qibla direction, weather, navigation, currency conversion, and notifications. This application helps pilgrims find their lost peers using the navigation capability [18].
"Al-Haramain" is an official application introduced by the Ministry of Hajj and Umrah. The application answers the worshipper's questions live via audio and video in different languages and shows if the Holy Mosques are crowded or not. The worshipper can also request a wheelchair. It also provides the usual services like Hajj and Umrah rituals guide, supplications, prayer times, and navigation [18].

d. Suggested Applications:

This section shows suggested applications that could be useful in Hajj and Umrah, especially if developed for smartwatches. These proposed applications can benefit and assist pilgrims, camps, and organizations [18], [20].

Pilgrims & Camps.

One of the ideas that can be used to help the pilgrims or camp leaders is location tracking via the smartwatch's GPS. For example, it is possible to monitor the pilgrim while offering their rituals inside the two holy mosques, providing a solution for camp leaders to quickly find lost pilgrims and direct them to the nearest gathering center.
Pilgrims also need to determine the direction of Qibla, indoor or outdoor, to pray in the right direction. Determining the Qibla outdoors is usually highly accurate. However, determining it indoors is still an open challenge.

Organizations.

One of the practical applications that can be used in Hajj and Umrah is Big Data analytics. If distributed at a large scale, the smartwatch could be a great source of data collection that could help various organizations managing Hajj and Umrah make better decisions and predict future patterns and scenarios, besides the fact that it would be a memorable souvenir documenting the sacred journey for the pilgrim. For example, if smartwatches were used in Tawaf (circumambulation around Kaaba), they would help the decision-maker count the number of worshippers and predict future Tawaf patterns throughout the year.

4. Implementation

As mentioned previously, many applications can be developed using smartwatches to help in Hajj and Umrah. We will showcase four applications using "Bangle.js", an open-source (hardware/software) smartwatch released in 2019. It has a 64 MHz ARM Cortex-M4 processor with Bluetooth LE, 64 KB RAM, 512 KB on-chip flash, and 4 MB external flash. In addition, it has several sensors like a heart rate monitor sensor, a GPS receiver, and an accelerometer.
Moreover, various open-source applications can be installed from the smartwatch website, while new applications could be developed from scratch using JavaScript or Blockly languages [21].

The first step to developing an app and uploading it to "Bangle.js" is writing the code in the "Espruino" Web IDE [22] or the emulator using JavaScript, as shown in Figure 2.

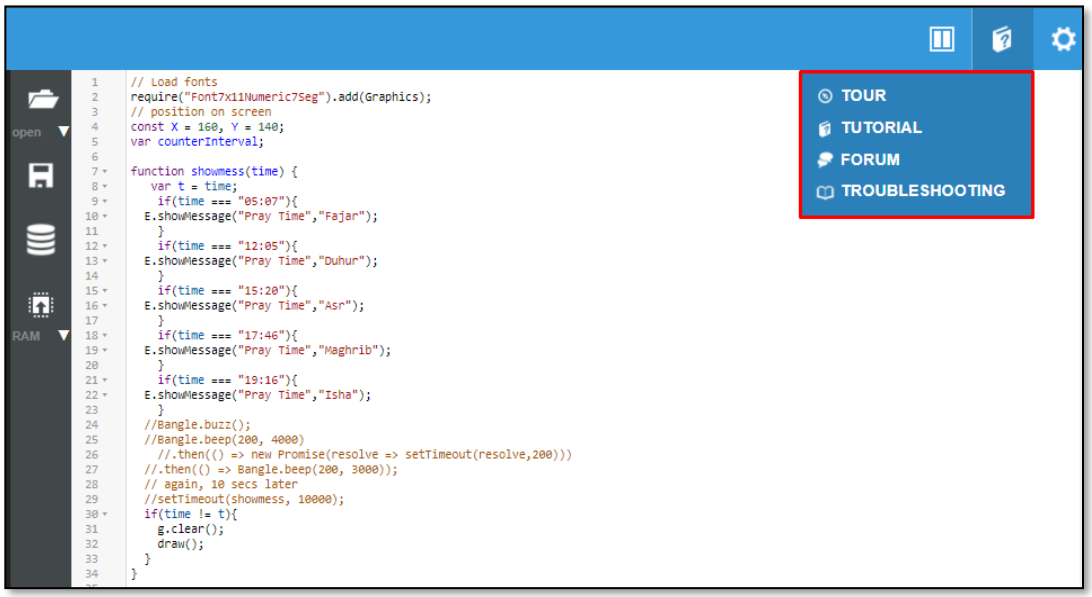

Figure 2. A screenshot of a code written in the "Espruino" Web IDE.

After writing the app in the "Espruino" Web IDE, the app must be uploaded to the app loader by forking the existing "Bangle.js App Loader" and enabling GitHub pages, as shown in Figure 3.

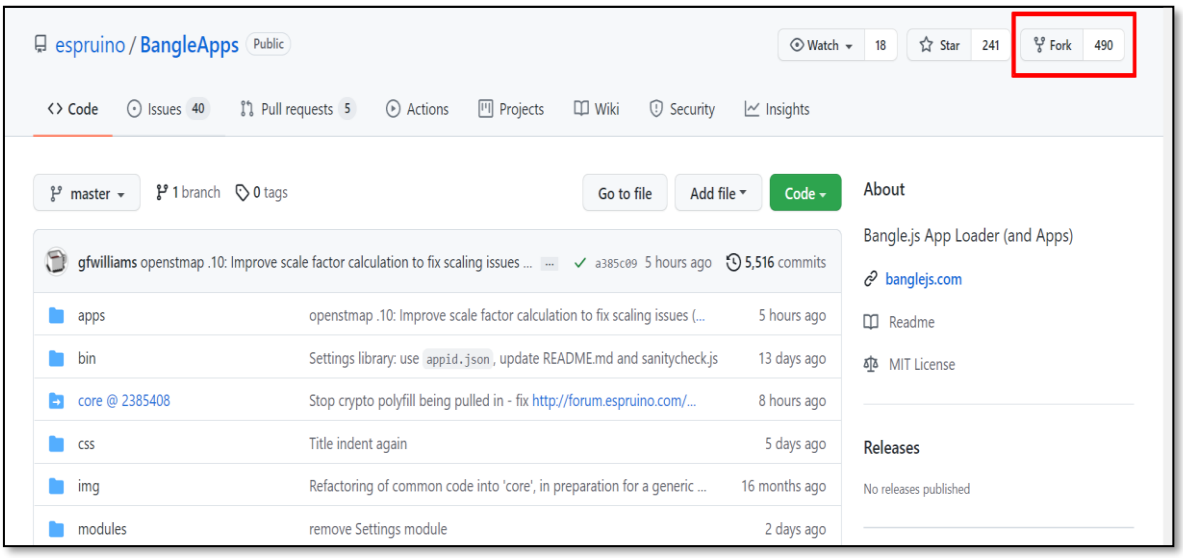

Figure 3. Forking "Bangle.js" apps on GitHub.

Finally, after uploading the files to GitHub, the app is added to the app loader as an object in an "apps.json" file on GitHub, as shown in Figure 4.

```
},
{ "id": "timer",
  "name": "My Timer App",
  "shortName":"My Timer",
  "icon": "app.png",
  "version":"0.01",
  "description": "This is a description of my awesome timer app",
  "tags": "",
  "storage": [
    {"name":"timer.app.js","url":"app.js"},
    {"name":"timer.img","url":"app-icon.js","evaluate":true}
  ]
}
]
```

Figure 4. A screenshot of an app's json file.

For research reproducibility and educational purposes, we shared the codes of the following four applications on GitHub "Daqiqah SmartWatch" repository [23] and made an Arabic video on YouTube explaining how to use the smartwatch and develop apps on it briefly [24].

a. First Application: (Watch Interface & Prayer Time Alarm)

There is no doubt that many applications can determine prayer times. However, most of them are available on mobile applications only, unsuitable for working in smartwatches. Some of them lack accuracy in calculating the prayer time compared to Umm Al-Qura calendar, the official calendar of the Kingdom of Saudi Arabia. We developed a smartwatch application to generate prayer times identical to Umm Al-Qura calendar. At first, we searched the Internet for the calculation method used in Umm Al-Qura calendar for prayer times. Unfortunately, we did not find the correct calculating method identical to the one adopted by Umm Al-Qura calendar. We have found some sources that provide Umm Al-Qura calculation method, but when tested, we found that they are not identical.

Since the primary goal of this application is that the prayer times should be 100% identical to Umm Al-Qura calendar, and in the absence of an exact and correct Umm Al-Qura calculating method code or API, we have used the lookup table method. We chose the city of Makkah and created a lookup table that includes the five daily prayer times and sunrise times from the beginning of 2022 to the end of 2025. Figure 5 shows screenshots of the application's interface.

Figure 5. Screenshots of "Bangle.js" showing the Prayer Times interfaces.

We got the official prayer times and the Hijri dates from the official Umm Al-Qura calendar website [25]. Then we divided the collected data into four tables, each year having its own table. Each table starts from the first day of that year to the last day of the same year. Thus, we have four tables with ten columns: the Gregorian day of the year, five daily prayer times, sunrise times, and corresponding Hijri dates (day, month, and year). Figure 6 presents a sample of the 2023 lookup table for Makkah prayer times. Figure 7 shows the flowchart of the app. The code is here [26].

```
function  lookupTable2023(x)  {

      day= {
1  : " 05:38 06:58 12:25 03:29 05:50 07:20 8 06 1444 " ,
2  : " 05:38 06:58 12:25 03:30 05:51 07:21 9 06 1444 " ,
3  : " 05:38 06:59 12:26 03:30 05:52 07:22 10 06 1444 " ,
4  : " 05:39 06:59 12:26 03:31 05:52 07:22 11 06 1444 " ,
5  : " 05:39 06:59 12:26 03:32 05:53 07:23 12 06 1444 " ,
6  : " 05:39 06:59 12:27 03:32 05:54 07:24 13 06 1444 " ,
7  : " 05:39 07:00 12:27 03:33 05:54 07:24 14 06 1444 " ,
8  : " 05:40 07:00 12:28 03:34 05:55 07:25 15 06 1444 " ,
9  : " 05:40 07:00 12:28 03:34 05:56 07:26 16 06 1444 " ,
10  : " 05:40 07:00 12:29 03:35 05:56 07:26 17 06 1444 " ,
```

Figure 6. A snippet of the lookup table code for Makkah Prayer Times in 2023.

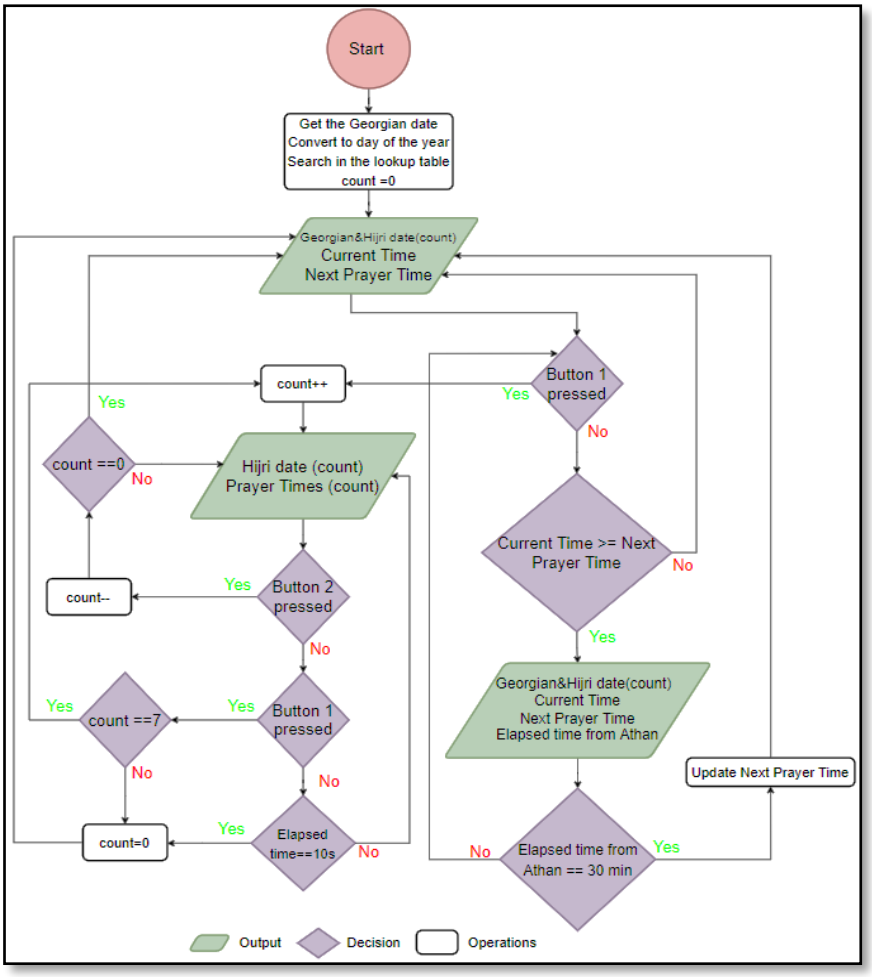

Figure 7. The flowchart of the Athan app.

b. Second Application: (Tawaf Counter)

Tawaf (circumambulation around Kaaba) counter is an application that automatically counts the number of rounds using the smartwatch's GPS sensor. The worshipper will start the Tawaf by setting the starting point. The center of the screen displays the number of rounds, it also displays how far the worshipper is from the starting point. After completing the seven rounds, the app will display "Taqabal Allah" (May Allah accept), indicating the end of Tawaf. As far as we know, no previous work has implemented an automatic Tawaf counter. Figure 8 displays a screenshot of the application's interface when tested in the Holy Mosque.

Figure 8. Screenshots of "Bangle.js" showing the Tawaf counter's interface before and after a round.

In addition, the app can also guide the worshipper to reach known sacred places like Mina, Muzdalifa, and Arafat and inform the worshipper if they are within their sacred boundaries or not. Figure 9 shows how the Tawaf counter works. The green line indicates the starting point, "beginning of Tawaf", which the worshipper determines by pressing the middle button. The grey circle is the range in which the round is incremented on the smartwatch screen automatically every round. It is a circle because the worshipper might reach the end of the Tawaf round from any direction or point as far as they are within less than 30m. The app saves the previous and present destinations to prevent false incrementing while still in the grey circle. Figure 10 displays the app's flowchart. The code is here [27].

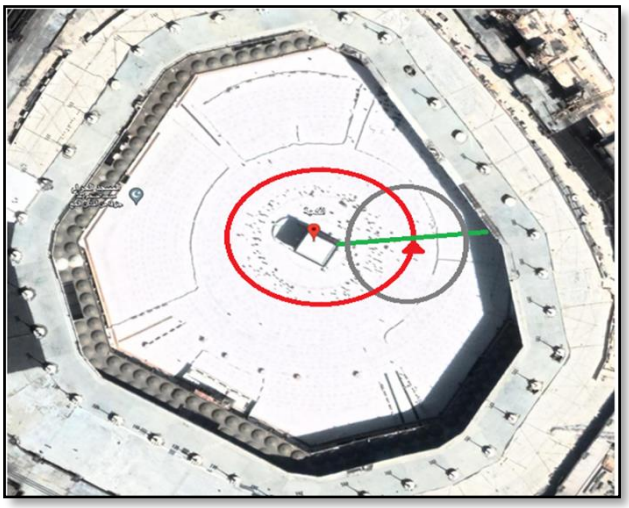

Figure 9. Tawaf counter mechanism.

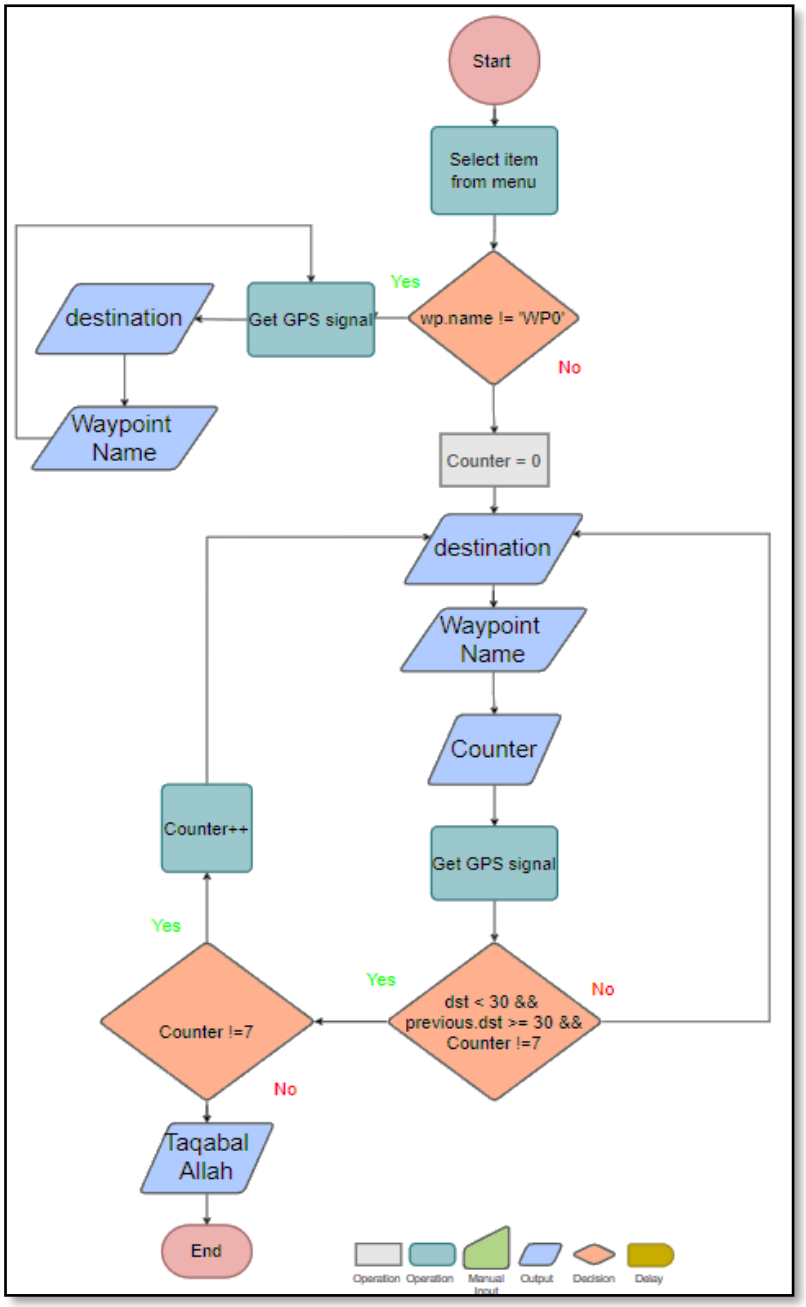

Figure 10. The flowchart of the Tawaf app.

c. Third Application: (Heartbeat Monitor)

The heart rate monitor is another helpful app for the smartwatch, as it allows the heart rate to be read, and a widget record the rates in the background, which helps to determine the health status of the pilgrims and to analyze health indicators based on them, we develop and modify an existing application form “Bangle.js” community app-loader [28]. Figure 11 shows a screenshot of the edited code and the application interface.

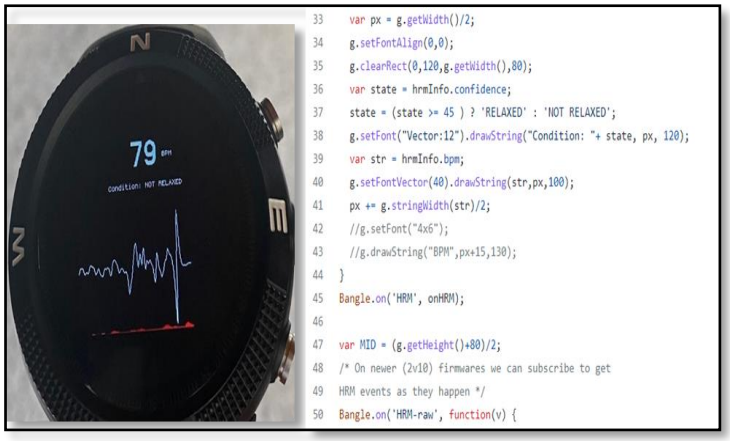

Figure 11. A snippet of the code and the application interface of the Heartbeat Monitor app.

Future work might consider using machine learning to detect whether the pilgrim has a heart attack based on the recorded heart rates in the application and then send an emergency signal to authorities to rescue them as soon as possible. Figure 12 displays the flowchart of the app. The code is here [29].

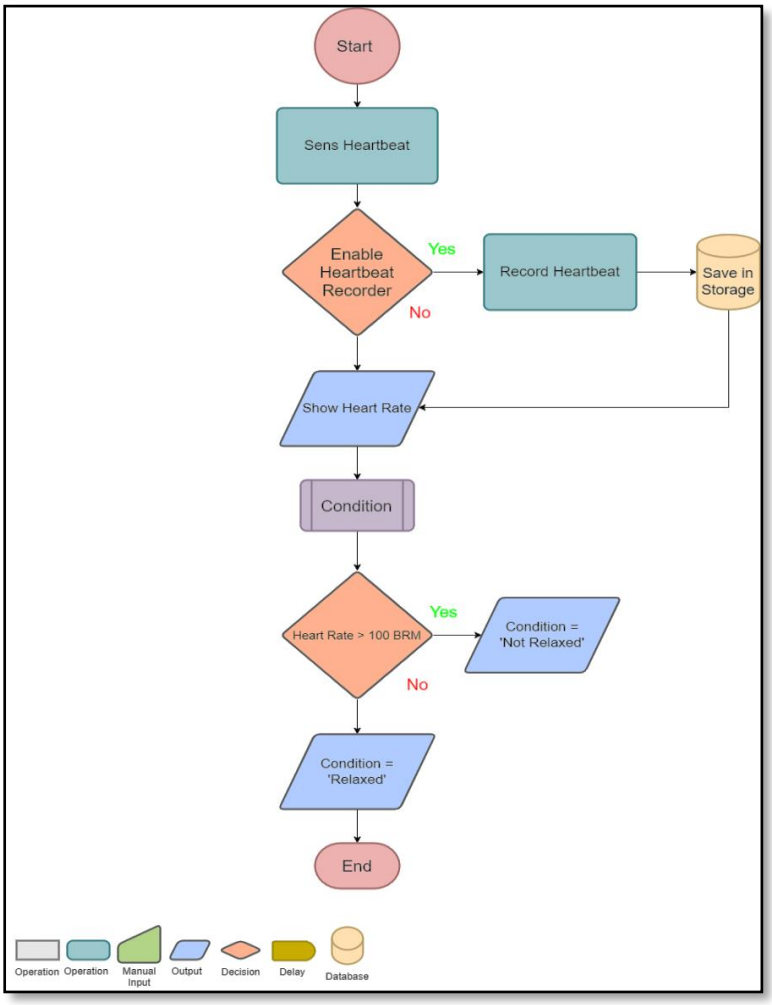

Figure 12. The flowchart of the Heartbeat Monitor app.

d. Fourth Application: (Misbahah)

Misbaha is an application to help the worshipper with Tasbeeh, which resembles the actual dhikr beads. Every 33 counts, the watch beeps to alert the user. Figures 13 and 14 show a snippet of the application code and its flowchart. The code is available here [30].

```
setWatch(() => {
  g.clear();

  counter += 1;
  if(counter==33){
Bangle.buzz(200, 1);


  }
  if(counter==66){
Bangle.buzz(200, 1);


  }
  if(counter==99){
Bangle.buzz(200, 1);



  }


  if(counter==101){

    counter=0;
  }
  updateScreen();
}, BTN1, {repeat:true});
```

Figure 13. A snippet of the code of the Misbahah app.

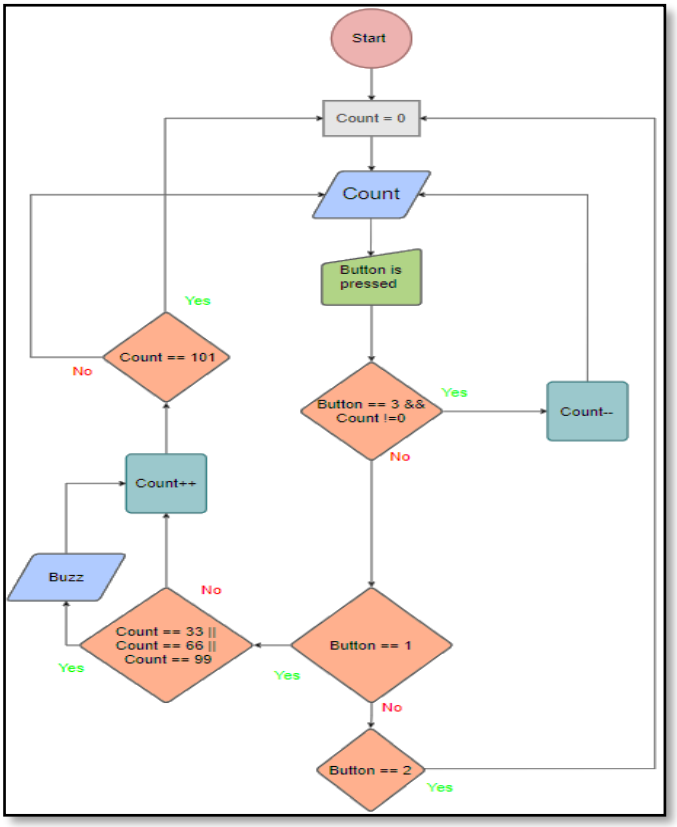

Figure 14. The flowchart of the Misbahah app.

5. Conclusion & Future Work

This paper presented the importance of using smartwatches in Hajj and Umrah. In addition, we mentioned and presented various smartwatches applications, many features, and capabilities that smartwatches could provide in Hajj and Umrah to enhance the pilgrim's experience and facilitate attaining the vision of our country towards digital transformation in Hajj and Umrah. Except for "NUSK" and this effort, no previous work has studied and opened the ground for adopting smartwatches in Hajj and Umrah digital transformation. Although this paper showcases some smartwatch applications, many could be developed dramatically. For example, adding multiple languages to the smartwatch is vital for future work. In addition, updating the prayer times based on the current location automatically is another potential future work.

Regardless of the type and service of the developed applications, smartwatches and internet-of-things gadgets would not only be an accelerator towards digital transformation and enhancing the pilgrims' experience at the Sacred Sites; they would also be a great source of data collection that could help countless organizations managing Hajj and Umrah to make smarter decisions and predict future patterns provided the glory of artificial intelligence and machine learning in particular [31], [32].

This work is part of our capstone project (graduation project) requirement in the Computer Engineering Department at Umm Al-Qura University. We believe that using open-source smartwatches such as "Bangle.js" in microprocessor courses will significantly broaden students' perceptions, skills, and abilities towards creating and developing real-life applications that would put our academic knowledge into practice while enabling a future generation capable of attaining the Saudi Vision 2030 and the fourth industrial revolution.

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