Introduction:

Recent times have witnessed increasing growth in the number of elderly. It is reported that the number of elderly is expected to rise to nearly two billion by 2050 [1]. Medical reports also indicate that the prevalence of various degenerative ailments in the elderly and younger generation is on the rise [2]. These degenerative diseases including cancer, Alzheimer, dementia, osteoporosis, stroke, visual impairment, attention deficit hyperactivity disorder and asthma affect the cognitive skills of affected people, rendering them vulnerable and often incapable of performing basic activities of daily living (ADL) [3], [4]. Nonetheless, the demand by most elderly and affected people to live independently with minimal assistance makes ambient and assisted living (AAL) an interesting research subject.

The rapid advancement of the wireless sensor network and the Internet of Things (IoT) to recognize human activity is an improved possibility using different sensor readings [5], [6]. For most applications, the sensor is worn by users as wearable devices or embedded into household wares. The readings from the sensor are then collected, interpreted for possible activity recognition. One key purpose of activity recognition is change detection via identifying sudden change in metrics such as mean and covariance which represents a change in time series data within an indoor environment [7]. Accurate manipulation of these metrics using a robust algorithm would define the class of activity performed within a timeframe. In general, activity recognition is a critical component of context-aware systems which allows smart home applications to understand user requirement and adapt to the various circumstance of the user. Human activity recognition (HAR) is crucial to assist different emergency-related healthcare and wellbeing services. This is achieved by monitoring different physical activities for reliable real-time first responder and nursing services within care homes and domestic environments [8], [9]. However, developing a robust, scalable, real-time indoor HAR system in a real environment often presents a daunting research task due to the complexity of indoor environments.

Therefore, several interesting solutions have been proposed in the literature to recognize human activities for AAL. Traditional HAR systems are based on cameras and computer vision. These approaches are useful for large coverage and pedestrian activity recognition. However, camera and computer vision approaches are often limited by potential privacy issues because of their invasive nature. To overcome this limitation, recent HAR solutions are based on wearable approach using wearable sensors or devices including smartphones [10]–[11][12]. However, wearable solutions are sometimes unobtrusive as they are often associated with target inconvenience since users need to always remember to equip the sensing devices. Moreover, wearable solutions depend on the target to determine where the wearable device is worn and the device position with respect to the performed activity. This implies that the transition between positions has to be detected. Furthermore, several wearable solutions rely on subject-specific approach, where the target must collect the data and characterize them. These requirements present potential limitations to wearable HAR solutions, particularly to sensitive elderly and vulnerable.

Today`s smart world consisting of smart home devices, smartphones, wearables, and software applications have greatly influenced the human lifestyle. These technologies have given much power to a single individual, thus significantly reducing the dependency on others.

These smart technologies not only changed the lifestyle but also revolutionized almost every aspect of human life.

With these smart technologies came the concept of Ambient Assisted Living (AAL). And this is our answer to the challenge of ensuring the life quality of our senior citizens!

Ambient Assisted Living (AAL) provides a system comprising of smart devices, medical sensors, wireless networks, computer and software applications for healthcare monitoring. AAL can be used for various purposes like preventing, curing, and improving wellness and health conditions of older adults.

AAL aims at ensuring the safety and health quality of the older adults and extending the number of years the senior citizens can live independently in an environment of their own preference. Also, it reduces the number of informal caregivers, by allowing the patients to be in control of their health conditions.

Another emerging technology in this regard is the Ambient Intelligence (AmI). It is defined as the ability of a computing system to sense its environment and respond to the presence of people.

Systems built on Ambient Intelligence are called AAL tools.

There are a variety of AAL tools, each with their own diverse applications. AAL tools such as medication management tools and medication reminders, allow older adults to take control of their health conditions.

AAL technologies can also offer more safety for the elderly, using mobile emergency response systems, fall detection systems, and video surveillance systems.

Other AAL technologies provide help with daily activities, based on monitoring activities of daily living and issuing reminders, as well as helping with mobility and automation.

Finally, such technologies can allow older adults to better connect and communicate with their peers, as well as with their family and friends.

Information Technology (IT) has taken the concept of AAL to new heights. The use of Information Technology based systems in disease management make the patient be in control of the situation, leading to a lowering of the healthcare costs.

Under this scenario, their treatment will take place at home, through the use of smart technologies and appliances that will cater for real-time monitoring and evaluation of critical data, triggering alarms and making recommendations, in case of necessity.

Family and relatives will also be empowered, as they will have access, in real time, to the collected information.

Today, Smartphones are the most common and the most important element of our lives. These smartphones are equipped with various sensors such as an accelerometer, gyroscope, proximity sensor, and a global positioning system (GPS), which can be used for detecting user activity and mobility.

Non-invasive sensors (Not involving the introduction of instruments to the body) in the form of patches, wearable devices, smart garments have also been developed to monitor health signals.

RFID is identified as a potentially viable candidate for truly pervasive computing applications. With overcoming the traditional limitations of RFID including universally accessible infrastructure and complication in its use, RFID has found its use in a wider variety of applications. Moreover, with the increasing use for automatic target and location identification, RFID is popular as an open, scalable and shared technology capable to automatically identify and collect information about entities and interactions between them in a completely transparent manner to end users [13]. Furthermore, recent desirable improvements in RFID technology has facilitated the development of cheap, high sensitivity and high read range (≥ 10m) passive tags that support innovative, cost-effective emerging pervasive and IoT-based healthcare solutions [14]–[15][16][17].

To this end, the present work is motivated from previous investigations [18], [19]. The motivation is to provide a robust, cost-effective solution that meets the clinical requirement of ambient patient activity profiling with guaranteed freedom of movement. To achieve such solution, a novel ambient approach using SmartWall is proposed. The SmartWall is used to sample sequential and concurrent activities. Human activity in the present work is formulated as a multivariate classification problem. The proposed activity classification framework augments *a prior* information from RSSI of passive RFID tags to obtain more detailed activity profiling. For patients with chronic diseases, position, orientation, mobility and degree of activities are key indices for guiding reliable clinical management decisions, and as such, different real-life indoor case scenario of activity hinging on these indices is sampled on four subjects in the present work.

The major contributions of the present paper include:

* We propose the SmartWall; a novel RFID-enabled approach that implements the pervasive nature of UHF passive RFID tags to recognize sequential and concurrent activities.
* We develop machine learning via multivariate Gaussian algorithm using maximum likelihood estimation to classify and predict the sampled activities.
* We conduct comprehensive experiments of various real-life physical activities via ambient sensing for data collection, evaluation and classification.

The paper is structured as follows: Section II highlights related works on the present research objectives. In Section III, the methodology of the proposed method is presented. Human activity is formulated as a multivariate Gaussian problem. In Section IV, a detailed description of the proposed SmartWall, features for activity classification and the results of the experiment are presented and discussed. Next, we present the proposed algorithm. Section V presents the performance evaluation of the proposed solution using different performance metrics. The observation and areas for further improvement are summarized in section VI.