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Wearable Technologies for Healthcare in Sports

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Gusare Lalisa Ejeta	**Wearable Sensors:** • Wearable sensors application in sports • Device that use wearable sensors for HAR • Global companies involved in wearables **Wearable sensors based HAR for sport related healthcare:** • Data from sensors • Workflow of wearable sensor based HAR system for sport application

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Hadero Besufekad Tadele	**Applying this system in Africa** • Estimated budget and importance of the system • HAR system prototype showcase **PPT preparation**

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Abstract

Sports related health issues are a growing concern in developing countries, particularly in Africa, where limited healthcare resources and infrastructure exacerbate the impact of injuries on athletes. To address this problem, wearable technologies have emerged as a promising solution for early health problem detection and prevention. In this project, we propose an innovative approach that combines wearable devices with Human Activity Recognition (HAR) techniques to monitor athletes' movements and identify potential health risks. The HAR algorithms will be developed using deep/machine learning methods, to classify different activities and detect abnormal patterns that may indicate health issue. The ultimate goal of this project is to provide a cost-effective and accessible solution that can improve the safety and performance of athletes in developing countries, while also reducing the burden on healthcare systems.

Keywords: HAR, injuries, wearable technologies, Africa

Chapter 1 Introduction

1.1. Popular sports in Africa

Africa is a diverse continent with many different countries, cultures, and traditions. Africa has successfully upheld the standard by producing internationally renowned sports icons. The sporting sector has an enduring beneficial impact on the African economy. Today, Africa has an equal chance to host prestigious international sporting events that have elevated the continent's standing in the world of sports. By dominating various sports disciplines and becoming well-known international sports figures, notable African athletes have enhanced the image of their region. The variety of sports being played on the continent offers a level playing field for various groups of people with various interests. There are several popular sports in Africa that are enjoyed by people from different parts of the continent.

1.1.1. Football

Football, also known as soccer, is one of the most popular sports in Africa. The game has a rich history on the continent and has played an important role in shaping African culture and identity. The history of football in Africa can be traced back to the colonial period when European powers introduced the sport to the continent. In the early years, football was played mainly by European expatriates, but it soon gained popularity among Africans. By the 1920s, the sport had spread to all corners of the continent, and African teams were competing against each other in regional tournaments.

Fig 1-1 Football

Today, football is played by millions of Africans at all levels, from grassroots to professional. Many African countries have established football leagues, and their national teams have achieved international recognition. African players have also made their mark on the global stage, with some of the world's best players coming from the continent. Football has become more than just a sport in Africa. It has become a cultural phenomenon that brings people together and unites communities. In many African countries, football is a source of national pride, and the success of the national team is of great importance. During major tournaments such as the African Cup of Nations and the World Cup, the whole continent comes together to support their teams and celebrate the game. In addition to its cultural significance, football has also had a significant impact on the continent's development. The sport has created employment opportunities for many people, from players to coaches to support staff. It has also brought in significant revenues through ticket sales, sponsorships, and media rights. These revenues have been used to fund infrastructure projects, education, and healthcare, among other things.

Generally, football is a significant part of African culture and identity. It has brought people together, created employment opportunities, and contributed to the continent's development. While there are challenges that need to be addressed, the future of football in Africa looks bright, and the sport is sure to continue to play an important role in shaping the continent's culture and identity.

1.1.2. Athletics

Athletics is a popular sport in Africa, producing some of the world's top athletes. African athletes have dominated long-distance running events such as marathons and middle-distance events for many years. Athletics is an essential part of African culture, and it is not uncommon to find people from all walks of life engaging in running or jogging for exercise. The history of athletics in Africa can be traced back to the early 20th century when Europeans introduced the sport to the continent. Athletics quickly gained popularity among Africans, and it was not long before the continent started producing world-class athletes. African athletes have dominated various international events, including the Olympic Games, the World Championships, and other major global sporting events. One of the reasons why African athletes excel in athletics is their physical attributes. Africans are known for their lean and muscular bodies, which are well-suited for long-distance running. The continent's high altitude also plays a significant role in the success of African athletes. Many African countries, especially those located in the highlands, have altitude training centers that enable athletes to train at high altitudes and improve their

endurance. Another factor that contributes to the success of African athletes in athletics is their training regimen. Many African athletes come from humble backgrounds and are trained in rudimentary facilities.

Fig 1-2 Athletic

However, their determination, hard work, and dedication have seen them achieve great success in athletics. African athletes are known for their discipline and work ethic, which is crucial in the sport of athletics. Athletics has also provided a platform for social change in Africa. The sport has enabled athletes to transcend social and economic barriers and succeed despite their backgrounds. Athletics has also been used to raise awareness about social issues such as poverty, disease, and gender inequality.

Generally, athletics is an essential part of African culture and has produced some of the world's top athletes. African athletes excel in long-distance running events, and their physical attributes, training regimen, and work ethic have contributed to their success. Athletics has also provided a platform for social change in Africa. However, the sport still faces several challenges, including inadequate facilities and funding. Addressing these challenges will enable African athletes to continue excelling in athletics and contribute to the continent's development.

1.1.3. Wrestling

Wrestling is a sport that has been practiced in Africa for centuries, and it continues to be popular today. Historically, wrestling in Africa was often used as a way to settle disputes between communities or individuals. Wrestling matches would be held as a way to determine the winner of a conflict without resorting to violence. This tradition is still practiced today in many parts of Africa, particularly in rural areas. In addition to its use as a means of conflict resolution, wrestling also has cultural significance in many African societies. Wrestling matches are often accompanied by music, dance, and other cultural traditions. Wrestlers may wear

traditional clothing or ornaments, and matches may be held during cultural festivals or other important events. One of Africa's most famous styles of wrestling is Senegalese wrestling, also known as Lutte Traditionnelle. This style of wrestling has become very popular in Senegal and other West African countries, and it has gained a following around the world. Senegalese wrestling matches are often held in large stadiums, and they are accompanied by music, dance, and other cultural traditions. Another popular style of wrestling in Africa is Nuba wrestling, which is practiced by the Nuba people of Sudan. Nuba wrestling is known for its acrobatic moves and athletic prowess, and matches are often held as part of cultural festivals or other celebrations.

Fig 1-3 Wrestling

Wrestling has also gained a following in other parts of Africa, including South Africa, Ethiopia, and Nigeria. In Nigeria, wrestling is known as kokawa, and it is often practiced as part of traditional cultural ceremonies. In recent years, African wrestlers have gained international recognition, competing in major wrestling tournaments around the world.

In conclusion, wrestling is a sport that has a rich history and cultural significance in Africa. From its use as a means of conflict resolution to its role in cultural festivals and celebrations, wrestling has played an important role in African society for centuries. Today, wrestling continues to be popular in many parts of Africa, and African wrestlers are gaining international recognition for their skills and athleticism.

1.1.4. Basketball, Cricket, Rugby and Boxing

Basketball is a growing sport in Africa, thanks in part to the success of African players in the NBA. The Basketball Africa League, a professional basketball league with teams from across the continent, was launched in 2021, and it is expected to further increase the popularity of the sport in Africa. Cricket is another popular sport in Africa, particularly in countries like South Africa, Zimbabwe, and Kenya. The sport was introduced to the continent by British colonizers, and it has since become a favorite pastime for many Africans. Rugby is a popular sport in South

Africa, and the national team, the Springboks, has won the Rugby World Cup three times. The sport has a significant cultural significance in South Africa, particularly in the context of the country's complicated history of race relations. Boxing is a sport that has produced many world-class African fighters, including Muhammad Ali and George Foreman. The sport has provided opportunities for many African boxers to escape poverty and become champions.

Generally, sports are an important part of African culture, and they have played a significant role in shaping the continent's identity. Football, athletics, basketball, cricket, rugby, and boxing are just a few of the many popular sports in Africa. These sports provide opportunities for Africans to showcase their skills, compete at the highest levels, and achieve success on the global stage.

1.2. Injuries related to sports in developing countries in Africa

According to available data, there is a significant difference in the incidence and prevalence of sports-related injuries between developing countries in Africa and developed nations. Several factors contribute to this difference, including disparities in access to healthcare, training and education, and sports infrastructure.

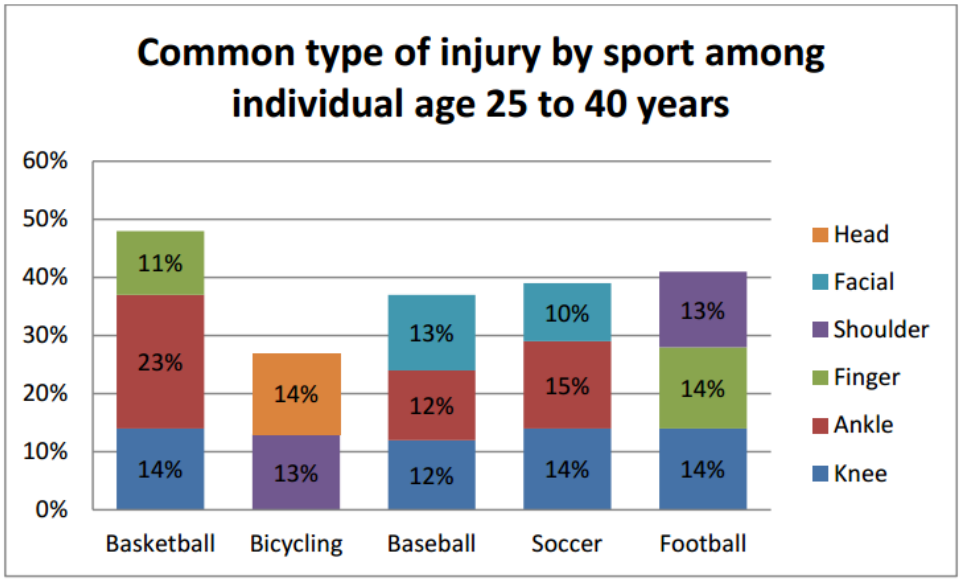

Fig 1-4 Common types of injury by sport

In developing countries in Africa, sports-related injuries are often underreported due to a lack of appropriate reporting systems and inadequate healthcare facilities. Additionally, the majority of sports activities in these countries are informal and unregulated, leading to a higher risk of injuries. Injuries are also more likely to occur due to poor playing conditions and equipment. The lack of infrastructure and resources in many African countries has made

it difficult for the sport to reach its full potential. Many talented players are unable to develop their skills because they lack access to proper training facilities and equipment. Especially, injuries related mistreatment of health conditions has plagued sport in Africa, leading to give up the training and competition for many players. Injuries are a major public health concern worldwide, and the burden of injuries in Africa is often higher than in developed countries. For instance, Rwanda and Swaziland reported severity injury between 1-28 days after a soccer match. As seen described in Fig 1-5, of the total injuries of the Rwandan population, the most common According to Figure 1-5, the majority of injuries sustained by Rwandan individuals were of moderate severity, which required them to stay away from playing soccer for 8-28 days. On the other hand, the least common injuries were slight, which only required 1-3 days away from soccer. In contrast, in the Swaziland population, the most commonly reported injuries were slight, which caused 1-3 days away from soccer, whereas the least common injuries were major, requiring more than 28 days away from soccer. Out of all the injuries suffered by people in Rwanda and Swaziland, 324 injuries were recorded. The injuries that were most commonly reported had a moderate severity level, which meant that the injured person had to take 4-7 days off from playing soccer. On the other hand, injuries that required more than 28 days away from soccer were the least commonly reported.

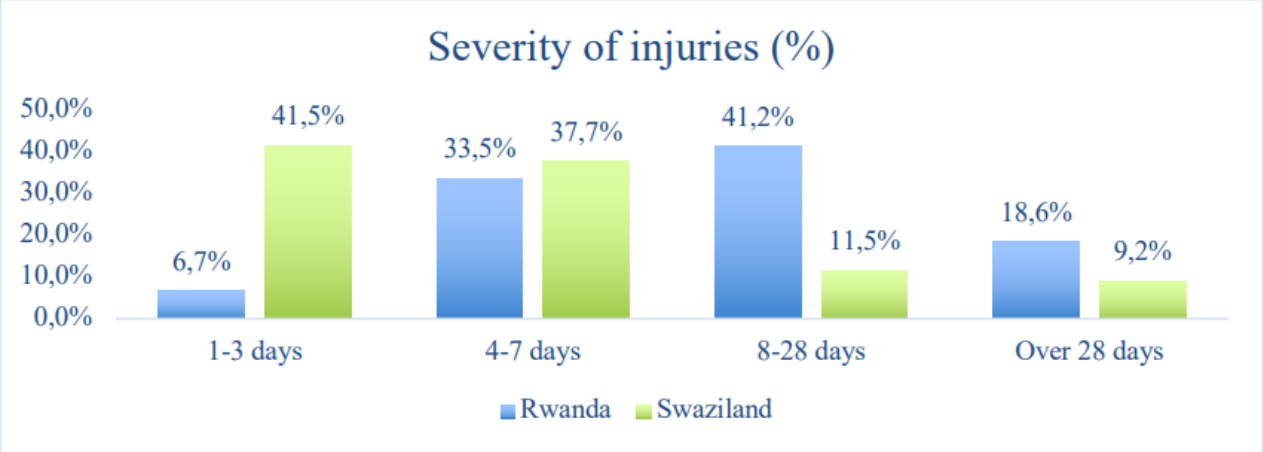

Fig 1-5 Severity of injuries described as percentages (%)

On the other hand, developed nations have more structured and organized sports activities, with better regulations and safety guidelines. This results in lower incidence rates of sports-related injuries. Developed countries also have better healthcare facilities and access to medical care, which allows for quicker and more effective treatment of sports injuries.

In conclusion, the statistics for sports-related injuries in developing countries in Africa

are generally higher than those in developed nations due to a variety of factors. However, more research is needed to fully understand the extent of the differences and how they can be addressed to improve sports safety in developing countries.

1.3. Objective

The objective of this work is to propose wearable sensor based human activity recognition system to create a more efficient and effective means of monitoring athletes' physical activity during training and competition, with the ultimate goal of improving their performance and reducing the risk of injury. This technology has great potential to enhance the overall health and well-being of athletes in developing countries, where access to advanced training and medical resources may be limited. By utilizing wearable sensors, coaches and trainers can collect real-time data on athletes' physiological parameters such as heart rate, respiration rate, and body temperature. They can also track their movements and posture during training and competition. With this information, coaches and trainers can detect any potential health risks or injuries that may arise and take necessary actions to prevent them.

In addition to injury prevention, wearable sensors can also provide valuable insights into the training regime of athletes. Coaches and trainers can analyze the data collected from the sensors to optimize the performance of athletes. For example, they can determine whether a particular exercise is more effective for a certain athlete or identify areas where an athlete needs to improve.

Overall, the development of a wearable sensor-based human activity recognition system has the potential to revolutionize sports training and performance in developing countries. By leveraging technology for early detection and prevention of health issues related to sports activities, coaches and trainers can enhance the overall well-being and longevity of athletes. The result will be a healthier, more successful athlete population, which will benefit not only individual athletes but also the sports community as a whole.

Chapter 2 Wearable sensors

2.1. Introduction to Wearable Sensors

Wearable sensors are small electronic devices that can be worn on the body or are integrated into wearable objects like clothing to measure and monitor various physiological and environmental parameters which help monitor health and provide clinically relevant data for care [1]. Such devices allow for the continuous monitoring of the biometrics of an individual in a non-invasive or minimally invasive manner, enabling the detection of small physiological changes from baseline values over time [2]. Wearables have existed for decades; for example, the Holter monitor, a medical sensor used for measuring the electrical activity of the heart, dates back to the 1960s [2].

The use of wearable sensors has grown significantly in recent years, driven by the increasing demand for real-time, continuous monitoring of health and well-being. Wearable sensors have applications in healthcare, sports, fitness, and wellness, among other fields. These sensors can track various activities such as motion, brain, heart, and muscle [3]. The use of wearable sensors in sports and other applications where human locomotion is concerned has grown steadily [4]. This rise in popularity can be attributed to several technological trends as well as the increasing sophistication of the field of biomechanics.

Body-worn sensors or wearable technology are attractive because of their potential to measure human movement unobtrusively in the ambulatory environment and their comparative cost when compared to laboratory-based equipment [4]. However, there are barriers to adoption, including limited availability, perceived validation of the technology, and the skill sets required to use the technologies effectively.

Athletic and clinical testing for performance analysis and enhancement has traditionally been performed in the laboratory, where the required instrumentation is available and environmental conditions can be easily controlled [4]. It is between these two environments that the interplay of environmental validity versus laboratory reliability must be carefully considered as new technologies, such as wearables, emerge.

Most research in this field, until about a decade ago, relied on exploiting rigid electronic devices developed in the semiconductor electronics industry. However, the recent focus has shifted to wearable sensing platforms that exploit stretchable and flexible electronics [1].

These flexible sensors have disparate mechanical properties, which makes their fabrication more challenging. Typical approaches to fabricating soft sensors comprise integrating

deformable conducting material patterns onto a stretchable substrate using various techniques such as transfer printing, screen printing, photolithography, microchannel molding, filling, and lamination [1]. There are many examples of wearable sensors. Some common examples include smartwatches, headsets, smart glasses, fitness trackers, jewelry, face masks, fitness bands, tattoo-like devices, bandages or other patches, and textiles [2, 5]. Other examples of wearable sensors include air quality and pollution sensors, blood pressure monitors, biometric authentication devices, glucose level monitors, and sweat sensors [6]. Popular commercially available wearable devices include wearable fitness trackers like Fitbit Charge 4, Amazfit Bip, and Garmin vívosmart 43 and smart health watches like Fitbit Versa 3, Samsung Galaxy Watch 3, and Apple Watch Series 63 [7].

Wearables such as smartwatches have already proven their capability for the early detection and monitoring of the progression and treatment of various diseases, such as COVID-19 and Parkinson's disease, through biophysical signals [2]. Next-generation wearable sensors that enable the multimodal and/or multiplexed measurement of physical parameters and biochemical markers in real-time and continuously could be a transformative technology for diagnostics.

2.1.1. Types of Wearable Sensors

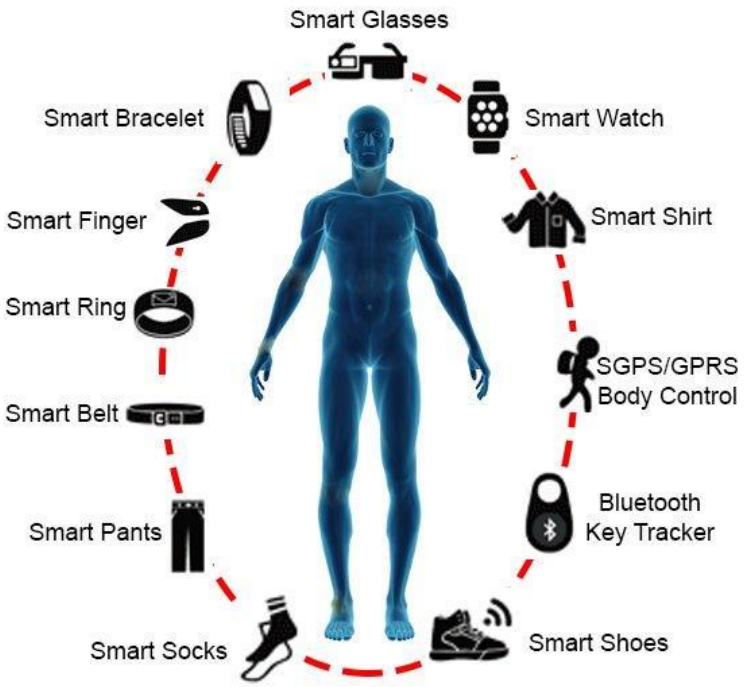

Fig 2-1 Different types of wearable technology

Wearable sensors can be categorized based on their sensing mechanism or the type of data they measure. Some common types of wearable sensors include:

Motion sensors: These sensors measure acceleration, velocity, and orientation of the body. Examples of motion sensors include accelerometers, gyroscopes, and magnetometers [8]. Inertial measurement units (IMUs) are another type of sensor included in wearable devices that collect and calculate data about human body activity. These sensors can capture snapshots of our day-to-day activity and update that information by syncing with mobile devices or laptop computers [2].

Biometric sensors: These sensors measure physiological parameters such as heart rate, blood pressure, skin temperature, and sweat. Examples of biometric sensors include electrocardiogram (ECG), photoplethysmogram (PPG), and galvanic skin response (GSR) sensors [9].

Environmental sensors: These sensors measure environmental parameters such as temperature, humidity, and air quality. Examples of environmental sensors include temperature sensors, humidity sensors, and gas sensors [9].

Table 2.1 the different types of wearable sensors.

Type of Sensor	Description	Examples of Applications
Accelerometers	Measures acceleration or movement	Fitness tracking, fall detection, gesture recognition
Gyroscopes	Measures rotational movement or orientation	Virtual reality, gaming, sports analytics
Magnetometers	Measures magnetic fields	Navigation, orientation, compasses
Temperature sensors	Measures temperature	Health monitoring, sports performance, comfort management

Heart rate monitors	Measures heart rate	Fitness tracking, health monitoring, stress management
Blood pressure monitors	Measures blood pressure	Health monitoring, medical diagnosis

Type of Sensor	Description	Examples of Applications
Electrocardiograms (ECGs)	Measures heart activity	Health monitoring, medical diagnosis
Electroencephalograms (EEGs)	Measures brain activity	Sleep monitoring, neurofeedback, medical diagnosis
Electromyograms (EMGs)	Measures muscle activity	Prosthetics, sports performance, rehabilitation
Skin conductance sensors	Measures changes in sweat gland activity	Stress monitoring, lie detection
Oxygen sensors	Measures oxygen levels in blood	Health monitoring, altitude training, sports performance
Ambient light sensors	Measures light levels	Sleep monitoring, energy efficiency, environmental controls

UV sensors	Measures UV radiation levels	Skin health monitoring, sun safety
Type of Sensor	**Description**	**Examples of Applications**
GPS	Measure’s location	Navigation, fitness tracking, safety monitoring

This list is not exhaustive, and there may be other types of wearable sensors not included here. Additionally, some sensors may have multiple applications beyond those listed.

2.1.2. Applications of Wearable Sensors

The applications of wearable sensors are diverse, and they are becoming increasingly popular in healthcare and wellness. Wearable sensors can provide real-time monitoring of various physiological parameters, which can be used to diagnose and manage chronic conditions such as diabetes, hypertension, and heart disease. They can also be used to monitor physical activity, sleep, and stress levels, which can help individuals improve their health and well-being [8]. Furthermore, wearable sensors can be applied in the areas of interactive gaming, performance monitoring, and navigation tracking.

Fig 2-2 Application of wearable devices in the healthcare and biomedical monitoring systems.

Wearable sensors also have applications in sports and fitness, where they can be used to track performance, prevent injuries, and optimize training. For example, wearable sensors can be used to monitor an athlete's heart rate, respiration, and motion during training and competition to help identify areas for improvement and prevent injuries [10].

2.1.3. Challenges and Future Directions

Despite the many benefits of wearable sensors, there are also challenges associated with their use. One of the biggest challenges is ensuring the accuracy and reliability of the data collected by these devices. Wearable sensors are subject to motion artifacts and environmental interference, which can affect the quality of the data they collect. Additionally, the vast amounts of data generated by wearable sensors require sophisticated algorithms for analysis and interpretation [9].

Fig 2-3 Challenges facing Wearable Technology

In the future, wearable sensors are expected to become even more sophisticated and versatile, with the ability to measure an even wider range of physiological and environmental parameters. Advances in sensor technology and data analytics will also improve the accuracy and reliability of the data collected by these devices. As wearable sensors become more integrated into healthcare and wellness, they have the potential to transform the way we monitor and manage our health [8].

2.2. Major advances in Wearable technologies and application

Wearable technology has become increasingly prevalent over the past decade. It has transformed from simple step counters to a vast array of sensors, devices, and systems that

monitor a wide range of health and fitness parameters. One of the driving forces behind this growth is the ongoing rollout of 5G, which enables many new types of data services, many of which will be delivered through wearables [11]. Today, researchers are making wearable technologies that can monitor many aspects of our health in real-time, detect health issues early, and provide personalized health recommendations [12]. More than 30 percent of people in the United States use wearable health tracking tools today — about half of them on a daily basis. These devices can track workouts and progress, particularly workouts that include distances, which has been a huge training breakthrough for many athletes. Wearables have also been used to monitor physical activity, which is a well-established marker of current health status and future health risks. Wearables for remote digital health and physical activity monitoring have been validated in various settings [13]. Wearable devices are also being integrated with other healthcare technologies, such as telemedicine and electronic health records (EHRs), to provide a more comprehensive approach to healthcare delivery. For example, wearable devices can collect data on an individual's vital signs and transmit this information to healthcare providers in real-time, enabling remote monitoring and early intervention [14].

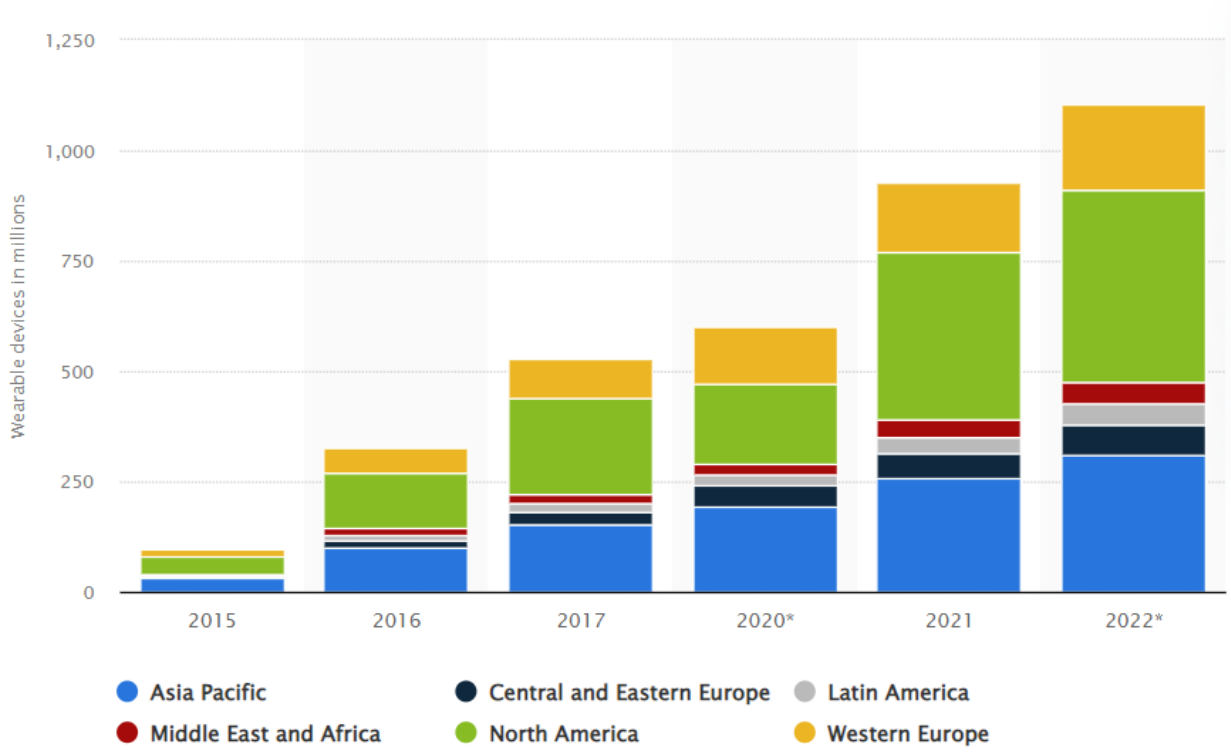

Fig 2-4 Number of connected wearable devices worldwide by region from 2015 to 2022

One of the significant advances in wearable technology is the development of devices that can monitor and record physiological parameters such as heart rate, blood pressure, oxygen

saturation, and respiration rate [15]. Wearable devices such as fitness trackers, smartwatches, and patches have made it possible for individuals to track their health status and receive feedback on their performance. In addition, medical professionals can use these devices to monitor patients' health status, track medication adherence, and detect early signs of medical conditions [16].

Another major advancement in wearable technology is the development of electroencephalogram (EEG) sensors that can monitor brain activity. EEG sensors can be used to diagnose and treat a wide range of neurological conditions such as epilepsy, sleep disorders, and anxiety disorders [17]. EEG sensors can also be used to monitor cognitive function and mental health. Wearable devices such as headsets and smartwatches equipped with EEG sensors can provide real-time feedback on cognitive performance and stress levels.

Many smartwatch makers are now adding blood oxygen (SpO2) sensors, ECG monitors, and other sensors to their devices as standard. These features provide warnings that something may be wrong with us, as well as the capability to analyze data over time and make suggestions about how we might improve our health [11].

Advances in wearable technology have also provided tools for early diagnosis of diseases such as congestive heart failure, prevention of chronic conditions such as diabetes, improved clinical management of neurodegenerative conditions such as Parkinson’s disease, and the ability to promptly respond to emergency situations such as seizures in patients with epilepsy and cardiac arrest in subjects undergoing cardiovascular monitoring [18].

Another significant advance in wearable technology is the development of digital biomarkers, which are measurable indicators of physiological or behavioral characteristics that can be detected by wearable sensors. Digital biomarkers have the potential to improve clinical trials by providing more accurate and objective measurements of disease progression and treatment outcomes. For example, wearable sensors can detect changes in gait patterns or tremors in patients with Parkinson’s disease, providing a more precise assessment of disease severity and treatment response [19].

Smart clothing is another significant advancement in wearable technology. Smart clothing is embedded with sensors that monitor vital signs, body temperature, and activity level [68]. The data collected can be used to detect early signs of medical conditions and monitor the recovery process after surgery. Smart clothing can also be used in the sports and fitness industry to monitor performance, reduce the risk of injuries, and optimize training. Furthermore, advances in wearable technology have also led to the development of smart fabrics, which are textiles that

can sense and respond to changes in the environment or wearer. Smart fabrics have a wide range of potential applications, including healthcare, sports, and fashion. For example, smart fabrics can be integrated into clothing to monitor an athlete's heart rate and hydration levels during a game, providing real-time feedback to coaches and trainers [11].

Another major advance in wearable technology is the integration of artificial intelligence (AI) and machine learning algorithms. AI-powered wearable devices can analyze vast amounts of data collected from sensors and provide personalized recommendations to users to improve health and fitness. Wearable devices can monitor an individual's heart rate, activity level, and sleep patterns, and use this data to provide tailored recommendations for improving their overall health and wellness [11]. For example, AI-powered wearable devices can detect patterns in sleep quality and provide recommendations to improve sleep habits [21].

In conclusion, wearable technology has made significant advances over the past decade. These advancements have led to the development of wearable devices that can monitor a wide range of physiological parameters, diagnose and treat neurological conditions, monitor cognitive function, and optimize athletic performance. The integration of AI and machine learning algorithms has further expanded the applications of wearable technology. As wearable technology continues to evolve, we can expect even more innovative applications in various fields.

2.3. Applications of wearable sensors in sport

I. Performance Analysis

Performance analysis using wearable sensors involves placing sensors on an athlete's body to track their movements and collect data on various parameters such as speed, acceleration, and body posture. This data can be analyzed in real-time to provide feedback to athletes and coaches on areas for improvement. For example, if a sensor detects that an athlete is not maintaining proper form during a squat, the athlete and coach can be alerted to make adjustments to their technique. Performance analysis using wearable sensors can also be used to optimize training programs by identifying areas where an athlete is excelling or struggling.

II. Injury Prevention

Injury prevention using wearable sensors involves monitoring an athlete's movements to detect any irregularities that may lead to injury. For example, if a sensor detects that an athlete is not maintaining proper form during a lift, the athlete and coach can be alerted to make adjustments to their technique to avoid injury. Wearable sensors can also be used to monitor an

athlete's load and recovery, which can help to prevent overuse injuries. By monitoring an athlete's movements and workload, coaches and trainers can take preventative measures to avoid injuries before they occur.

III. Fitness Tracking

Fitness tracking using wearable sensors involves tracking an athlete's fitness level and progress over time. Sensors can measure parameters such as heart rate, step count, and calories burned, which can be used to track progress and adjust training programs accordingly. Wearable sensors can also be used to monitor an athlete's sleep patterns, which is essential for recovery and optimal performance. By tracking an athlete's fitness level and progress over time, coaches and athletes can adjust training programs to achieve fitness goals.

IV. Rehabilitation

Wearable sensors can be used to monitor an athlete's progress during rehabilitation from injury. This can include tracking range of motion, muscle activity, and joint movement during exercises. The data collected can be analyzed to track the athlete's progress and adjust the rehabilitation program accordingly. For example, if a sensor detects that an athlete is not achieving the desired range of motion during an exercise, the rehabilitation program can be adjusted to focus on that specific area. By monitoring an athlete's progress during rehabilitation, coaches and trainers can ensure that the athlete is making progress towards recovery and avoid re-injury.

2.4. Devices that use wearable sensors for HAR

Smartwatches: Many smartwatches come with built-in sensors that can track physical activity, such as steps taken, distance traveled, and calories burned.

Fitness trackers: These devices are specifically designed for tracking physical activity and often come equipped with sensors that can monitor heart rate, sleep patterns, and other metrics.

Smart clothing: Some companies have developed clothing that incorporates sensors to track movement and other physical activity.

Medical devices: HAR via wearable sensors can also be used in medical devices to monitor patients' physical activity and provide feedback to healthcare providers.

Smart glasses: Smart glasses can incorporate sensors to track head movements and eye movements, providing information on where the wearer is looking and what they are focusing on.

Smart jewelry: Some companies have developed jewelry that incorporates sensors to track

physical activity, stress levels, and other health metrics.

Smart shoes: Smart shoes can include sensors that track the wearer's gait and provide information on their walking or running patterns.

Smart insoles: Insoles for shoes can be equipped with sensors that track the pressure and movement of the wearer's feet, providing insights into their walking or running patterns.

Smart gloves: Smart gloves can incorporate sensors that track hand and finger movements, providing information on fine motor skills and dexterity.

Smart watches for children: Smartwatches designed for children can include sensors that track physical activity and location, providing parents with information on their children's health and safety.

Smart socks: Smart socks are equipped with sensors that can track the pressure and movement of the wearer's feet. This information can be used to monitor gait and running patterns, as well as detect potential foot injuries or imbalances.

Smart helmets: Smart helmets can incorporate sensors that track head movements and provide information on the wearer's posture and balance. This can be useful for athletes, cyclists, and other individuals who need to maintain proper form and avoid injury.

Smart backpacks: Smart backpacks can include sensors that track the wearer's movements and provide information on posture and body position. This can be useful for individuals who need to maintain proper posture and avoid back pain or other injuries.

Smart patches: Smart patches are small, wearable devices that can be attached to the skin and incorporate sensors that track vital signs, such as heart rate and respiration. These patches can be used for remote patient monitoring and to track the health of individuals with chronic conditions.

Smart earbuds: Smart earbuds can include sensors that track the wearer's movements and provide information on posture and balance. They can also be used to monitor heart rate and other health metrics.

Smart watches for children: Smartwatches designed for children can include sensors that track physical activity and location, providing parents with information on their children's health and safety. They can also include features such as emergency alerts and parental controls.

2.5. Companies that manufacture devices which use wearable sensors

1. Apple

   Apple Watch Series 7: includes sensors that can track heart rate, blood oxygen levels, activity, and sleep.

   AirPods Pro: includes sensors that can track activity and provide audio coaching during workouts.

2. Fitbit

   Fitbit Charge 5: a fitness tracker that tracks activity, heart rate, and sleep, and includes a color display and GPS.

   Fitbit Versa 3: a smartwatch that tracks activity, heart rate, and sleep, and includes GPS, voice control, and access to apps and notifications.

3. Garmin

   Garmin Forerunner 945: a GPS running watch that tracks activity, heart rate, and other health-related data, and includes features like music storage and smart notifications.

   Garmin Venu 2: a smartwatch that tracks activity, heart rate, and other health-related data, and includes GPS, music storage, and access to apps and notifications.

4. Samsung

   Samsung Galaxy Watch 4: a smartwatch that tracks activity, heart rate, and sleep, and includes GPS, voice control, and access to apps and notifications.

   Samsung Gear Fit2 Pro: a fitness tracker that tracks activity, heart rate, and swim laps, and includes a color display and GPS.

5. Polar

   Polar Vantage V2: a GPS multisport watch that tracks activity, heart rate, and other health- related data, and includes features like music control and smart notifications.

   Polar Ignite 2: a fitness watch that tracks activity, heart rate, and sleep, and includes features like GPS, training guidance, and weather forecasts.

6. Whoop

   Whoop Strap 4.0: a wearable sensor designed specifically for athletes that tracks heart rate, heart rate variability, sleep, and other health-related data.

   Whoop Body: a scale that measures weight, body fat percentage, and muscle mass,

and syncs with the Whoop app to provide personalized insights and recommendations.

7. Jawbone

Jawbone UP3: a fitness tracker that tracks activity, heart rate, and sleep, and includes smart coaching and personalized insights.

Jawbone UP Move: a clip-on activity tracker that tracks steps, calories burned, and other activity data.

8. Suunto

Suunto 9 Baro: a GPS multisport watch that tracks activity, heart rate, and other health- related data, and includes features like weather alerts and route planning.

Suunto 3 Fitness: a fitness watch that tracks activity, heart rate, and sleep, and includes personalized training guidance.

9. Strava

Strava Summit: a subscription-based service that provides advanced features for the Strava app, including personalized coaching, custom goals, and live performance tracking.

Strava Beacon: a feature within the Strava app that allows you to share your real-time location with friends and family while you're out on a run or ride.

10. Withings

Withings Body Cardio: a smart scale that measures weight, body fat percentage, and heart rate, and includes advanced features like cardiovascular health tracking and a pregnancy mode.

Withings Sleep Analyzer: a device that tracks sleep quality, heart rate, and snoring, and provides personalized recommendations for improving your sleep.

11. Bellabeat

Bellabeat Time: a hybrid watch that combines smart features like activity tracking and notifications with traditional watch design.

Bellabeat Balance: a meditation and mindfulness app that includes guided meditations, breathing exercises, and personalized insights based on your heart rate data.

12. Biostrap

Biostrap Essential: a wearable sensor that tracks heart rate variability, sleep, and other health-related data, and includes features like live coaching and goal tracking.

Biostrap EVO: a more advanced version of the Essential, with additional features like temperature tracking and personalized health insights.

13. Oura

Oura Ring: a smart ring that tracks sleep, activity, and other health-related data, and includes features like personalized sleep coaching and a readiness score to help you optimize your daily activity.

Chapter 3 Artificial intelligence (AI)

Artificial intelligence, often referred to as AI, is the capacity of a digital computer or a computer- operated robot to execute tasks that are typically associated with intelligent entities. The aim of AI development is to create systems that possess cognitive abilities like humans, including the power to reason, comprehend meaning, generalize, and learn from past experiences. The development of digital computers in the 1940s proved that they can be programmed to accomplish complex tasks such as finding mathematical theorems and playing chess with exceptional proficiency. However, despite significant improvements in computer processing speed and memory capacity, there are currently no programs that can equal human flexibility in broader domains or tasks that demand extensive everyday knowledge. On the other hand, some programs have achieved the same performance levels as human specialists and professionals in performing specific tasks. As a result, AI in this limited sense can be seen in various applications, including medical diagnosis, computer search engines, and voice or handwriting recognition. As a result, companies across all sectors are investing in AI.

3.1 Trends of AI

The 2022 AI Index was published by Stanford HAI on March 16. This is the fifth consecutive yearly report that examines the advancements and effects of AI. The index is developed by a team from various fields at HAI in collaboration with academia, industry, and government. It studies and simplifies industry patterns, including investment, new businesses, technical capabilities, education, and public policy. The key highlights this year include a sharp increase in private investment, noteworthy technological accomplishments, and a heightened focus on fairness and prejudice concerns.

As it was stated by AI Index, in 2021, the highest percentage of job postings related to AI were for positions requiring machine learning skills, accounting for 0.6% of all job postings. This was followed by postings for artificial intelligence at 0.33%, neural networks at 0.16%, and natural language processing at 0.13%. The number of job postings for AI positions in machine learning and artificial intelligence has increased significantly over the past few years. Machine learning job postings have nearly tripled since 2018, while artificial intelligence job postings have increased by about 1.5 times.

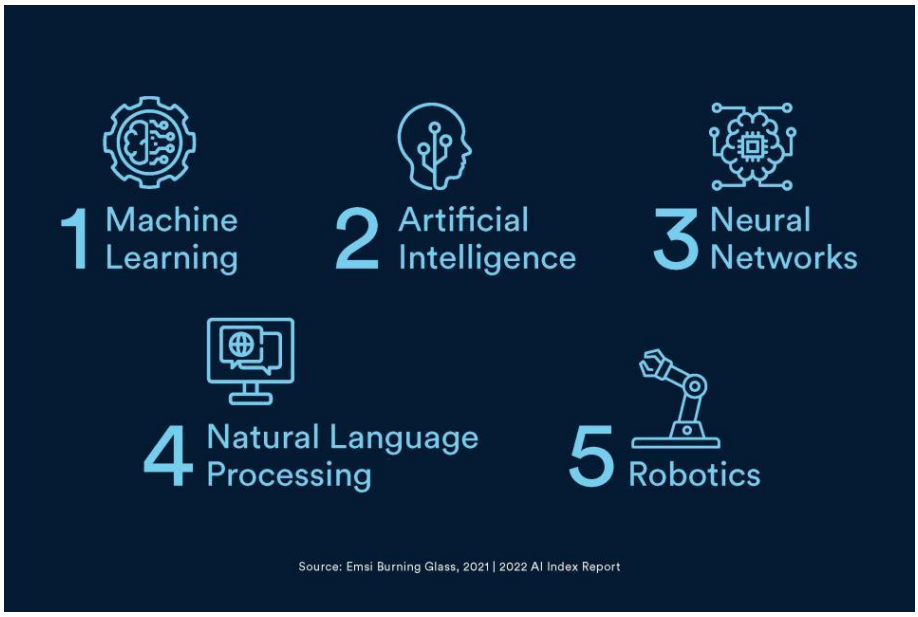

Fig 3-1 Job Positions requiring skills

rate

Over the last decade, there has been an increase in the number of individuals obtaining PhDs in the field of AI. Most of these individuals in the United States choose to work in industry, while only a small percentage opt for government positions.

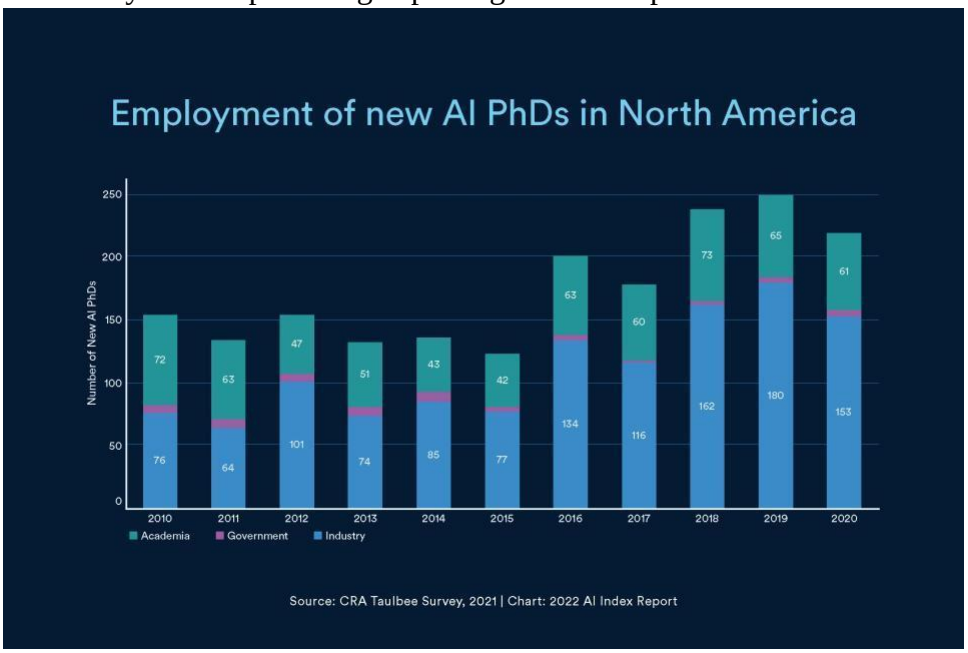

Fig 3-2 Employment of new AI PhDs in North

America

An increasing number of academics are directing their attention towards pattern recognition and machine learning, as evidenced by the fact that the number of publications in

these fields has more than doubled since 2015. However, other fields that are heavily impacted by deep learning, such as computer vision, data mining, and natural language processing, have only experienced modest increases in the number of published works.

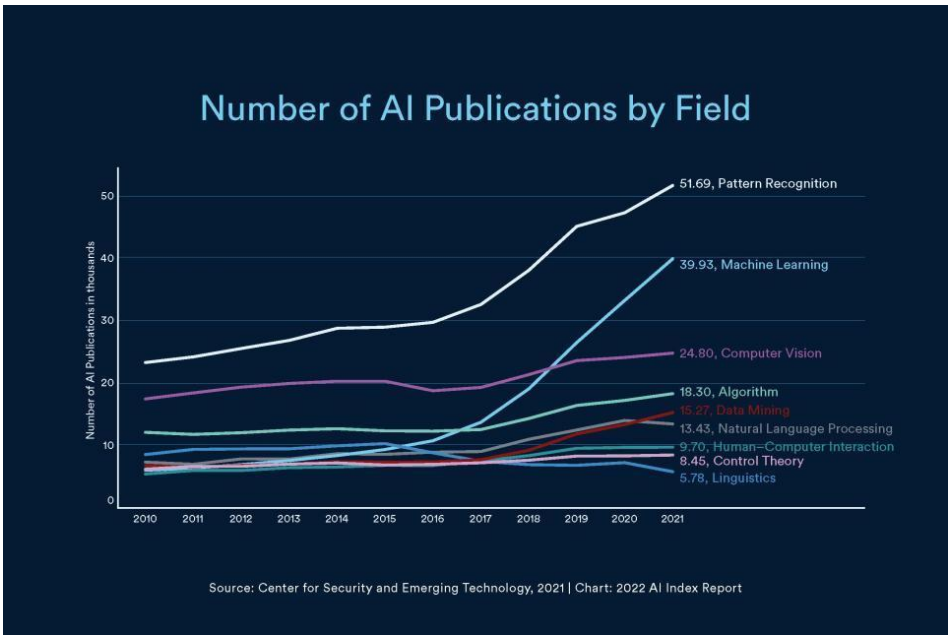

Fig 3-3 Number of AI publication by field

Precedence Research estimates that the artificial intelligence (AI) industry will experience a significant expansion and is expected to grow at a compound annual growth rate (CAGR) of 38.1% between 2022 and 2030, with the market size projected to exceed US$ 1,597.1 billion by 2030.

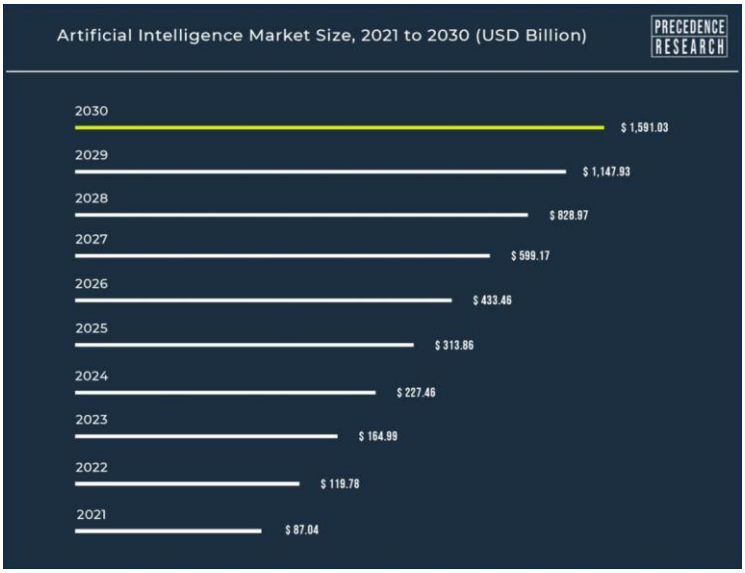

Fig 3-4 Artificial intelligence (AI) market size

According to a press release from Ottawa dated April 19th, 2022, the worldwide market for

artificial intelligence (AI) had a value of $87.04 billion in 2021. Since its introduction to the market, AI technology has been gaining popularity at a rapid pace. This growth is largely due to increasing demand for AI across multiple industries such as retail, BFSI, healthcare, food and beverages, automotive, and logistics. Additionally, the pharmaceutical manufacturing sector is expected to play a significant role in driving the growth of the AI market in the future as the technology becomes more widely adopted in that field.

3.2 Application of AI

Artificial Intelligence is being applied in various ways in contemporary society and is increasingly becoming indispensable due to its ability to solve intricate problems efficiently across numerous industries including Healthcare, entertainment, finance, education, among others. AI is contributing to making our daily lives more comfortable and faster. Some of them will be discussed in this section.

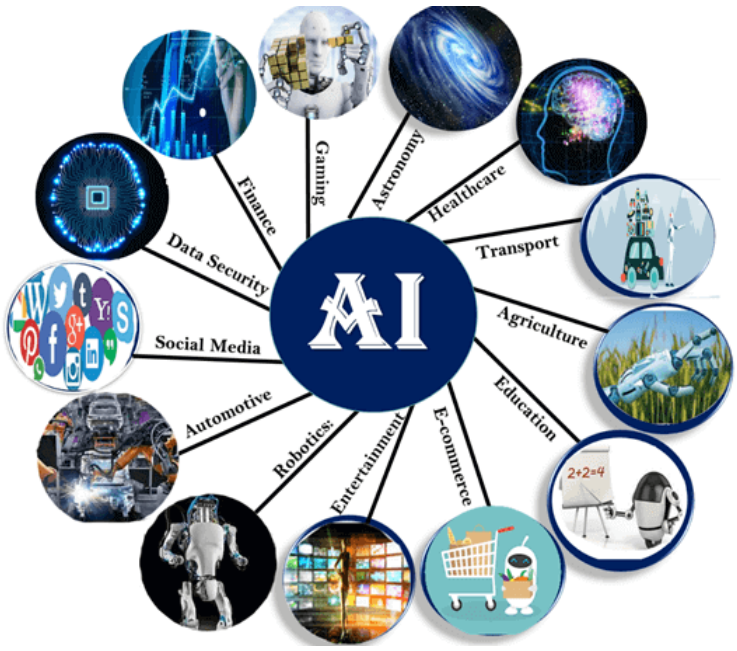

Fig 3-5 Applications of AI

Personalized Shopping:

AI technology is employed to build recommendation engines that enhance your interaction with customers. These suggestions are based on their past activities, inclinations, and likes. This contributes to strengthening your bond with customers and fostering their allegiance to your brand.

Fraud Prevention:

Two major challenges for E-Commerce businesses are fraudulent credit card activity and fabricated reviews. AI technology can assist in mitigating the risk of credit card fraud by analyzing usage patterns. In addition, AI can identify and manage counterfeit reviews, which are influential in customers' purchasing decisions.

Autonomous Vehicles:

Companies such as Toyota, Audi, Volvo, and Tesla in the automotive manufacturing industry utilize machine learning techniques to educate computers to think and adapt like humans with respect to navigating any surroundings and recognizing objects in order to prevent collisions.

Spam Filters:

Our everyday email usage involves an AI system that identifies and segregates spam emails into spam or trash folders, leaving us with only relevant content to view. Gmail, a commonly used email service, has achieved a spam filtering accuracy of almost 99.9%.

Facial Recognition: Facial recognition techniques are utilized by our preferred devices such as phones, laptops, and PCs. These techniques use face filters to detect and identify individuals for secure access purposes. Facial recognition technology is not only used for personal reasons but is also a commonly employed Artificial Intelligence application across various industries, particularly in high-security areas.

Recommendation System:

The recommendation system is a popular application of Artificial Intelligence that is utilized by many industries, including e-commerce, entertainment websites, social media platforms, and video sharing platforms such as YouTube. These platforms use the recommendation system to collect user data and offer personalized recommendations to users with the goal of boosting user engagement.

Robotics

Artificial Intelligence is frequently utilized in the field of robotics. AI-driven robots can detect obstructions in their path and plan their route immediately by utilizing real-time information updates.

It can be used for:

- Carrying goods in hospitals, factories, and warehouses
- Cleaning offices and large equipment
- Inventory management

Navigation:

MIT's research reveals that GPS technology can enhance safety by offering precise, timely, and comprehensive information to users. This technology utilizes Convolutional Neural Networks and Graph Neural Networks to identify the number of lanes and road types obscured by obstructions on the roads, thereby making users' lives easier. Uber and other logistics firms use AI extensively to boost operational efficiency, evaluate traffic patterns, and optimize routes.

3.3 AI in Sport

The utilization of AI and statistical modeling in sports has gained significant attention in recent times due to the advancement in professional sports analytics. This could be attributed to the fact that the implementation of machine learning algorithms and the availability of computer processing capabilities have aroused a desire among the sports fans to explore novel approaches and practical applications.

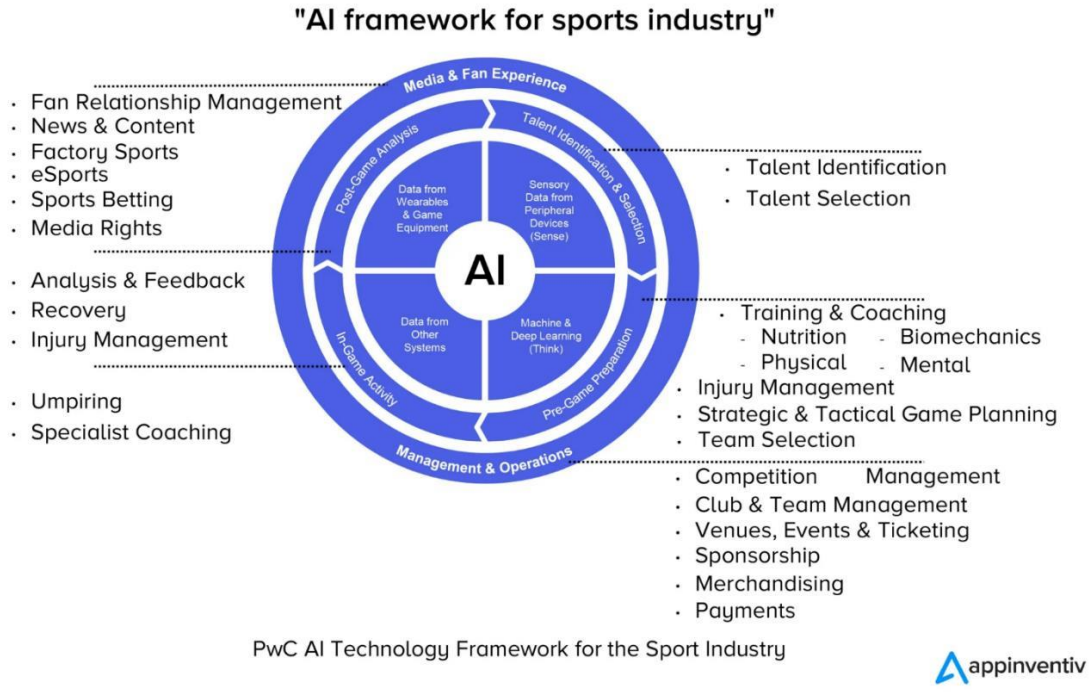

Fig 3-6 AI framework for sports industry

AI-powered technologies have come to the rescue as the determining factor in many close games. Officials can now analyze the probability and visual data of each game. The sports industry benefits from AI in numerous ways beyond this, with a myriad of other scenarios.

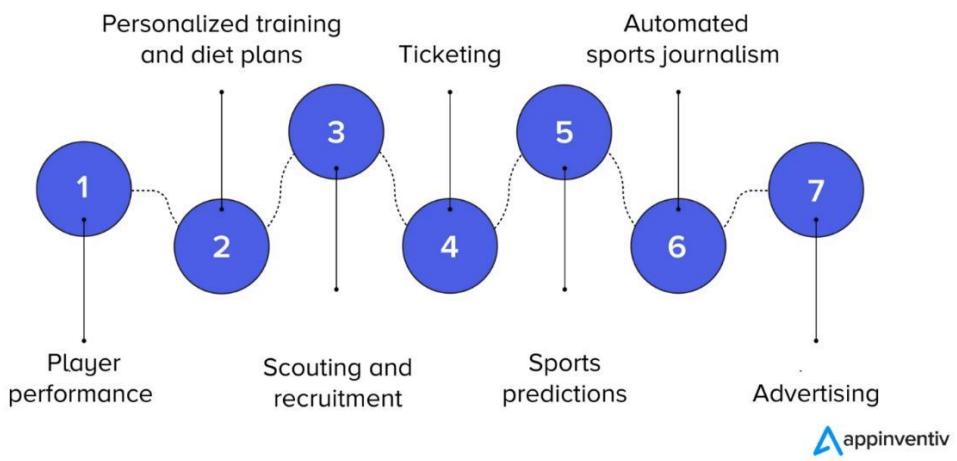

Fig 3-7 AI application in sport

Player performance

The utilization of predictive analytics in sports through the aid of AI has led to an enhancement in performance and physical well-being. Wearable technology has enabled athletes to collect data on their level of strain and the risk of injury, allowing them to take preventive measures. This has also aided teams in developing effective tactics and strategies while maximizing their strengths. A common application of AI in sports involves using human pose estimation to analyze a swimmer's performance beneath the water's surface. This technique replaces the traditional approach of manually annotating the swimmer's body for quantitative evaluation.

Personalized training and diet plans

AI's dominance in sports seems inevitable, given its ability to revolutionize personalized training. With the help of machine learning, an AI-powered diet plan can create tailored meal plans for athletes according to their specific requirements and routines. This is only the starting point for the potential impact of AI on sports. Let's not overlook the abundance of AI-powered fitness apps that are currently dominating the market. These applications utilize various methods and technologies to teach algorithms how to recognize human movements in real-time.

Scouting and recruitment

Sports organizations are enhancing the intensity and competitiveness of competitions by incorporating Artificial Intelligence into their methods for scouting and recruiting. They monitor all aspects of players' on-field performance, including their movements and body positioning, to make informed decisions.

Ticketing

Many times, spectators have difficulty arriving at sports stadiums in a timely manner for major events. Previously, there was no solution to the problem of overcrowding until artificial intelligence intervened. Columbus Crew recently implemented facial recognition technology based on AI, enabling fans to enter the stadium without needing to show their tickets. This approach eliminated congestion and improved the efficiency of the stadium entrance.

Sports predictions

It is well known that officials have been attempting to analyze large amounts of data in order to make predictions and earn profits for many years. However, simply analyzing the first half of a match or tracking statistics like aces and scores is not a reliable method of prediction, as it only relies on probability. While AI in sports cannot provide precise predictions, it can come much closer than human predictions by using advanced algorithms. AI-based predictive models can now forecast the outcomes of matches in more than 40% of sports categories. These models are developed by considering factors such as team formation, number of goals scored, key passes leading to goal-scoring opportunities, and the number of passes exchanged between teammates. By analyzing these data, AI tools can generate accurate match predictions.

Automated sports journalism

Sports journalism is a significant industry that requires coverage of every noteworthy event. This includes providing comprehensive coverage of tournaments andminor leagues, particularly regarding data and statistics. Artificial intelligence (AI) has made sports journalism more manageable by providing automated platforms that can convert raw data into readable stories using natural language. These platforms utilize computer vision and automated insights to intelligently sync with live events and provide real-time score updates.

Advertising

AI in Advertising has a little-known advantage: it can detect chances for targeted advertising based on demographic data, resulting in more effective branding. By analyzing game highlights with AI, brands can better tailor their ads. Additionally, the automated learning algorithms of AI and machine learning can track players' behavior and viewers' reactions during matches.

3.4 Human Activity Recognition

Human activity recognition (HAR) is the process of identifying and naming various activities using Artificial Intelligence (AI). This is accomplished by analyzing raw data

collected from different devices, including wearable sensors, smartphone inertial sensors, Kinect cameras, CCTV cameras, and commercial equipment. HAR is crucial for many different application domains, including healthcare, remote care for the elderly, smart homes/offices/cities, and sports and exercise monitoring. The diverse sources of data used in HAR make it an important tool for improving human safety and quality of life.

Generally, HAR can be divided into four phases (as shown in Fig 16): (1) signal activity capture, (2) data pre-processing, (3) activity recognition based on artificial intelligence (AI), and (4) a user interface for HAR management. There are various techniques that can be used for each phase, which can make the HAR system more complex. This means that selecting the appropriate domain, data acquisition device, and AI algorithm for activity detection can be difficult and involves multiple options.

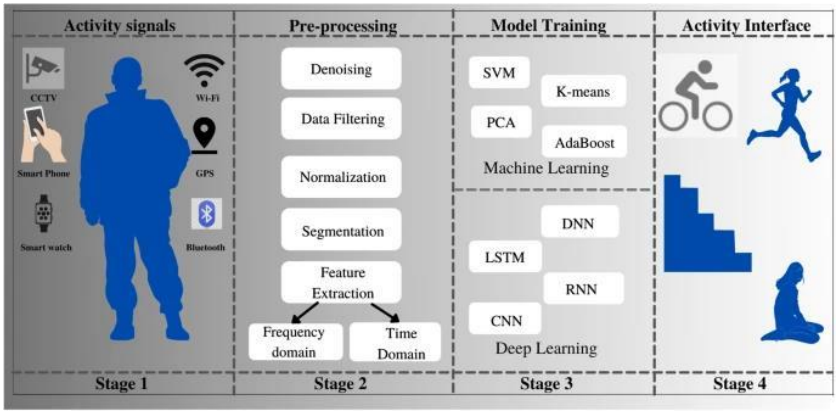

Fig 3-8 HAR phases

3.4.1 Trend of HAR

(Neha et al. 2022) conducted a thorough investigation of the HAR framework, focusing on AI techniques, types of devices, and application domains. Fig. 18a displays an analysis of HAR devices, based on articles published between 2011 and 2021, demonstrating how the pattern of HAR devices has changed over time. Fig 3-9b shows the growth of ML and DL techniques in HAR and suggests that DL-based techniques are becoming more popular. Fig 3-9a provides a more detailed breakdown of HAR devices, while Fig. 19b distinguishes between wearable sensor (WS) and smartphone sensor (SPS) for sensor-based HAR. Vision-based HAR is divided into video and skeleton-based models in Fig 3-10c, and the different types of HAR application domains are presented in Fig 3-10d.

According to the analysis of device as shown in Fig 3-9, vision-based human activity recognition (HAR) was common from 2011 to 2016. However, sensor-based models became more prominent from 2017, which is the same time when deep learning (DL) techniques were

introduced to HAR. Furthermore, Wi-Fi devices became one of the sources of data for activity monitoring between 2017 and 2021**.**

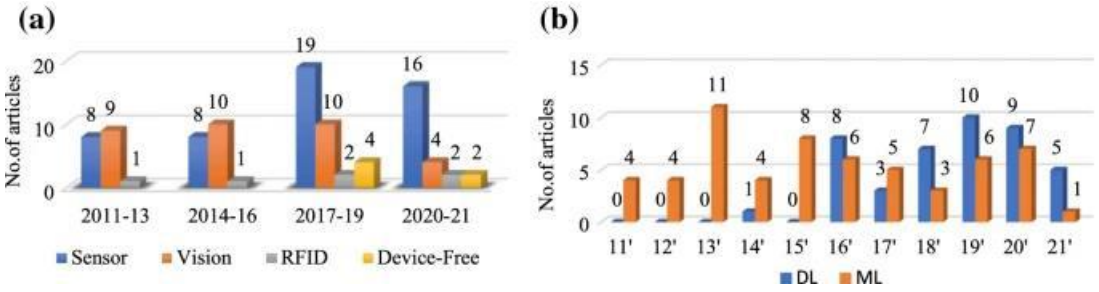

Fig 3-9 **a** Changing pattern of HAR devices over time, **b** distribution of machine learning (ML) and deep learning (DL) articles in last decade

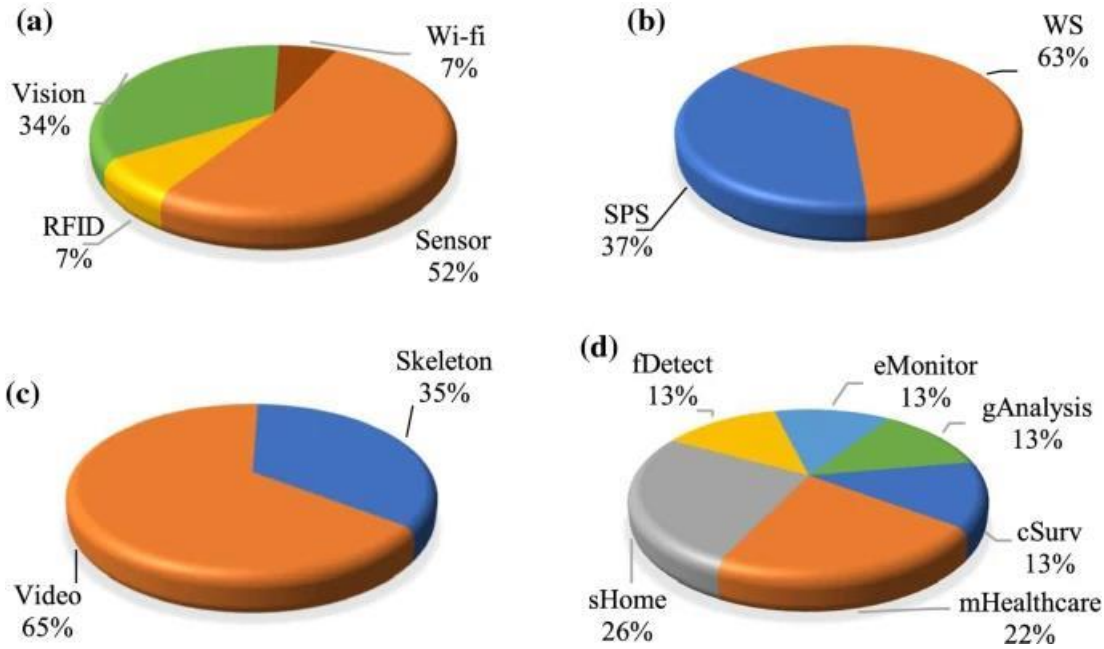

Fig 3-10 **a.** Types of HAR devices, **b.** sensor-based devices, **c**. vision-based devices, **d**. HAR applications. WS: wearable sensors, SPS: smartphone sensor, sHome: smart home, mHealthcare: health care monitoring, cSurv: crowd surveillance, fDetect: fall detection, eMonitor: exercise monitoring, gAnalysis: gait analysis

3.4.2 HAR in Sport

The human activity recognition in sports entails utilizing different sensors to detect players or identify the actions and movements of athletes. These activities can be monitored during various stages such as warm-up and fitness training, specific sport training, matches, or competitions. Therefore, the application of HAR can be useful in monitoring athlete

performance, comparing actions executed by different players or repeated actions by a single player (such as backhand in tennis or serve in volleyball) to aid in technique training and improvement, and conducting automated statistical analysis of sports matches or individual performances.

At present, different sports are under investigation by researchers to determine their suitability for implementing HAR. These sports include individual ones like skiing and swimming, two-player games such as tennis, and team sports like basketball, soccer, baseball, hockey, volleyball, handball, and so on.

There are various advantages to using HAR in sports. For instance, it can assist in enhancing players' performance and helping coaches in doing so as well. Additionally, it may aid physiotherapists in avoiding player injuries and enable journalists to gather data such as the number of shots on target.

Chapter 4 Wearable sensors based HAR for sport related

4.1 Data from wearable sensors

Wearable sensors have been used in sports and physical activity to monitor physical activity, assess performance, track recovery, and prevent injuries. These sensors can provide real-time data on a range of biometric and environmental factors, such as heart rate, temperature, and activity level. This data can be used to track individual health and fitness goals, monitor patients remotely, and even predict and prevent workplace injuries. The use of wearable sensors can provide athletes with valuable information about their physical activity, such as the intensity and duration of their workouts, and help them to identify areas for improvement. Some of the data collected from wearable sensors are listed below.

Heart Rate: Heart rate is a crucial indicator of an athlete's performance. Wearable sensors can measure the heart rate in real-time during exercise and help monitor the athlete's cardiovascular health.

Oxygen Saturation: Oxygen saturation measures the amount of oxygen in the blood. Wearable sensors can help monitor the oxygen saturation levels of an athlete during exercise, which is particularly useful for endurance athletes.

Power Output: Power output is the amount of work done over time. Wearable sensors can measure the power output of an athlete during exercise, which can help determine their overall fitness level and progress over time.

Speed: Speed is the rate at which an athlete is moving. Wearable sensors can measure the speed of an athlete during exercise, which is particularly useful for sprinters and runners.

Cadence: Cadence is the rate at which an athlete is cycling or running. Wearable sensors can measure the cadence of an athlete during exercise, which can help improve their technique and prevent injuries

Body Temperature: Body temperature can affect an athlete's performance. Wearable sensors can monitor an athlete's body temperature during exercise, which can help prevent heat exhaustion or hypothermia.

Muscle Activity: Wearable sensors can measure the electrical activity of muscles during exercise, which can help identify muscle imbalances and weaknesses.

Breathing Rate: Breathing rate measures the number of breaths taken per minute. Wearable sensors can measure the breathing rate of an athlete during exercise, which can help optimize their breathing technique and prevent respiratory issues.

Posture: Good posture is essential for proper movement and technique during exercise. Wearable sensors can measure an athlete's posture during exercise, which can help identify any imbalances or weaknesses.

Fatigue: Wearable sensors can track an athlete's fatigue levels during exercise, which can help determine the optimal training load and prevent overtraining.

Gait Analysis: Wearable sensors can analyze an athlete's gait during running or walking, which can help identify any issues with their running technique and prevent injuries.

Balance: Balance is important for all types of athletes, but particularly for those in sports such as gymnastics or snowboarding. Wearable sensors can measure an athlete's balance during exercise, which can help identify any areas for improvement.

Reaction Time: Reaction time measures the time it takes for an athlete to respond to a stimulus. Wearable sensors can measure an athlete's reaction time during exercise, which can help improve their coordination and reflexes.

Hydration Levels: Hydration is essential for an athlete's performance and health. Wearable sensors can measure an athlete's hydration levels during exercise, which can help prevent dehydration and optimize performance.

Blood Lactate Levels: Blood lactate levels are a marker of an athlete's anaerobic performance. Wearable sensors can measure an athlete's blood lactate levels during exercise, which can help optimize their training routine and prevent overtraining.

Calories Burned: Calories burned measures the energy expended during exercise. Wearable sensors can measure an athlete's calories burned during exercise, which can help monitor their energy expenditure and optimize their nutrition and training routine.

Sleep Quality: Sleep quality is essential for an athlete's recovery and overall health. Wearable sensors can measure an athlete's sleep quality and provide insights into how to optimize their sleep routine.

Blood Pressure: Blood pressure is an important indicator of an athlete's cardiovascular health. Wearable sensors can measure an athlete's blood pressure during exercise, which can help monitor their cardiovascular health and optimize their training routine.

ECG (Electrocardiogram): ECG measures the electrical activity of the heart. Wearable sensors can provide an ECG during exercise, which can help detect any heart irregularities and prevent cardiovascular issues.

Body Composition: Body composition measures the amount of muscle, fat, and bone in an

athlete's body. Wearable sensors can measure an athlete's body composition, which can help optimize their nutrition and training routine.

Oxygen Consumption: Oxygen consumption measures the amount of oxygen that an athlete is using during exercise. Wearable sensors can measure an athlete's oxygen consumption, which can help optimize their training routine and improve their endurance performance.

4.2. Workflow of wearable sensor based HAR systems for sports applications

Wearable sensors can be attached to various parts of the body, such as the wrist, ankle, chest, or thigh, to capture biometric and motion data during sports activities. The data collected by these sensors can then be processed by HAR algorithms to recognize different sports activities, such as running, cycling, or swimming.

HAR systems in sports perform a supervised learning task, which typically involve several steps, including data collection, feature extraction, feature selection, and classification. During the data collection step, wearable sensors collect raw data, which is then pre-processed to annotate data, remove noise and artifacts. Feature extraction involves identifying important features from the pre-processed data, such as the frequency of motion or the magnitude of acceleration. Feature selection then involves choosing the most relevant features for each sport activity, which can vary depending on the sport and the specific motion being performed. Finally, classification algorithms, such as artificial neural networks, support vector machines, or decision trees, are used to classify the features into different sport activities. In the past, feature extraction was done manually using traditional machine learning methods, as shown in Fig. 20. However, with the emergence of deep learning, this process has become automated as shown in Fig. 21.

The output of wearable sensor-based human activity recognition (HAR) systems can provide valuable information for sports applications. The system typically generates a sequence of recognized activities along with their corresponding time-stamps. These activities can be further analyzed to provide insights into the sports performance of the user.

For example, in a running activity, the system can recognize different phases such as warm-up, jogging, sprinting, and cooling down. By analyzing the time spent in each phase, the system can provide insights into the user's running style, pace, and endurance. Similarly, for a weightlifting activity, the system can recognize the type of lift (e.g., squat, deadlift, bench press) and the number of repetitions performed. This information can be used to monitor the progress of the user and provide feedback on their lifting form and technique.

In addition, the output of the HAR system can be used to monitor the user's overall physical activity level, track their progress towards fitness goals, and provide personalized recommendations for training and recovery. Wearable sensor based HAR systems offer a non-invasive and accurate method for tracking sports activities, which can be useful for monitoring athletic performance, preventing injuries, and promoting overall health and wellness. Overall, wearable sensor-based HAR systems have the potential to enhance sports performance and improve the overall health and well-being of sports enthusiasts. Furthermore, the continuous data from other wearable sensors like heart rate, sugar level and blood pressure can be estimated by AI algorithms to aid the performance analysis of an athlete and provide enhanced healthcare and training recommendation for athletes.

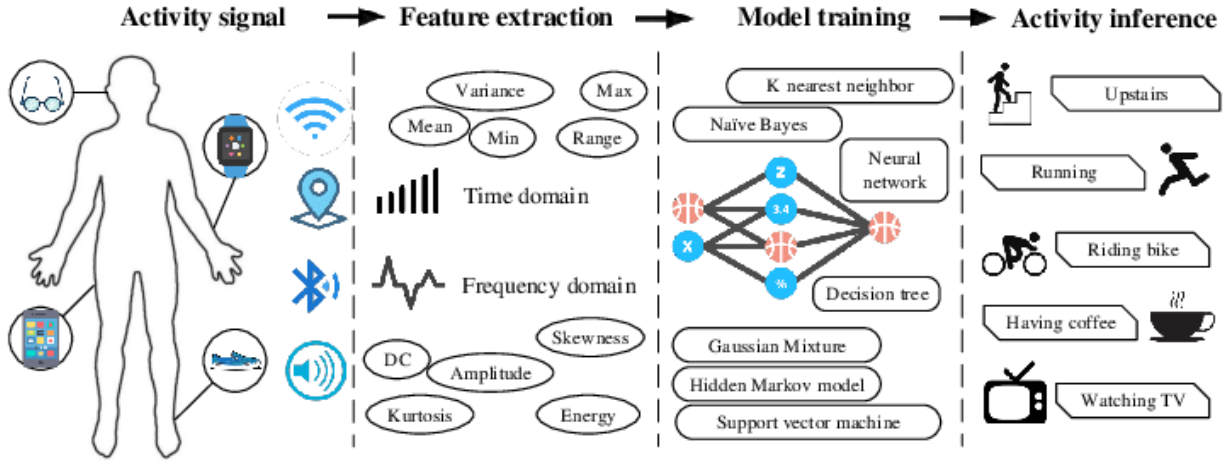

Fig 4-1 An illustration of wearable sensor-based activity recognition using conventional machine learning approaches.

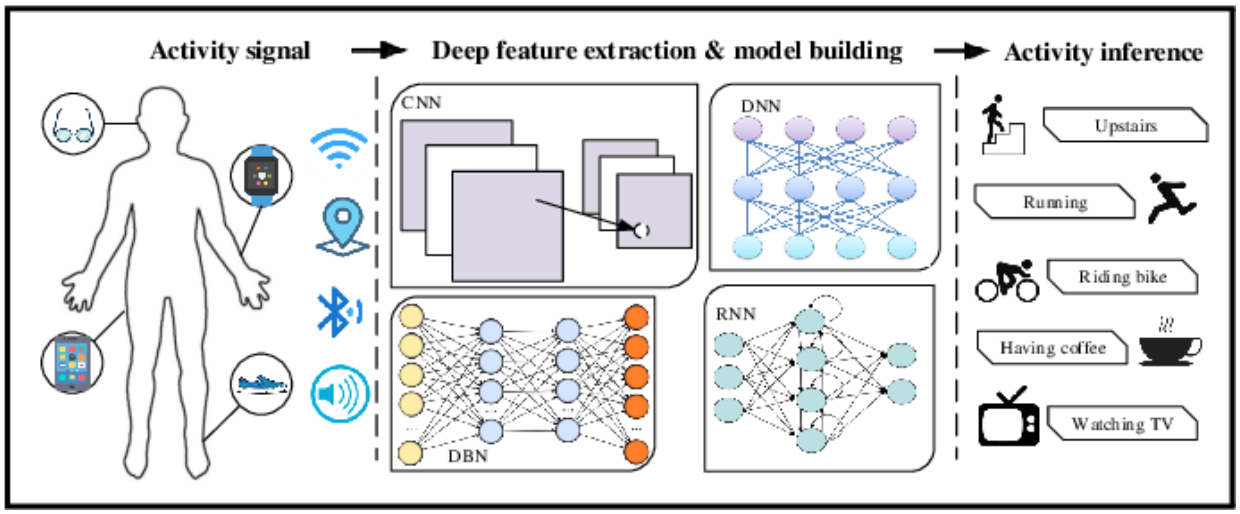

Fig 4-2 An illustration of wearable sensor-based activity recognition using deep learning approaches.

4.2.1 Self-help platforms

Wearable sensors can also be used to monitor an athlete's performance during training and provide real-time feedback to coaches and athletes. Self-help athletes in Africa often have limited access to resources and facilities that can support their physical activity. Wearable sensors can provide a cost-effective and convenient means of monitoring their physical activity and tracking their progress. This technology can help self-help athletes in Africa to set realistic goals, adjust their training programs, and improve their performance. Wearable sensors can also be used to prevent injuries and support recovery.

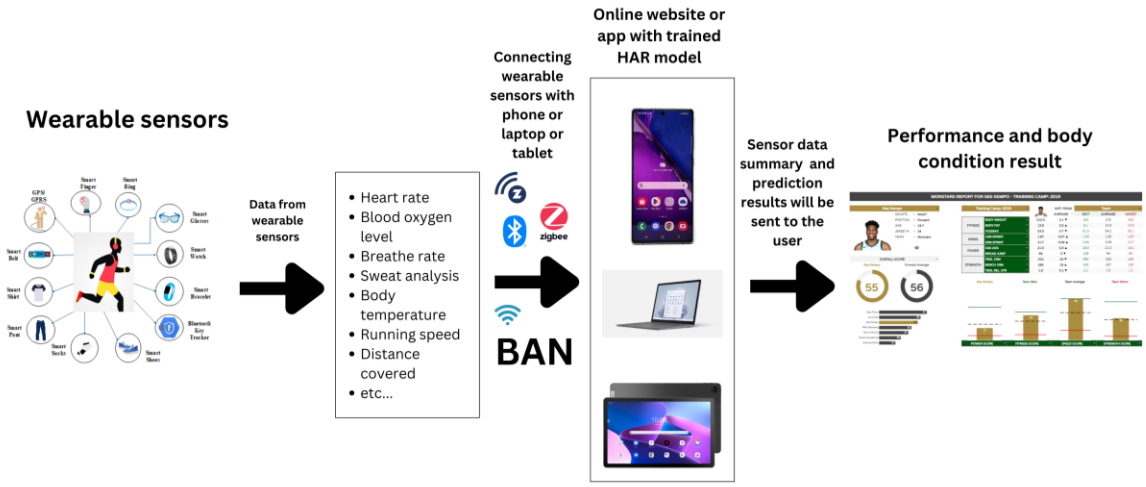

Fig 4-3 Self-help platform for athlete

4.2.2 Online coaching platforms

With the growing availability and affordability of wearable sensors, there is a significant opportunity to harness the power of these devices to support athletes in their training and performance goals. By using wearable sensors to collect data on metrics such as heart rate, activity levels, and sleep patterns, coaches and trainers can develop personalized training programs that take into account an athlete's individual strengths, weaknesses, and training history. This approach has the potential to improve both the effectiveness and efficiency of training programs, helping athletes to achieve their goals more quickly and with fewer setbacks. By enabling athletes to receive coaching and feedback remotely, regardless of their location, wearable sensors have the potential to level the playing field and support greater participation and success in sports.

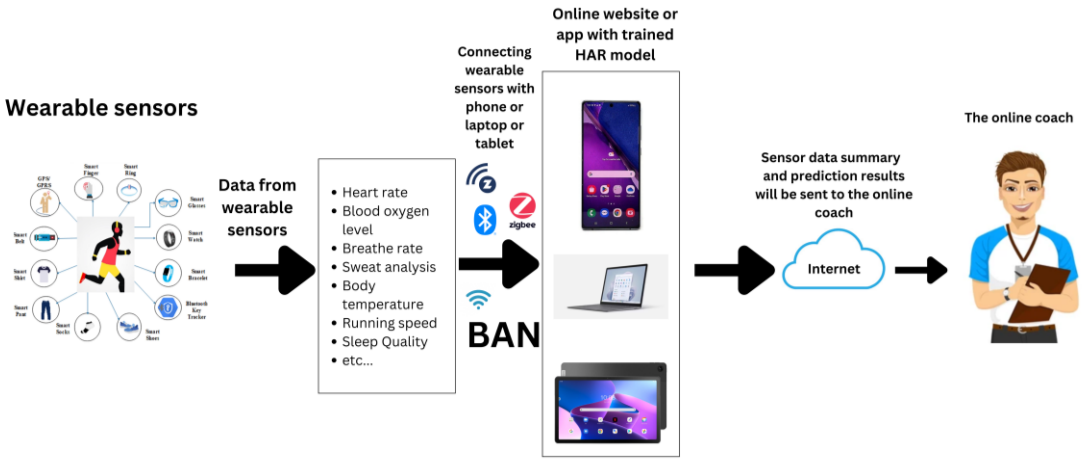

Fig 4-4 Online coaching platform for athletes

4.2.3 Online healthcare platforms

Wearable sensor technology has revolutionized the way athletes monitor and manage their health. With the help of wearable sensors, athletes can track their physical activity, heart rate, body temperature, and other vital signs in real-time. This data is then analyzed by healthcare professionals who can provide personalized recommendations and treatment plans.

In the world of sports, wearable sensor-based online healthcare has become increasingly popular. Athletes can now use sensors to track their performance, prevent injuries, and optimize their training. These sensors can also help healthcare professionals diagnose and treat injuries quickly, reducing downtime and improving overall performance.

Wearable sensors are now commonly used in sports to monitor an athlete's heart rate, body temperature, and activity levels. They can also be used to track the intensity of training sessions, the amount of time spent in different zones, and the overall workload of the athlete. This data can be used to optimize training and prevent injuries.

Wearable sensor-based online healthcare is not just limited to professional athletes. Recreational athletes can also benefit from this technology. Wearable sensors can help recreational athletes track their performance, monitor their health, and prevent injuries. Online health care platforms can provide these athletes with personalized recommendations and treatment plans, just like professional athletes.

In conclusion, wearable sensor-based online healthcare has revolutionized the world of sports. Athletes can now monitor their health and performance in real-time and receive personalized recommendations and treatment plans from healthcare professionals. This technology has not only improved the performance of professional athletes but has also made it

easier for recreational athletes to monitor their health and prevent injuries. With the increasing popularity of wearable sensors, the future of sports looks bright.

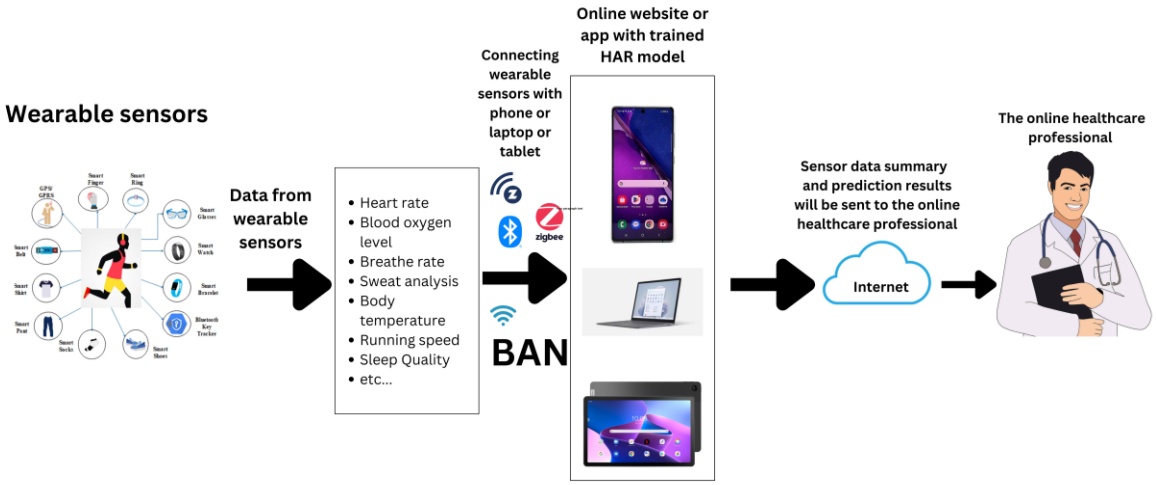

Fig 4-5 Online healthcare platform for athletes

4.4 Types of sports where this system can be applied

Endurance sport: These athletes participate in sports or activities that require sustained, prolonged effort over a long period of time. Examples include marathon runners, long-distance cyclists, triathletes, and cross-country skiers.

Strength sport: These athletes focus on building muscular strength and power. Examples include weightlifters, powerlifters, and strongmen.

Power sport: These athletes rely on explosive movements and speed to excel in their sport. Examples include sprinters, jumpers, and throwers.

Skill-based sport: These athletes rely on specific skills and techniques to excel in their sport. Examples include gymnasts, figure skaters, and martial artists.

Team sport: These athletes compete as part of a team in sports such as basketball, football, soccer, and hockey.

Adaptive sport: These athletes have physical or intellectual disabilities and compete in adaptive sports. Examples include Paralympic athletes, Special Olympics athletes, and wheelchair athletes.

Fitness sport: These athletes participate in fitness competitions that test their strength, endurance, and overall physical fitness. Examples include CrossFit athletes, bodybuilders, and fitness models.

Endurance team sport: These athletes participate in team sports that require sustained effort

over a long period of time. Examples include rowing, cycling, and cross-country skiing teams.

Water sports sport: These athletes participate in sports that take place on or in water, such as swimming, diving, and water polo.

4.5 Performance improvements for athletes

Below are some of the performance improvements of athletes that can be obtained from wearable sensor based HAR systems.

Increased strength: An athlete who is engaging in strength training may see improvements in their ability to lift heavier weights, perform more reps, or maintain their form for longer periods of time.

Improved endurance: An athlete who is engaging in cardiovascular training may see improvements in their ability to sustain physical activity for longer periods of time, such as running farther or cycling for longer distances.

Increased speed: An athlete who is engaging in speed training may see improvements in their ability to move quickly and explosively, such as running faster or jumping higher.

Improved technique: An athlete who is practicing a specific skill or technique may see improvements in their ability to perform that skill more efficiently and effectively, such as improving their shooting accuracy in basketball or their stroke technique in swimming.

Increased flexibility: An athlete who is engaging in flexibility training may see improvements in their ability to move their joints through a wider range of motion, which can help prevent injury and improve performance.

Improved recovery: An athlete who is engaging in recovery practices such as stretching, massage, or foam rolling may see improvements in their ability to recover from intense physical activity more quickly, allowing them to train more effectively and consistently.

Increased agility: An athlete who is engaging in agility training may see improvements in their ability to change direction quickly and efficiently, such as in sports like basketball, soccer, or football.

Improved balance: An athlete who is engaging in balance training may see improvements in their ability to maintain stability and control, which can be important for sports that require jumping, landing, or sudden changes in direction.

Increased power: An athlete who is engaging in power training may see improvements in their ability to generate force quickly, such as in sports like track and field, weightlifting, or martial arts.

Improved reaction time: An athlete who is engaging in reaction time training may see improvements in their ability to quickly respond to stimuli, such as in sports like tennis, volleyball, or baseball.

Improved cardiovascular fitness: An athlete who is engaging in cardio training may see improvements in their ability to deliver oxygen to their muscles and sustain physical activity for longer periods of time, which can be important for endurance sports like distance running or cycling.

Increased explosiveness: An athlete who is engaging in explosive training may see improvements in their ability to generate power quickly, such as in sports like sprinting, jumping, or throwing.

Improved mobility: An athlete who is engaging in mobility training may see improvements in their ability to move their joints through a full range of motion, which can be important for preventing injury and improving performance in sports like martial arts, dance, or gymnastics.

Increased muscular endurance: An athlete who is engaging in muscular endurance training may see improvements in their ability to perform a high number of repetitions of a particular exercise, which can be important for sports that require repeated bursts of activity, such as basketball or soccer.

Racquet sports: These athletes participate in sports that involve hitting a ball or shuttlecock with a racquet, such as tennis, badminton, and squash.

Target sports sport: These athletes participate in sports that involve shooting at a target, such as archery, shooting, and biathlon.

Fitness enthusiasts sport: These individuals may not necessarily compete in organized sports, but they prioritize physical fitness and may participate in activities such as running, hiking, and weightlifting for personal wellness and enjoyment.

4.6 Challenges and drawbacks of using wearable for sports

Accuracy: The accuracy of wearable sensors can vary depending on the type of sensor and the activity being monitored. Some sensors may be more accurate than others, and some may not be accurate at all in certain situations. This can lead to incorrect data being collected, which can affect the usefulness of the data. In addition to this the performance of wearable sensors can be affected by environmental factors such as temperature, humidity, and altitude.

Battery life: Wearable sensors require power to operate, and their battery life can be a limiting

factor. Some sensors may require frequent charging or battery replacement, which can be inconvenient for athletes and coaches.

Cost: Wearable sensors can be expensive, which can be a barrier for athletes and coaches who do not have access to the necessary funding. Additionally, the cost of replacing sensors that become damaged or obsolete can add up over time.

Data management: Wearable sensors can generate large amounts of data, which can be difficult to manage and analyze. Coaches and athletes may require specialized software or expertise to analyze and interpret the data, which can add additional costs and complexity.

Privacy and security: Wearable sensors can collect sensitive data, such as physiological parameters and location data. It is important that this data is stored securely and that the privacy of the athlete is protected.

Human coaching: While wearable sensors can provide valuable data, they cannot replace the expertise and guidance of human coaches and trainers. Coaches and athletes must work together to interpret the data and make appropriate adjustments to training programs.

Technical challenges: Wearable sensors may encounter technical challenges, such as connectivity issues or sensor malfunction, which can affect the quality of the data collected. It is important to have contingency plans in place for dealing with these technical issues.

Data security: Wearable sensors collect sensitive data, such as personal and medical information, and it is important to ensure that this data is secure and protected. Coaches and athletes must take steps to ensure that the data collected by wearable sensors is secure and that appropriate measures are in place to prevent unauthorized access.

Chapter 5 Applying this system in Africa

5.1 Policy

The purpose of establishing a new healthcare system using wearable sensor healthcare in sport with HAR (human activity recognition) in Africa is to improve the health and well-being of athletes, enhance their performance, and reduce the risk of injury. Wearable sensors can track various physiological parameters such as heart rate, body temperature, and respiratory rate, which can help detect early signs of health problems or fatigue in athletes. By monitoring athletes' health and performance using HAR, coaches and healthcare providers can tailor training regimens and make adjustments to prevent injuries and improve overall performance. Additionally, the use of wearable sensors and HAR can provide valuable data for research and development of new healthcare technologies and techniques for improving sports performance and health outcomes in Africa. Overall, the purpose of this healthcare system is to promote better health and well-being for athletes in Africa, while also advancing the field of sports medicine through the use of innovative technologies.

The target population that will be affected by the healthcare system using wearable sensor healthcare in sport with HAR in Africa are athletes, both professional and amateur. This includes athletes across various sports disciplines, such as track and field, football, basketball, rugby, and many others. The healthcare system can be implemented at various levels, such as national sports federations, sports clubs, schools, and universities, to ensure that athletes at all levels of competition have access to the benefits of the technology. Additionally, coaches and healthcare providers who work with athletes will also be affected by the healthcare system, as they will be responsible for implementing and monitoring the technology to ensure optimal performance and health outcomes for the athletes they work with.

There should be steps that will be taken to implement the healthcare system. This may include identifying the appropriate technology, securing funding, and training personnel. In order to develop the healthcare system utilizing wearable sensor healthcare in sport with HAR in Africa, the following actions can be taken:

1. Identify stakeholders: Identify the key stakeholders that will be involved in implementing the healthcare system, such as athletes, coaches, healthcare providers, and relevant sports organizations.

2. Assess technology requirements: Assess the technology requirements for the healthcare system, including the types of wearable sensors and HAR technology that will be used.
3. Procure technology: Procure the necessary wearable sensors and HAR technology from reliable vendors or manufacturers.
4. Develop protocols: Develop protocols for monitoring athletes' health and performance using the technology, including data collection, data analysis, and data interpretation.
5. Train healthcare providers: Provide training to healthcare providers, coaches, and other stakeholders on how to use the technology, how to interpret the data, and how to adjust training regimens based on the data collected.
6. Implement the healthcare system: Implement the healthcare system in sports clubs, schools, universities, and other relevant organizations. This may involve installing the sensors, providing access to the technology, and setting up procedures for data collection and analysis.
7. Monitor athlete health and performance: Continuously monitor athlete health and performance using the technology and adjust training regimens as needed to improve outcomes.
8. Evaluate the effectiveness of the healthcare system: Evaluate the effectiveness of the healthcare system over time, by analyzing data collected from the sensors and tracking the health and performance outcomes of athletes. Use the data collected to make improvements to the system as necessary.
9. Ensure data privacy and security: Ensure that all data collected by the sensors is protected by appropriate privacy and security protocols, in compliance with relevant regulations and laws.
10. Provide ongoing support: Provide ongoing support to athletes, coaches, and healthcare providers as needed to ensure the success of the healthcare system.

The successful adoption of this healthcare system requires collaboration and engagement from all stakeholders, including athletes, coaches, and healthcare providers, it can be improved to meet their needs and preferences, ultimately leading to better adoption and improved health and performance outcomes for athletes.

5.2 Estimated Budget and importance of the system

Sport related health issues and injuries are a major burden for both individuals and society in Africa. According to a study by Injury Prevention, the incidence of sports and recreational injury in South Africa was 17.4 per 1000 persons per year (in 2001), and the average cost per injury episode was R 1,174 (in 2001 South African Rand) . These costs do not include the indirect costs of lost productivity, reduced quality of life, and long-term disability.

Implementing a machine learning system to predict and prevent sport injuries for athletes would require some initial investment, but it could also generate significant savings and benefits in the long run. The exact budget required to implement such a system would depend on various factors, such as the type and scope of the system, the data sources and quality, the development and maintenance costs, and the expected outcomes and impacts.

To evaluate the cost-effectiveness of our machine learning system, we can use a method called cost-benefit analysis (CBA), which compares the costs and benefits of different alternatives. One way to measure the benefits of our system is by using a metric called quality-adjusted life year (QALY), which reflects both the quantity and quality of life gained by an intervention. A study by Frontiers in Digital Health found that an AI system for cervical cancer screening in Kenya was cost-effective if it could generate at least 0.01 QALYs per patient . Assuming a similar threshold for our system, we can estimate how many QALYs our system could generate by preventing sport injuries and improving health outcomes for athletes.

Based on these estimates, we can argue that even if our machine learning system requires some budget allocation to implement, it would be worth the investment because it would reduce the overall cost of sport related health issues and injuries and improve the quality of life for athletes and society in Africa.

According to the search results, the cost of wearable sensor based HAR system would depend on various factors, such as the type and number of sensors, the data processing and storage methods, the recognition algorithms and models, and the evaluation and validation procedures. However, one possible estimate is based on a study by Stanford University, which developed a system that uses two inexpensive sensors (a heart rate monitor and an accelerometer) to measure calories burned during activity. The study claims that this system is more accurate than smartwatches for this purpose, and provides the instructions for making the system for yourself for free online 2. Assuming that we follow these instructions and use similar sensors, we might be able to build a lab of wearable sensor based HAR system for a relatively low cost.

The cost would depend on various factors, and we might need to do more research and compare different options and alternatives to find the best solution for our needs and budget.

However, if we want give a rough estimate based on the Stanford study, we might consider the following:

The study used two sensors: a heart rate monitor and an accelerometer. According to Amazon, a typical heart rate monitor costs around $30, and a typical accelerometer costs around $10. Therefore, the cost of one set of sensors would be around $40. The study used a Raspberry Pi 4 as the data processing and storage device. According to Amazon, a Raspberry Pi 4 costs around $60. Therefore, the cost of one data processing and storage device would be around $60. The study used Python as the programming language and TensorFlow as the machine learning framework. Both are free and opensource software. Therefore, the cost of the software would be zero. The study provided the instructions for making the system yourself for free online. Therefore, the cost of the instructions would be zero.

Based on these assumptions, the cost of building one wearable sensor based HAR system would be around $100. However, this does not include other possible costs, such as the labor cost, the maintenance cost, the validation cost, and the overhead cost. If we do rough estimate pf the total cost it would be b/n 2000 to 4000 US dollars.

5.3 HAR System Prototype Showcase

We have built a demo for the wearable sensor based HAR system using Streamlit, which is a Python library that allows us to create and share interactive web applications. Streamlit makes it easy to display the data, the recognition algorithms and models, and the results of the system in a user-friendly way. The input of the system is sensor data from smartphone sensors (Accelerometer and Gyroscope), which capture the movements and behaviors of the participants. The output of the system is human activity recognition, which classifies the sensor data into 18 different activities, such as walking, running, sitting, standing, etc. We used a dataset from Kaggle called KU-HAR, which contains information on 18 different activities collected from 90 participants using smartphone sensors. We trained the data for the system on Google Colab, which is a cloud service that provides free access to GPUs and TPUs for machine learning. Google Colab enables us to run and share our code in a notebook environment without installing anything on our local machine. We used XGBoost, which is a scalable and efficient implementation of gradient boosting trees, as the machine learning method for the recognition

task. By using Streamlit, Google Colab, and XGBoost, we were able to create and showcase a working prototype of the wearable sensor based HAR system.

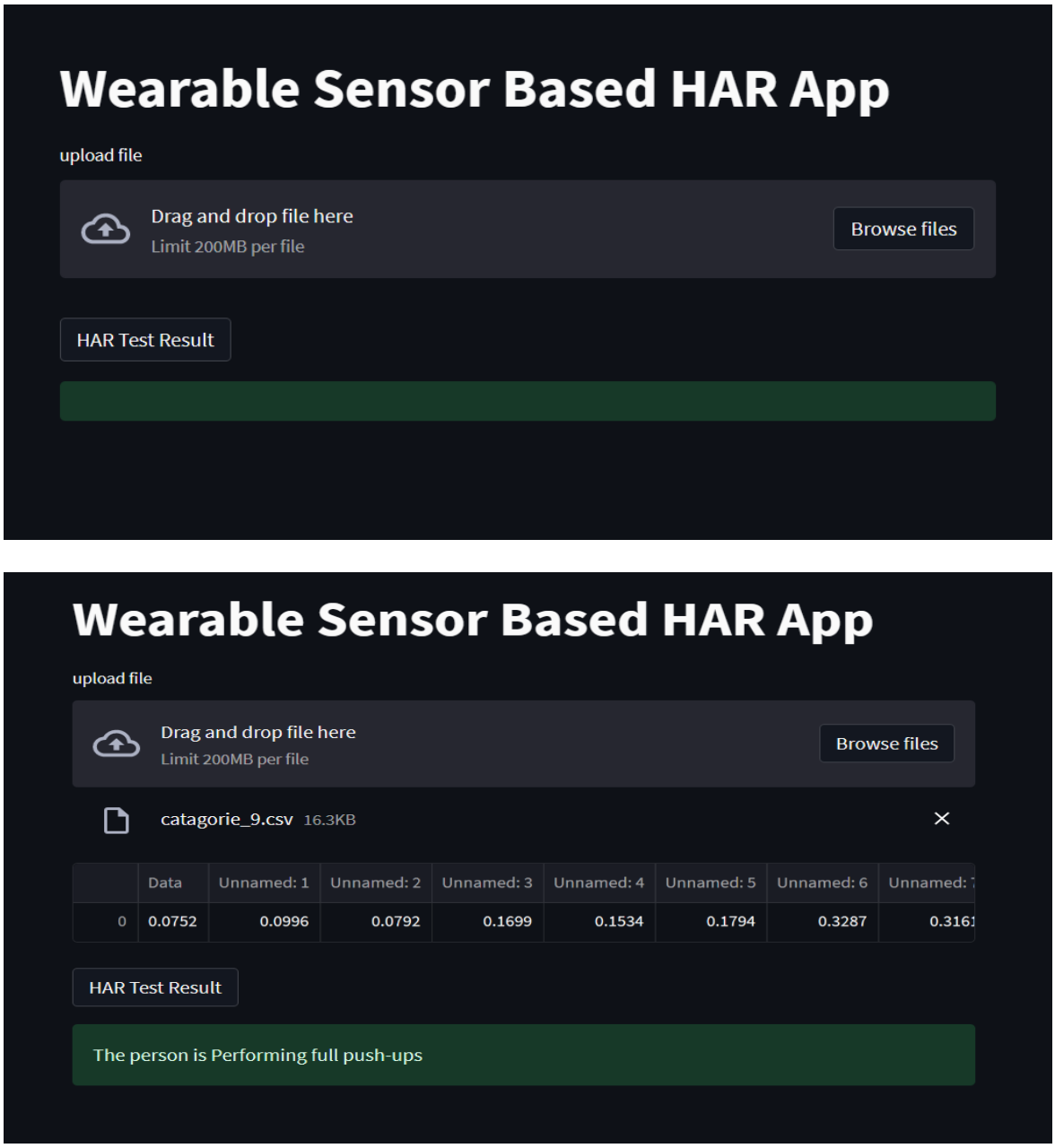

Fig 5-1 Working prototype of the Wearable Sensor Based HAR system

Chapter 6 Conclusion

Based on the findings and discussions presented in this project, it is evident that innovating wearable technologies for healthcare in sports is a relevant and critical area of research. This is particularly significant for developing countries in Africa where sports-related injuries are prevalent, and access to advanced healthcare technologies is limited. The project highlights the importance of wearable sensors and human activity recognition (HAR) technology in sports, which can help prevent injuries, enhance athletes' performance, and optimize healthcare services. The integration of wearable sensors with HAR technology enables real-time data collection and analysis, providing insights into athletes' health status and training levels. Additionally, the project emphasizes the significant role of artificial intelligence (AI) in the implementation and optimization of wearable technologies in sports. AI-powered systems can help interpret data from wearable sensors, provide recommendations, and make informed decisions based on athletes' health status and performance.

The discussion on how to apply this system in Africa highlights the need for collaboration between different stakeholders, including athletes, coaches, healthcare providers, and policymakers. This collaboration will facilitate the adoption of wearable technologies in sports and address the challenges, including limited resources and infrastructure in developing countries.

In summary, this project underscores the importance of innovating wearable technologies for healthcare in sports, particularly in developing countries like Africa. With the integration of wearable sensors, and HAR technology, athletes' health status can be monitored, injuries prevented, and healthcare services optimized. The implementation of this system requires collaboration among stakeholders, addressing the challenges, and future research to optimize the system.

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