A SURVEILLANCE ALGORITHM FOR FALL DETECTION AND INITIATION OF AN E-MAIL

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ABSTRACT

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Demographic patterns are demonstrating that the world is a maturing society. Advances in medical treatments extend people's life spans. Elderly care is a burden on families' and states' budget. Moreover, elder people want to age in their place without the breach of their privacy and losing independency. Statistically unexpected falls happen to one third of individuals in excess of 65. This thesis focuses on fall problem on elderly, who age at their place. Smart assisting for elderly is an essential need for health care and emergency response when needed. Since sleep assistance is a complex subject, this project covers only the part that, if they fall while standing or sitting they would get help. Thus this thesis aims to help people age in their place by providing fall detection via image processing. The approach can be described as data analysis and programming an algorithm in the area of fall detection. The system analyzes minimum bounding rectangle of a moving object, considers aspect ratio, centroid and diagonal angle. In the literature fall algorithms use computationally expensive algorithms to distinguish the focused person in the image. In this study distinguishing an inactive person is not included considering that a fall necessarily contains motion. The person of interest is distinguished with image differencing. However this technique amplifies the noise in the binarized image. This issue is eliminated using Gaussian filtering on differenced image. Due to experiment constraints an adequate amount of statistics was not possible to collect. However human movements can be imitated with computer software literally. For academic purposes open access to this software can make statistics available for fall algorithms. A series of scenarios of fall is presented in section 2.7.4 and for each category a sample was recorded. Scenarios are a total of 20 with 4 recoveries and 5 fall-like cases. Among them only 11 are real fall cases and they are all detected as true positives besides one. The rest 9 cases are either with recovery or fall like cases and only one of them gives a false positive alarm. Hence the true positive percentage is 91 per cent while the false positive ratio is 11, 1 per cent.

ÖZET

DÜŞME TESPİTİ VE E-POSTA GÖNDERİLMESİ İÇİN BİR GÖZETİM ALGORİTMASI

Nüfus ile ilgili örüntüler göz önünde bulundurulduğunda dünyanın yaşlanan bir topluluk olduğu görülmektedir. Bireyler özgürlüklerini yitirmeden ve özel alanlarının ihlali olmadan kendi yaşam alanlarında yaşlılık dönemlerini geçirmek istemekteler. Yaşın ilerlemesi sonucu bireyler kaslarında, yürüyüşlerinde ve dengelerindeki kontrolü yitirmekteler. İstatistiki olarak 65 yaşını geçen her üç bireyden biri beklenmedik biçimde düşmektedir. Bu proje yaşlı bireylerin evde düşme sorununa odaklanmaktadır. İhtiyaç anında destekli yaşam çok önemli bir gereksinimdir. Uyku sırasında destek karmaşık bir konu olduğu için bu proje otururken ya da ayaktayken, düşme meydana gelirse ihtiyaç duydukları yardıma kavuşmalarını kapsamaktadır. Bu proje görüntü işleme yöntemi yoluyla bireylerin özel alanlarında yaşlanmalarına destek olmayı amaçlamaktadır. Gösterilen yaklaşım, ürün çıkarılabilmesi için düşme algoritması alanında bir veri analizi ve programlama olarak tanımlanabilir. Sistem hareket eden cismin asgari sınırlayan dikdörtgenini, en-boy oranını, ağırlık merkezini ve köşegen açısını analiz etmektedir. Literatürde bulunan düşme algoritmaları çözümünde yüksek hafıza kullanımına ihtiyaç duyan yöntemler ile odaktaki kişiyi seçme çalışması yapmaktadır. Bu çalışmada düşmenin kesinlikle bir hareket içermesi göz önünde bulundurularak hareketsiz kişilerin ayrıştırılması algoritmaya eklenmemiştir. Odaktaki kişi resim farkı alınarak bulunmuştur. Ancak bu teknikle, ikili resimdeki gürültü oranı artmıştır. Bu yeni durum fark resmine Gaussian filtresi uygulanarak aşılmıştır. Deney kısıtları olması sebebiyle yeterli derecede istatistiksel sonuç sunulamamaktadır. Literatürden alınan düşme ile ilgili senaryolar bölüm 2.7.4'te sunulmuş ve her kategori için bir video kaydedilmiştir. Senaryolar 4 toparlanma ve 5 düşme benzeri durum ile birlikte toplamda 20 adettir. Videolar içerisinde sadece 11 tanesi gerçek düşme içermektedir ve onu için sonuç doğru pozitiftir. Geriye kalan kategoriler 9 tanedir ve sadece bir tanesi yanlış pozitif sonucu vermektedir. Sonuç olarak doğru pozitif oranı yüzde 91 ve yanlış pozitif oranı yüzde 11,1dir.

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ABSys	Abnormal Behavior Fall Detection System
ADL	Activities of Daily Living
AGS	American Geriatrics Society
ECG	Electrocardiogram
FPS	Frame Per Second
ITMI	Integrated Time Motion images
MBR	Minimum Bounding Ratio
MIT	Massachusetts Institute of Technology
NORC	Naturally occurring retirement communities
OOL	Object Oriented Languages
REM	Rapid Eye Movement
RGB	Red, Green, Blue
UK	United Kingdom
US	United States

1. INTRODUCTION

Demographic patterns are demonstrating that the world is a maturing society. Most European nations including Turkey will confront a huge build in the quantity of elderly individuals within a brief span of time. Advances in medical treatments extend people's life spans. The improvement of intelligent homes will enhance the personal satisfaction of seniors and the impaired individuals. Elder people want to just be able to go back home. Thus, a great deal of studies are acquainted with enhance intelligent homes in the most recent ten years.

It is accounted for that unforeseen falling is a significant issue and around one-third of individuals in excess of 65 falls unpredictably every year [1]. Fall related welfare and harm expenses are billions of dollars around the world. Additionally, unusual inactivity detection is also very important because of the sudden diseases like heart attacks. As a result, we focus on the falling person detection systems and decided that an ambient assisted living abnormal behavior and fall detection system (ABSys from now on) can be designed, using image processing, for this purpose.

Elderly care addressed differently among countries and is changing direction rapidly. Even within the same country there are regional differences in United States [2]. Moreover out of any other age group the most health expenses consumption has been observed in elder individuals [2]. Also increasing large ratio of worldwide elderly, especially in under-develop nations, because there is an ongoing emphasize on birth control and decreasing the amount of inhabitants [3].

Traditionally elderly care has been duty of core family members and provided that way. Progressively in advanced societies, elderly care is now being provided by government or charitable institutions [4]. The meaning behind this regulatory practice is the birth control policies, a longer expectancy in aged people life-span, environmental distribution of families and tendency for women to work [4]. Despite the fact that these developments

have influenced European and North American nations in the first place, they are currently continuously influencing Asian nations too [5].

In Europe in 2030 working versus inactive people ratio will shift from 5:1 to 2:1. That is a huge pressure on economy. European nation sees that area that has to force to be more innovative because traditional nursing homes will be incapacitated by the rapid growth in aged people. Next section will cover the countries' policy and point of view in care for aged and/or disabled individuals.

Developing countries and developed ones. Around the world economically poor people, who have less purchasing power are more likely to face an inability in their lifetime. Statistically wealthy nations have noticeably less amount of people incapacitated than underprivileged countries. Although there is no research to show a direct correlation between these two notions, recently there has been some research illustrating that poverty and disability are "mutually enforcing" [4].

Experts from UK Disabled Persons Council points out that ill health and poverty stimulate a "vicious circle". Statistics show that vicious circle people are more prone to bankruptcy and paralyzing. Despite the fact that governments have regulations to avoid leaving disable people unemployed, opportunities for training and work can be unattainable to them and this leaves disabled people bankrupted. Likewise underprivileged country residents have lower sanitation standards, health care, nutrition [6].

Since not even proper sanitation is nearby for underdeveloped countries, nursing facilities is impossible for those countries. Abnormal behavior and fall detection system (ABSys) is trying to integrate disability perspective of old age and poverty or need, into individuals private home even if elder people are not wealthy enough for a care facility or care-giver at home.

Worldwide trends: The population is aging worldwide. The projection for 2050 is that 21 per cent of the world's population, an estimated 2 billion will be aged 60 or older [7]. The aging population worldwide has provoked architects and designers to create new and more

geriatric appropriate housing — private homes for aging in place, communities for like-minded people who are getting on in years, and long term care facilities for those who can no longer take care of themselves. The collective environment extends beyond architect and designers, older people are beginning to collaborate on the purpose and design of places where they live. New trends in senior housing progress around the world, specifically in eight countries which have large aging populations (Japan, China, Netherland, Sweden, Denmark, Norway, Brazil, and Israel) that thrive to accommodate the needs of the elderly in new and innovative community solutions.

Japan: Older people don't want to give up their independence and their single family residence. Originally, the customary model was the "Nisetai Jukatu" of multigenerational household. But recently there has been a shift toward high tech homes that allow independent aging in place. The new homes are barrier free, and retrofitted homes are safer and easier to use. They rely on a mix of technologies and human services for these purposes. They link information communication technologies, caregivers and in some cases rooms into collaborative environments. There is an interest in use of robotics, networked appliances, telecommunication systems, bathing service vans and portable hot tubs [7].

China: Conventionally sons were responsible to care for their elderly parents according to the familial devotion norm. Due to the one child policy, many elderly people had no one to take care of them, until 30 years ago. There were no senior apartment buildings, senior daycares and very little nursing homes. Older people lived with relatives, according to their Confucian tradition. Nursing homes were considered for people without offspring, usually in the form of charity organizations. Today these are 95 per cent occupied. 18 per cent of China's older people are living today in senior housing and the industry is expecting 15 per cent growth a year. Senior housing is becoming more popular and socially adequate. In addition China is encouraging aging in place by making existing housing more senior friendly, and increasing the number of available services. Programs exist to encourage families to take care of aging family members at their homes. The senior population is wealthier, and expects more comfortable and attractive surroundings leading to more variety in architectural and financing options. The economic growth of the 1980's was

followed by large migration from rural countryside to the big cities. Most senior housing is owned by the government. More than half of the privately owned senior housing is family owned and operated. The remainder is corporate large institutions, some of which are beginning to join into chains [7]. The future for the senior housing industry in China will have more upscale senior housing growth, more corporately franchised nursing homes, growth of home repair industry, and growth in interest in interior design.

Netherland: In Netherland there is the "apartments for life" arrangement that combines services for the in poor health with conventional housing. It is a creation of an adaptable apartment building where service supports can be increased to a nursing home level to keep residents living independently. Common spaces are open to residents and to other people in the community.

Dementia residents stay in their apartments at night and join a daycare group during the day.
Services are monitored and delivered by a nurse or personal care assistant. This approach provides autonomy and privacy which appeals many of the elderly residents. Partnerships between housing developers and providers of long term care are encouraged. Most projects (unlike the US) are financed over a longer period (50-75 years) to make it financially possible to add innovative features to the buildings. Non-profit housing developers are encouraged to
pursue mixed use developments as well as more owner occupied housing. Atrium buildings for the elderly are common, which provide outdoor spaces during the winter [8].

Scandinavia- Sweden, Denmark and Norway: Sweden has one of the world's most rapidly aging populations with 17.2 per cent of the population 65+ in 2000 [8]. 90 per cent of the older people live on their own and not with their children. Independence of old age is a value. By law, cities have to help older people to be independent and continue to live on their own, by social services, community health centers, and health aides. The popular model for senior housing is independent housing with care ("servicehus"). Government reduced the number of beds in hospitals and nursing homes, and increased the number of home health workers. Sweden values equality, in gender and age. Older people are valued

members of the Swedish society. The majority (55 per cent) of elders' lives alone and about 45 per cent live in age integrated communities. The home care requires structural changes in the home.

Denmark is known for its experiments with cohousing. Senior cohousing is often created by a local group of elderly who want more socially integrated life. Residents eat together and help one another when they are temporarily sick or need a ride. The home care
system provides ongoing personal help and health care so the residents don't have to care for their neighbors needs in that sense. The Danish deliver care to a wide variety of housing types and are very liberal in adapting a range of housing forms. They value independence and emphasize larger units with more casual relationship to caregiving [8]. Norway focuses on two housing types- the first resembles the Danish or Swedish service house and is a large centralized building (100+ units) with housing for the frail and services that are available for older people in the community. The second type is targeted to 55+ people for aging in place. In addition, cooperative ownership is common in Norway [8].

Northern Europe tends to adopt a strategy in which the residents do as much as they can themselves, while in the US there's a tendency for staff to do everything for the residents, which develops the learned helplessness'. The Scandinavian countries have shown ways to deal creatively with their aging populations, and have more government subsidies relative to other countries, but the profile of their populations is very different from the American profile. Their populations are very homogenous, and they don't have the size and scope of the US population to deal with.

Brazil: By 2020 Brazil will have the seventh largest elderly population in the world. For the first time, their elderly population grows more rapidly than the youthful segment. Brazil traditionally was a youth obsessed culture, but now has greater appreciation to aging. Family life is transforming, as more women enter the workforce. Traditionally, elderly lived with or near their families or in nursing homes. Since 1990's assisted living facilities are more common as well as senior residence, which resembles high rise hotel

with similar facilities. Still the majority of Brazilians live with the family or age in place in their homes. Although it is illegal to discriminate based on age in Brazil, social norms dictate where elderly should live. Older people were not to expect better housing or speak out for their rights. Now the society is changing to be more receptive to elderly. Affluent older people can retrofit their homes and hire home health workers; Government programs help the needy to get the home health care. Popular senior housing is the "residencial"- modern high rise apartment buildings that look more like apartments than assisted living, which attract mostly the wealthy elders and are located in the largest cities. These have become a status symbol for the elites. The future of Brazil's seniors will include greater variety of housing option, for healthy old age.

Israel: Israel's population is aging differently than other places, resulting from increased life expectancy as well as migration of elderly. Many of Israel's 267 kibbutzim are becoming NORCs (naturally occurring retirement communities) as the residents age in place together, complete with geriatric health centers and assisted living. In addition Israel created sheltered communities and absorption centers for older incoming immigrants- Supportive neighborhoods where people of similar ethnic backgrounds learn skills in order to assimilate in Israeli life.

Absorption centers and hotels have been converted to additional housing for the elderly immigrants. Many of these have affordable rents and have community outreach services that are provided for the surrounding community as well. In spite of rapid change to society structure most elderly people still rely on family for social support. But it is not common for the elderly to live with their children. Most elderly age at home with supports from family members and from home care professionals, homemaking services and adult day care centers. Israel sponsors a number of organizations that send volunteers to help the elderly at their homes. There are organizations which help with emergency home repairs, upgrade to home safety and security, and home health workers. There is also a growth in nursing home construction. The financing and regulation of these has traditionally been government monopoly, but the sector is being deregulated and more private for profit companies enter the industry. A third of the Israeli kibbutzim, collective settlements, are being retrofitted and made more accessible to retain residents because the original settlers

have aged in place. Homes are retrofitted, and long term care facilities are built on site to accommodate the residents. The Kibbutzim originally specialized in farming and manufacturing. Over the years they have become naturally occurring retirement communities (NORC5) allowing architecture to respond to the age wave in Israel. Kibbutz architecture has responded to social and political changes before. It started with the ideals of equality, frugality, and rejection of private property which took shape in common dining areas, children nurseries, barrack like housing for all residents. In the 1950-1990s privatization grew in Israel, the original socialist idea of the kibbutz has weakened. Houses became private, with more of status displays of landscape, gates, etc. Today 75 of the kibbutzim are NORCs, with the original settlers 11 their 70s and SOs, with 3 distinct architectural forms.

The Japanese move toward technologically smart homes, the Scandinavian emphasis on independent housing with care, the Dutch experience with combination of services with conventional housing and success with developer-service provider partnerships, and the Israeli success with use of volunteer groups and retrofitting existing kibbutzim's infrastructure to fit the aging residential communities all suggest that there can be a solution that combines service and independent housing for elderly reusing the existing built stock, while upgrading it to fit the needs of the elderly. ABSys will help in this context, fitting available houses to elder needs.

Worldwide trends in senior housing: Worldwide senior housing in the 21 century appears to be divided into housing for the upper class and housing for the lower income masses. Family support for the elderly is weakening and family structure is breaking down because of decline in fertility, higher divorce rates, increase in number of living grandparents , and expectations of the state to care for elderly, all of which lead to creation of new forms of senior housing. Nations have developed ways to maintain older people in their homes- home health workers. Support services for transportation and emergency home repairs. The desire to age in place is universal, as well as to remain part of the community [9].

Change of family structure- As more women enter the labor force, there are less daughters or daughters-in-law that are able to be caregivers. The traditional extended family is changing, increasing the demand for congregate housing, assisted living facilities and nursing homes.

Desire for independence- Older people are thinking of themselves differently, enjoying their independence and more reluctant to move in with their children. More elderly people are living alone. The majority of older people around the world say that they want to live independently for as long as possible. Older people worry of being a burden on their families which stirs an interest in finding alternative housing arrangements to allow that.

Gerontologic and Universal design- and increased interest in Gerontology design (remodeling or modifying an existing space in response to deteriorating health of homeowner) as well as in Universal design (creation of environments that work for people of all ages and all abilities), planning a vision for the future that involves aging in place

Link to services- Housing is regularly linked with community based facilities- service house/community centers spread throughout the neighborhoods that serve as place for older mild to live. A combination of community center with assisted living housing serves other elderly from the community who don't live there as well [8]. Home health services are organized at service houses and day centers for older people living in the neighborhood- working out of service houses home care workers help service people living nearby. Supportive health and personal care services, as well as long term care are paid for by the governments [8].

Smart homes- There's a move toward houses for the elderly, which are barrier free, smart homes with robotics and networked appliances that carry heavy objects, do light housework, and even serve tea to help maintain the independence. Networked home appliances show a potential for creating safer, more manageable environment for the elderly.

Daycare for dementia- Service houses have day programs for people with dementia they are picked up from their homes and dropped off at the end of the day and are encouraged staying as independent as possible [8].

Small, residential scale housing- Most housing for the frail are made up of small group dusters- family like clusters of six-eight units, with five common spaces where residents spend most of their time. Emphasis on short stays, rehabilitation and respite- in community based system housing providers help older stay at their homes [8].

Needs based services- Some countries exhibit an approach to meet each resident's unique needs - adjusting the schedule to fit the needs of each residents individually, residents encourage to help themselves as much as possible [8].

Outdoor- There's a strong preference for relationship to outdoors and nature.
Single occupancy- Most new buildings feature single occupancy units.
Emergency systems- Efficient regionalized food and emergency call systems.
45+ -Adult communities arise in some countries to house people 45+.
Multigenerational programing- More opportunities to link with children are provided
Mechanical aid- Lifting devices are becoming more popular.
Social responsibility- Municipalities have more influence on planning- most developers in northern Europe are non- profit community providers motivated to create housing as public good rather than to make profit.

Considering all of the above conditions this thesis aims to help elder people to age in their place. Aging in place for the lower income masses is still impossible due to different factors. In order to attain this goal, ABSys (Abnormal Behavior Detection System) aims to give an opportunity to live in to people who want age at home. Despite the fact that none of the elder people who fall once defines them as a faller, this issue will be discussed later in causes of a fall topic; ABSys basically intends to eliminate falling and not being able get help problem. Next issue is literature review that is the research about remote sensing of fall.

1.1. LITERATURE REVIEW

ABSys (Abnormal Behavior Detection System) aims to sense a fall remotely. The idea behind the ABSys is that elder people want to age in their place but, since some of aged people are in decay in physical abilities occurrence of an emergency situation much more likely. Because of this situation fall detection is a trending research area. In this section relevant researches are mentioned.

There are several different types of smart home designs in the literature. Computer vision systems can be used to track the person and classify his/her movements in a house. In recent years, the number of the Kinect sensor based systems continues to increase for the smart home implementations. Wearable devices are often used in similar applications.

Methods of fall classification can be categorized into three different approaches: threshold based rule-based and machine learning approaches. Among all of the automatic fall detection systems rule-based approach is most used [10-42].The main idea behind that is to set rules that will help distinguishing the ADL's (Activities of Daily Living) and falls. The rules contain thresholds of one or more features. They usually use mean, standard deviation, and sum of vector magnitudes and tilt angle.

Moreover there are also completely and particularly machine learning based fall detection systems. Li et al. [10] used k-mean, naïve Bayes, entropy discretization and regression for posture recognition. For doing the same posture recognition Gjoreski et al. [43] applied machine learning algorithms. In Ojetola et al. [44] a decision tree is constructed based on sum vector magnitude and raw data. They used them to distinguish falls and ADLs.

Furthermore wearable devices can be divided into two categories: posture based and motion based, ambiance devices can be classified into presence and based on posture and vision based systems can be considered as; shape change, inactivity, and 3D head motion.

Mathie et al. [11] used accelerometer on waists. If the negative acceleration suddenly increases, because person is changing position from up to down, then this situation is taken

as fall. Bianchi et al. [12] wanted to improve available accelerometer based detection systems and introduced barometric pressure sensor. Idea was basically to measure altitude. Estudillo-Valderrama et al. [45] used multiple biomedical sensors and a personal server in order to process data. A wearable airbag was involved by Tamura et al. [13], as told in the first paragraph, when angular velocity and acceleration exceeds a thresholded value, and then airbags inflate. Lindeman et al. [14] used accelerometer placed on the head, behind ear, integrated to hearing aid. This is a thresholding based method again. In detection spatial direction of the head, the velocity just before contact with the ground and the impact on the head is considered.

Furthermore accelerometer gives information about physical activity and inactivity. Sixsmith et al. [46] used an array of infrared detectors. Target is monitored for inherent dynamics of fall and also inactivity intervals are supervised again in different locations with different acceptable periods. But in these approaches the must is to wear that particular device all day long and this is something elderly sees as a burden and depressing.

Also there are posture based fall detection methods. These methods use multichannel accelerometers for being able to distinguish posture and basic motion patterns. In other words while other accelerometer based methods measuring speed and acceleration only, along with other features this method uses posture information. Kaluza et al. [47] constructed a basically posture considering algorithm. Small wireless tags are placed around the person where is seen as important to define posture. The locations of the tags are identified by motion capture system. After a 3D reconstruction, posture is identified along with thresholded velocity and acceleration values.

Additionally in literature there are ambient based approaches. Tabar et al. [48] created a channel like operation between the user and the network through a wireless badge node. The user badge identifies falls via event sensing. By Alwan et al. [49] made a system that complies with the needs of elderly of not wearing anything. It is not intrusive and totally passive. This floor vibration-fall detector monitors floor’s vibrational patterns and a fall has different vibrations from daily activities. The floor surface is coated with a special piezoelectric sensor and a battery driven pre-processing circuit is in the system to analyze

vibration patterns. A binary signal is produced in the case of a fall. Rimminen et al. [50] used the shape, size, and magnitude collection to classify postural estimation from clusters of observations. The postural estimation conducted by Bayesian filtering as a replacement for using classified features. This system makes perfectly fall distinction and posture estimation except if the user falls on knees. This event produces the same pattern as standing.

Additionally there are camera (vision) based approaches. In image analysis to detect a fall, advanced or at least efficient and accurate human shape realization. In Foroughi et al. [51] a combination of Eigen space vector and integrated time motion images (ITMI). ITMI is spatiotemporal database motion information with an importance on the last event. Further inactivity or change of shape is basis for image processing algorithms. Later Foroughi [52] implemented an ellipse around body to detect shape change. After moving object segmentation projection histograms are evaluated and time-based changes of head is distinguished. Then extracted features are sent to MLP Neural Network similar to his earlier works in order to classify the motion that has occurred was a fall. Miaou et al. [53] used an Omni camera and personal information such as weight, height, electronic health history. In this algorithm object segmentation is implemented through background subtraction. Algorithm also contains noise reduction for accurate results. A bounding box and ratio of height to weight is used through consecutive six images resulting in five ratios on hand. Initially algorithm makes use of first two ratios to compare if they are greater than 1. If first two ratios are greater than 1, that means a fall event occurrence is likely. Fall detection is based on last three ratios. The last ratios are less than 1 and a predetermined threshold which is adjusted by Body Mass Index, then system decides there is a fall.

Miaou et al. [53] states that the basic to do in fall detection is to reliably detect and segment moving people using a self-learned background model and then use the segmented individuals height/width ratio. The main task here is to classify pixels if they are foreground or background where each pixel is represented with a multivariate Gaussian. If the pixel's hue, saturation and intensity value remains stable for a predetermined period of time, then this pixel is assigned as background. After classification aspect ratio is used. Miaou et al. not only uses "leftmost, rightmost, topmost and bottommost" pixels, but also

uses summation of number of changed pixels. They implemented falling motion inference combined with a simple two state machine. Meaning that Miaou et al. used and event-inference module that has two states “standing/walking” and “falling down”.

Wu et al. [54] uniquely identified velocity characteristics differences in normal and abnormal daily movements. Horizontal and vertical velocities are measured through the body at different places. Trend of velocity shows different patterns for different directions. For horizontal and vertical velocities there is discriminating patterns. Detecting falls from normal activities are determined by on when the magnitude changes and timing when the magnitude change happens in velocities.

Vishwakarma [55] uses an adaptive approach to detect moving objects by background subtraction and bounding boxes. Here emphasize is on horizontal and vertical gradients, aspect ratio and the angle of centroid to the horizontal axis of bounding box. If the angle becomes less than 45° then the system decides there has been a fall. Basically analysis emphasizes vertical velocities of the subject and by gradients, the patterns of velocities. Then these extracted features are sent to neural network that distinguishes characteristics of pre-determined rules of fall.

For fall detection posture information is also used. Cucchiara et al. [56] made use of classifying posture of the person. Analysis identifies projection histograms and compares with put in storage posture patterns.

Head position analysis is applied by head tracking that determines the event that is a large movement of the head. There are different models for head tracking. For example Hazelhoff et al. [57] uses two uncalibrated and perpendicular cameras for segmentation of foreground objects. The ratio of the variances in x and y directions and human body axis are found by principal component analysis. Since head tracking is present, the system robustness increases. With the use of Gaussian skin-color model, the position of the head is estimated and by exploring the nearby skin-colored blobs the system tails the head. And the decision is given by Gaussian classifier. Jansen and Deklerck [58] suggested that in the occurrence of a fall vertical motion is faster than horizontal motion. They used a binding

model with the use of three dimensional visual approaches information gained from images. Here the fall occurrence interpreted as a function of time, location and duration of the event.

There are also different kind of ambient houses as can be seen in Table-1.1 and Table-1.2. In different institutions there are different approaches just like the fall detection algorithms. All of the projects above help to age in place. For further information see referenced works.

Here in this thesis, fall detection has been implemented as a visionary algorithm. The algorithm makes use of bounding box ratio for discriminating the fall from everyday activities. Also other strong side of ABSys is that the system does not interfere with the user, meaning that it is just monitoring. ABSys does not breach individual privacy and besides that user does not have to wear anything. Next issue contains definition of fall.

Table 1.1. Assistive smart home projects

Project	**Institution**	**Reference**
Aging In Place	U. Of Missouri	Ranz
Aware Home	Georgia Tech	Abowd
CareLab	Germany	Nick
CareNet (MIDAS)	U. Of Wales, UK	Williams
CASAS	Washington State u.	Cook
DOMUS	U. De Sherbrooke	Giroux
Elite Care	OHSU	Adami
ENABLE	Netherlands	Van Berlo
Gator Tech	UF	Helal
HIS	Grenoble U., France	Noury
MavHome	U. Of Texas at Arlington	Cook
Millenium Home	Brunel U.	Perry
ProSAFE	LAAS, France	Chan
SELF	ETL, Japan	Nishida
Smart Medical Home	Rochester U.	Allen
Ubiquitous Home	UCG, Japan	Yamazaki
WTH	JMITI, Japan	Tamura
-	UNSW, Australia	Celler

Table 1.2. Ambient sensors used in smart environments

Sensor	**Measurement**	**Data Format**
PIR	Motion	Categorical
Active Infrared	Motion/Identification	Categorical
RFID	Object Information	Categorical
Pressure	Pressure on Mat, Chair, etc.	Numeric
Smart Tiles	Pressure on floor	Numeric
Magnetic Switches	Door/ Cabinet Opening /Closing	Categorical
Ultrasonic	Motion	Numeric
Camera	Activity	Image
Microphone	Activity	Sound

1.2. DEFINITION OF FALL

In order to understand what we are dealing with here it is essential to understand the meaning and scope of the term fall. The understanding of phenomenon will help to indulge content of the ABSys. Some define fall as the event when a knee touches the ground, nevertheless few define it as "a sudden movement of the human body bringing about in an injury". However, in simple words, a fall can be considered as "an unintended and uncontrolled movement of a human body causing it to lie down on the floor" [59]. Moreover, it may also be known as an unintentional and sudden change in position of an individual, causing him/her to land at a lower level, on an object, the floor or the ground [59]. To sum up, elderly or any other person would not precisely end up lying on a floor horizontally, to call event as a fall. After sudden and unintentional movement they may end up as resting on an inclined surface, stairs or any other object.

On the other hand if an intrusion or support in the course of fall prevents the person from resting on the floor, it is called stumble. Moreover finding a person on the ground does not mean that they fell if not the lying was unintentional. Also bending down or sitting on the floor shall not be mixed up with a fall. Falls are not always ends up with big injuries nevertheless, often they cause serious injuries and it can be foreseen that future falls could be.

A fall is such a trauma that once happened fall makes people so afraid of falling again [60] and as a result of trying to prevent future falls they reduce their physical activity [60]. In the long term, decreasing physical activity can lead to inactivity and reduced fitness, strength and balance control, growing the risk of falls. Ultimately, falls can lead to a loss of independence and increased mortality.

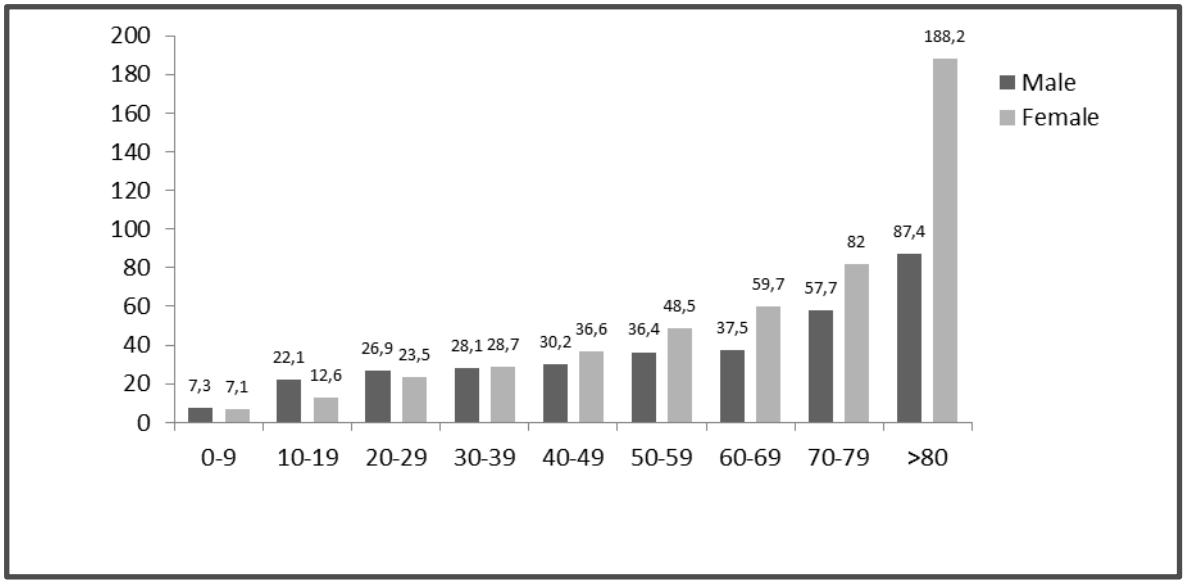

Figure 1.1. Prevalence of falls according to age [61]

Male adults show better rates in risk of fall prevalence. In most of the age groups, as seen in Figure 1.1, females are at high risk of falling more than males other than ages 30-49; in this interval sex difference does not apply any difference between individuals. Even though risk factor for female starts at 50-59 age group, elderly who is older than 65, without emphasis on gender, are at great risk of fall [61].

1.3. CAUSES OF FALL

Throughout the years, research has been directed to discover the reason for falls. Knowing the reason for the fall may prompt the productive corrective action and recognition of these occasions. In spite of the fact that numerous explanations behind a fall have been discovered, they are not particular enough to deliver an effective prudent model. Factors that are often associated with falls are: improper balance, medication effect, gait inconsistency, cardiovascular diseases, weakness/loss of strength, and impaired vision [62]. In spite of the fact that the reason for falls appear to be completely unique in relation to one another, they impart one common feature: every one of them have an unfriendly impact on the pace of the individual. When the impact on the stride might be discovered and recognized, treatment is conceivable, in light of the medicinal history of the individual, to keep the pending fall.

Unfitting sense of balance and pace inconsistencies may be the consequence of exhaustion or a previous damage. Besides, elderly patients experience the ill effects of shortcoming and loss of quality in muscles because of inactivity or low physical movement. In any case, if these indicators are perceived before the hardship, the elder might be liberated by giving the fitting exercise based recovery or treatment for the harm. Besides, an irregularity in the pace of an individual could be because of the impact of high medication. The individual may feel light-headed because of the high doses given daily. In any case, there may be a likelihood of decreasing prescription to anticipate falls if the impact is recognized on time.

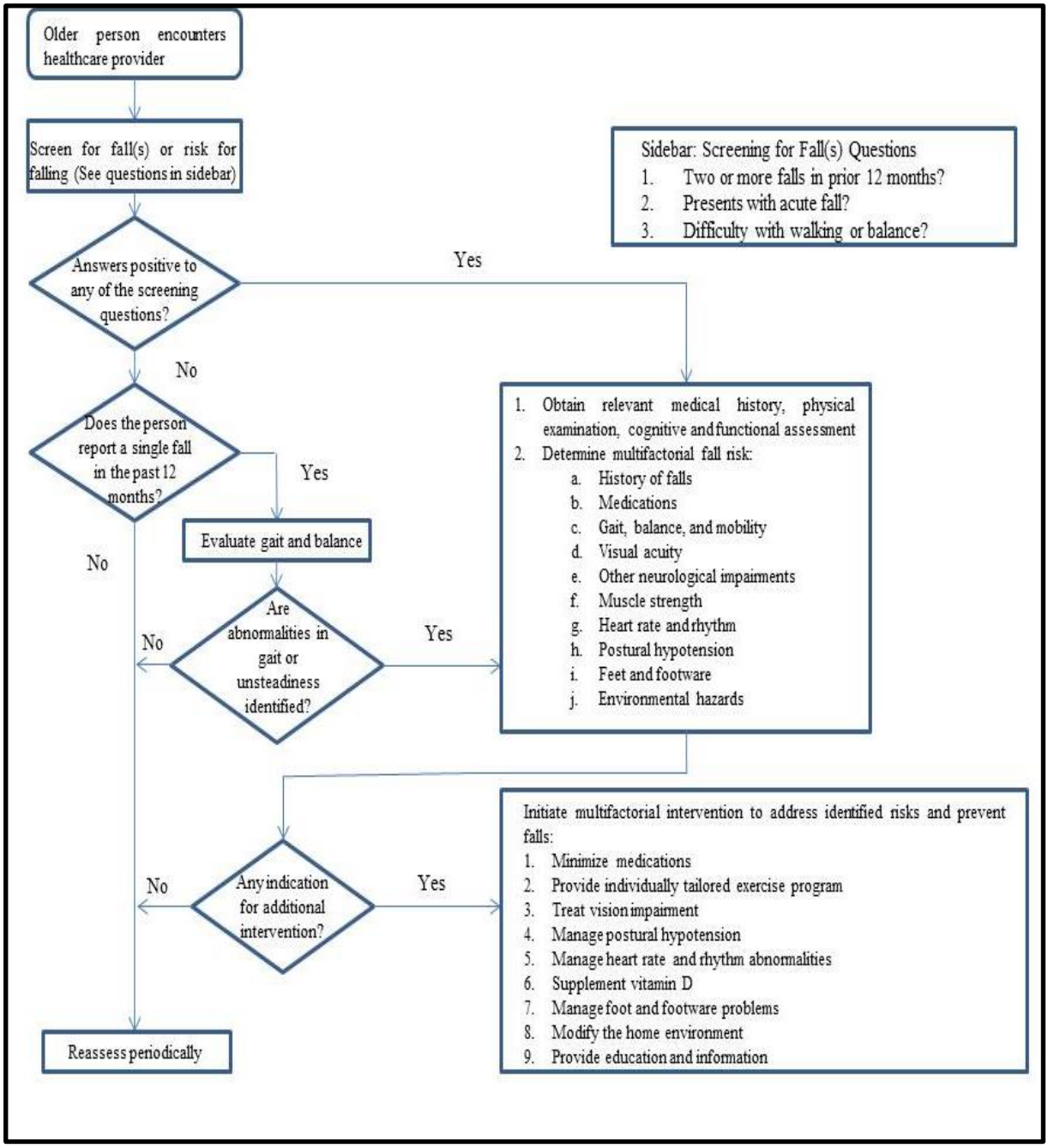

Figure 1.2. Diagnostic flowchart in patient with falls [63]

For fall diagnosis the elder first asked about his/her fall history. Fall history means prior 12 months, acute fall or difficulty with walking or balance. If there are no reported fall events in the past one year or the abnormalities within his/her unsteadiness cannot be identified, periodic reassessment is recommended.

Otherwise as seen in Figure 1.2, primarily thing to exam and asses results is patient's physical situation and cognitive conditions. There are 10 factors which is examined on elders that have a history of fall. Medications, foot ware and environmental hazards are three of the exogenous factors. Other than the external factors, there are health problems which lead to fall risk. Visual acuity, muscle strength, mobility, postural hypotension, feet and other impairments are the alternative factors which might lead to fall risk at old ages.

However without all of the above conditions presented, if there is any indication that the patient (elder) needs intervention, health-care provider should take following precautions. First step is to minimize medications as possible. An exercise program that helps to build gait and pace consistency along with providing a new perspective on associated risks of foot ware, home environment and supplement of vitamin-D and visual impairments including cataract is recommended. Additionally health-care providers should manage postural hypotension, heart rate and rhythm abnormalities and reassess the patient periodically.

1.4. CHALLENGES IN DETECTING AND PREDICTING FALLS

There are still challenges in fall prevention. A fall definition consensus hasn't been established. Formerly a faller is defined as "who experienced a fall within a fixed period of time". Because definition is a challenge medical personnel still remains incompetent considering falls. Profane published a fall prevention classification system [64] in order to have a metric among patients for reports and outcomes of fall. This metric system, if acknowledged by community, should make the assessments easier. In literature, although there is a main knowledge about fall, still most likely times for fall or most common places at home remains uncertain. A large sample of fall events with contributing factors such as time, pre-behavior change should be collected to model event of fall. Since patient's reports are biased, wearable sensors along with data recording should be much more useful for understanding fall. Elderly perception on wearable technologies is important to assert that elderly decline use of wearable devices. Other challenge in fall discernment is which risk factors to measure and how frequently. In literature there is a study carried out by TRIL Center. Results show that there is an observable decrease in blood pressure after lunch. However this information is not sufficient for drawing conclusions.

Elder people who fall frequently do not label themselves as faller. Most commonly first hearing of classification comes when they encounter health personnel. The social shame linked to fall is one of the biggest challenges in acknowledgement of risk factors for fall [64].

To sum up, besides the sampling process for fall has many complications, the contributing psychological factors are also an enormous challenge for studying fall. Elder people do not want to attach the label of faller because in their opinion the label implies the adjective "incapable". Consequently all reasons above add complications to asses fall risks and prevent falls.

1.5. SOLUTIONS AND RECOMMENDATIONS FOR PREVENTION OF FALL

Falls are inevitable since the individuals in excess of 65 falls unpredictably every year. It is impossible to cope with every fall situation under every circumstance. In this case together with preventable causes, it is a feasible approach to try to reduce the effects of fall. Reducing the effects can be applied with protector outfits. Besides this, awareness should be heightened about standard behaviors and consequences of after fall behaviors, i.e. trying to come up. Trial of recovery from fall sometimes leads to immobilizing of patients for several months.

Interventions needed in many aspects in fall subject such as; strength building and balance program, review of medication and home modifications. These exercises have shown great efficiency in reducing fall risk rates [65]. However if lifestyle is not changed, interventions become useless and risk of fall returns to same level.

Screening fall should become as important as for instance blood glucose level, other than simply just asking the history of fall. Prevention of fall becomes vital in some situations because of serious fractions of bones resulting from fall. The AGS guidelines states that older adults should be monitored every 12 months [62], including recurrent falls in the former examination. Guideline for prevention of fall [65] asserts that elderly who entertains risk of fall experiences difficulties in walking or balance or [60] has a fear of falling.

The underlying mechanisms of falls are still haven’t acknowledged comprehensively. An objective screening tool which can predict the risk of fall is needed.

Technologic developments still rely on wearable devices to measure these conditions. This is a big challenge on hypothesis testing regarding falls. However reusable and interoperable sensors such as SHIMMER platform [65] along with modular software platforms for instance BioMOBIUS platform is helping to understand the contributing factors of fall since another development takes place. Also all the developments should be in conformity with the regulations for interoperability of medical devices [65].

1.6. CONTRIBUTION

An objective, repeatable, and reproducible screening tool for assessing falls risk and in an emergency situation an alarming assistant is clearly needed. One of the main contributions of ABSys is surveillance and autonomy of the system without intervening privacy. As seen in the literature review section, ABSys is different from currently available systems because, either they are expensive or complicated to use. They are expensive because, either elderly need to move to residents as a standard way of living or elderly need to wear equipment for the rest of their lives or some of the available systems is not user-friendly.

Also in vision based approaches the algorithms are complicated because they use background extraction methods for human detection. ABSys does not require too much information, before-training. Also accuracy is expected to be higher because the system is not scenario dependent in other words non-specific. Other drawing points are the parts that ABSys covers such as recovery and illumination changes. Vision based algorithms do not mention falls with recovery. Furthermore other algorithms does not consider illumination changes, but this phenomenon is important because if ignored consequence would lead to false positives. ABSys has different qualifications than available fall algorithms methods in the literature. Although all of the methods have been deployed in image processing literature, utilization of the methods is different than literature.

Thresholds used in ABSys are found experimentally. The thresholds are adjusted according to a room size of 3x2x4. These thresholds should be developed to a metric that is free from vision area. In literature Miaou et al. [52] used BMI (Body Mass Index) to adjust the thresholds. However, since the weight of the person should be transmitted to the algorithm as a parameter, set-up is still needed.

Utilization of MBR ratio and an angle which is formed by MBR ratio is inspired from [54] for detecting fall. However monitoring centroid in order to recognize recovery from fall, and for recognition of recovery from fall, sequential frames are monitored and that is a contribution of ABSys. And justification of the threshold of centroid, which is height of the gravity center to standing point for an average female, is unique for ABSys.

Also Gaussian filter use on the image, which results from differencing, is also different from literature. The idea behind ABSys' fall detection algorithm is to be as simple as possible. To be able to compose a simple algorithm, the attempt to locate focused person is solved with different clustering techniques in the literature. Using image differencing to distinguish moving object from background has led to illumination problem. Illumination or reflection differences are issues because the intensity levels change according to amount of light that the surface reflects. This problem is solved with a threshold value for differenced image intensity levels and also the amount of pixel that is to be clustered.

ABSys success depends on followings;

- Elder falls and system recognizes that a fall has occurred
- Instantaneously fall warning e-mail (or alarm) initiated

Monitoring will fail if;

- False Negative: Fall happens and is not recognized by the algorithm.
- False Positive: Software mistakenly identifies a fall (i.e. a fall does not occur but a fall alarm takes place).

1.7. OBJECTIVES OF THE STUDY

This thesis aims to compose a fall detection algorithm that features privacy and independency while aging at their place. The algorithm improves the available methods in the literature. ABSys privacy and independency stands out because elder people want to stay in their home without intervention as they age. As well as privacy and independency, ABSys' inexpensive nature is another advantage. ABSys makes use of image processing. Through an algorithm, it detects fall of a person and initiates an emergency e-mail.

1.8. THESIS OUTLINE

This thesis is organized as follows, in chapter two a brief introduction is given on digital images. Secondly algorithm stages are explained. That is image differencing, binarization, and minimum bounding rectangle. The issues start with theoretical concepts and continue with implementation details.

In implementation section a brief introduction about object oriented programming is given. In order to be more robust about ABSys a short explanation on choosing MATLAB and MATLAB's distinctive features is given. At the end of the second chapter an analysis with predetermined tests and equations, quality and effectiveness is measured. After effectiveness measures discussion, ABSys with systems engineering approach and limitations of the study and future work should be implemented is also discussed.

2. ALGORITHM

2.1. DIGITAL IMAGES

As stated in Gonzalez et al. (2009) "An *image* may be defined as a two-dimensional function *f(x, y)*, where x and y are spatial (plane) coordinates, and the amplitude of *f* at any pair of coordinates is called the *intensity* of the image at that point. The term *gray level* is used often to refer to *the intensity of monochrome images*. Color images are formed by a combination of individual images. For example, in the RGB color system a color image consists of three individual *monochrome images*, referred to as the red (R), green (G), and blue (B) primary (or component) images. For this reason, many of the techniques developed for monochrome images can be extended to color images by processing the three component images individually. An image may be continuous with respect to the x- and y-coordinates, and also in amplitude. Converting such an image to digital form requires that the coordinates, as well as the amplitude, be *digitized*. Digitizing the coordinate values is called sampling; digitizing the amplitude values is called *quantization*. Thus, when x, y, and the amplitude values off are all finite, discrete quantities, we call the image a *digital image*." [66]

The transformation of an analogue image into a digital image is carried out as follows: Each area (pixels) need to be transformed to a representative single point. If an area contains different intensity values or elements then this representative point will average these intensity value differences. According to the precision value of an imaging tool lost information will be a small amount or vice versa. The *precision value* or *resolution* determines the overlapping ratio of the regions. These overlapping regions will have a higher intensity value since it is composed of several elements. As stated earlier, this transformation of an analogue to digital image is called quantization. The sampling process is done by taking equally spaced intervals on both axis (gridding) and taking a representative point from each grid. The amplitude of the image function values at sampled points is called *digitized values.*

The first step of digitizing process is to grid the vision area, second step is to take a sample (representative point) from each grid and then to compose a 2D array of M rows and N columns, for x = 0,1,2,…,M-1 and y = 0,1,2,…,N-1. If we let f(x, y) to be a continuous function representing the real image, then its origin takes place at the upper left corner of the rectangular array as depleted in Figure 2.1. . Here area A (real vision grid) is mapped into a single point which is an entry in the matrix. Figure 2.1 shows relation between area A and digitized image as shown in equation 2.1, four vertices of a grid is aggregated as follows;

$$agg\ [(x,y),(x+1,y),(x,y+1),(x+1,y+1)] = f\ (x+1,y+1) \qquad (2.1)$$

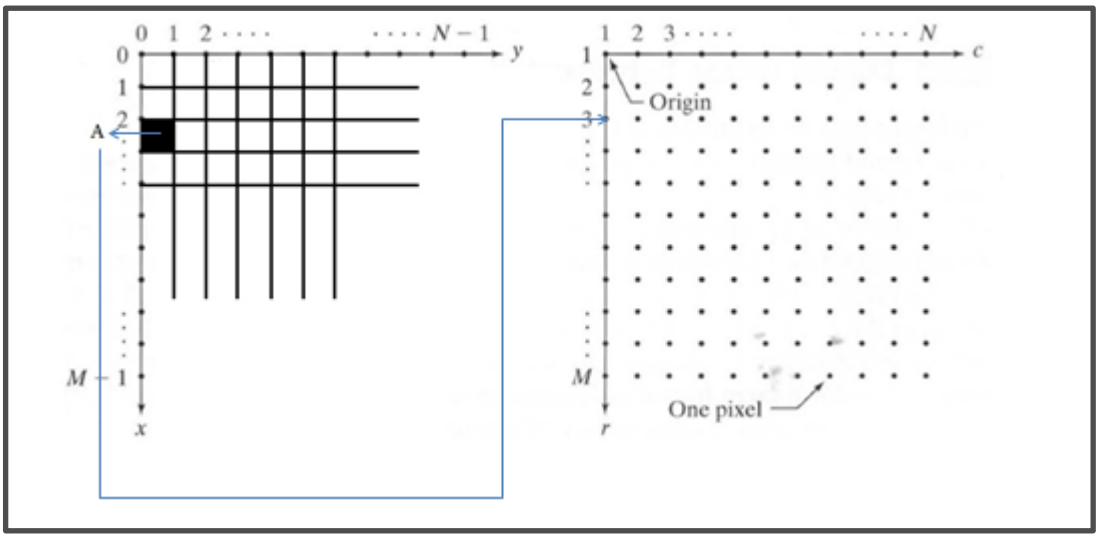

Figure 2.1. A rectangular image of size M-1xN-1

Numerical arrays are used for algorithms in image processing. In equation (1.1) the MxN numerical array is as follows;

$$f(x,y) = \begin{matrix} f(0,0) & f(0,1) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & \dots & f(1,N-1) \\ \vdots & \vdots & \dots & \dots \\ f(M-1,0) & f(M-1,1) & \dots & f(M-1,N-1) \end{matrix} \quad (2.2)$$

The matrix represents the intensity levels of each grid (picture element). Every element of this matrix is called a pixel. Images might measure different physical entities such as heat, energy or heat light. In other words the sensors measure the physical attribute of a particular picture element and then this feature is transformed to digital information. This information then takes numerical forms and then measurements become an image represented in different colors.

Light is a specific kind of electromagnetic radiation. Electromagnetic spectrum is composed of six broad regions, with fuzzy boundaries, that blend smoothly. Human eyes can see only a part of the spectrum. The color that human eyes see is defined by the object reflection of wavelengths. A region appears to be white if all wavelengths are reflected. Any skewness in the reflection of wavelengths results in a color other than white in our perception.

“Light that is void of color is called monochromatic light.” [67] Monochromatic light only has the intensity feature. And because intensity levels for human eye range from white to black, the term grayscale is used for monochromatic images. A typical grayscale image example can be seen in Figure 2.2.

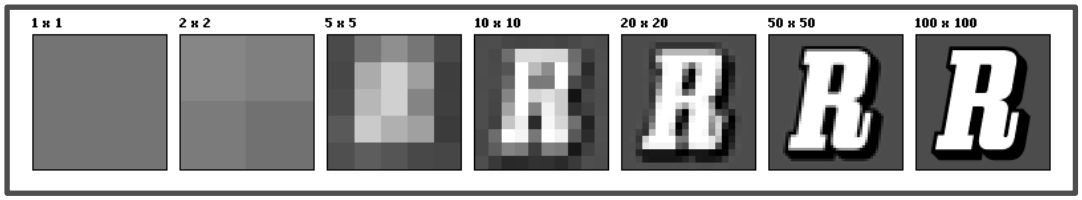

Figure 2.2. A typical greyscale images of different resolutions

Intensity resolution refers to smallest observable change. Here another notion has to be defined that is dynamic range. Gonzalez et al. simply defines *dynamic range* in an image to be the ratio of the maximum measurable intensity to the minimum detectable intensity level in the system. For example, for an eight-bit image 256 discrete intensity levels are used due to storage requirements.

The ABSys makes use of intensity levels and matrix representation of digital images. The algorithm uses intensity level changes at image differencing calculations and that information is utilized to generate minimum bounding box. Explanation of minimum bounding box is given in the section 2.5.

2.2. FLOWCHART OF THE SYSTEM

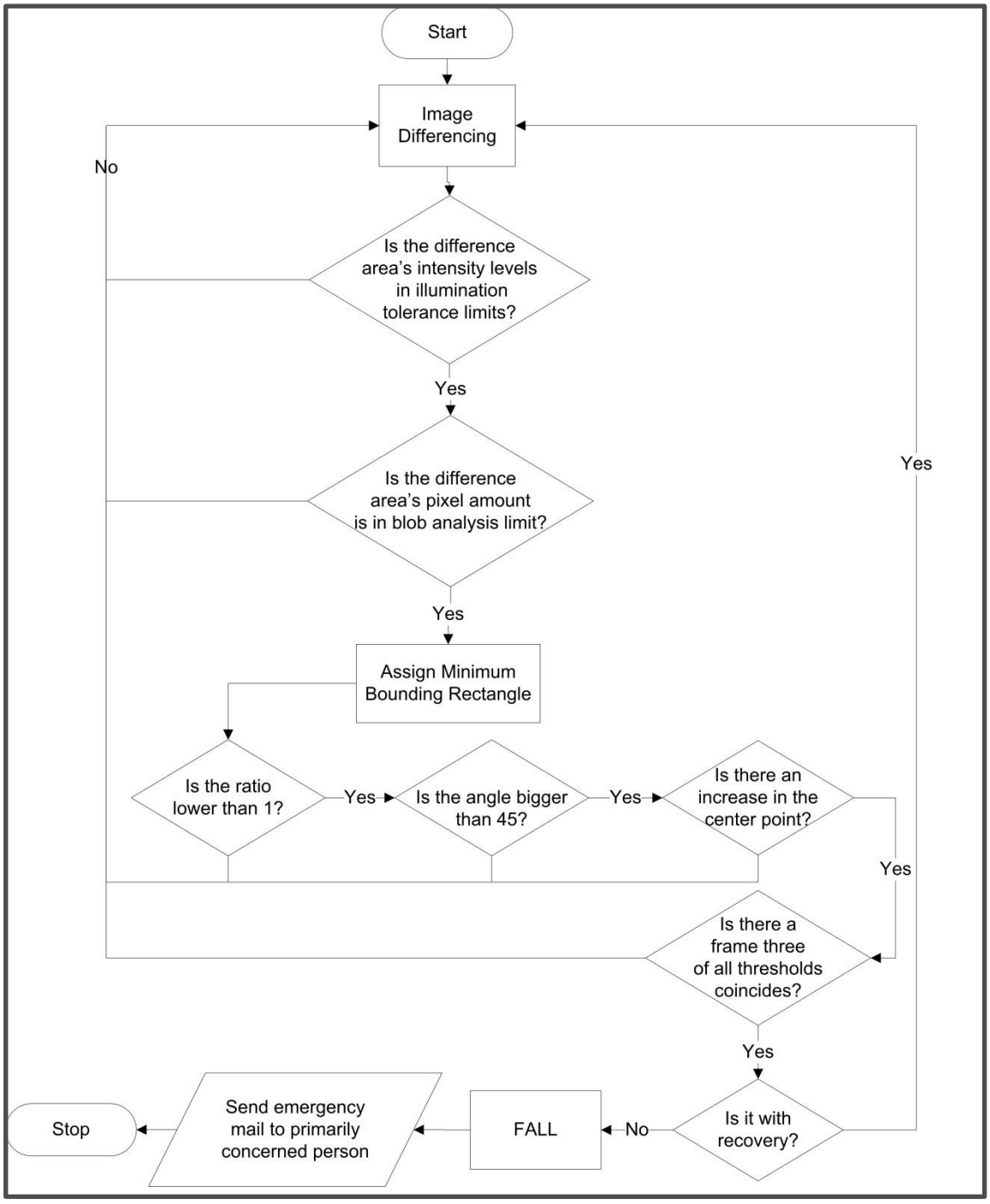

Figure 2.3. Flowchart of ABSys

2.3. IMAGE DIFFERENCING

Image differencing is a pixel-based technique in image processing to determine any change in image sequence [68]. ABSys deals with fall occurrence through video. Since in an infinite time plane, the frames taken in discrete points of time can be added up to be a video [68]. However each frame in a video contains some information related to the image. Hence each frame can be used as an image. Also as mentioned in digital images topic the images are divided into small square pieces in order for computer to be able to store. In other words image is divided into storable and meaningful parts. These parts called picture elements (pixels).

The difference between two images is calculated by differencing the pixel intensity values and creating a new image according to those changes [69]. In order to be able to function this technique, the images must be aligned or should be taken from the same angle, so that the corresponding points-that is considered with coordinate values – should coincide.

To be more precise, in this technique, images that are taken from same area, acquired from time plane at t_{n-1} and $t_{n-4,}$ (x, y) are the coordinates of the pixels. Mathematically image difference is computed at different time points;

$$\Delta I\,(x,y) = \mid I_{n-1}\,(x,y) - I_{n-4}\,(x,y) \mid \qquad (2.3)$$

Where n is the discrete time index. ΔI is difference image and I_{n-1} is the frame extracted from video sequence at time n-1.

Frame rates differ according to camera speed or personal preference. Frame rate is defined as, “Frames per second (FPS) is a unit that measures display device performance. It consists of the number of complete scans of the display screen that occur each second. This is the number of times the image on the screen is refreshed each second, or the rate at which an imaging device produces unique sequential images called frames” [70]. Videos are seen as continuous and objects seem in motion by showing stable images in sequence.

The number of images shown per second is the frame rate of the video and unit is FPS (frame per second). Frame rate as a unit can describe the playback pace or recording speed of the camera. Frame rates are chosen according to local electrical standards to avoid electrical interference with the picture on television or online broadcasting. For ABSys in-use configurations and frame rates will be discussed later in this paragraph. Hardware configurations used are 64 Bit, Windows 8.1 operating system with eight GB RAM, i7 2.4 GHz computer. With these qualifications notification takes under 45 seconds.

As stated in the previous paragraphs differencing will be executed between the images of time t_{n-1} and t_{n-4}. Based on this mathematical expression we expect that intensity differences due to changes in the horizon, will give motion detection. Taking difference in every three images was a trade of between computational time and total pixel analysis, and experimentally the number three was decided. As human eye detects nuances of brightness in the scene, the algorithm does exactly same thing [71]. The pixels and value of them in the gray scale are recorded as a matrix. An explanation about grayscale images should be given here. For grayscale images, the pixel value is a single number between 0 and 256 that represents the brightness of the pixel. Also pixel's coordinates are recorded. The coordinates are as important as gray scale values because differencing will be executed between aligned points, meaning that differencing is executed for each coordinate separately. As a result of this subtraction; the algorithm differentiates the elder-moving person- in video sequence. When subtraction is completed if the total pixel amount that shifts is between threshold values algorithm continues to assigning minimum bounding box and other features to this blob. Blob analysis is applied to binarized image however since the resulting total pixel amount helps to discover if there is a human or something else defining blob analysis within image differencing level is important. Blob analysis is used to access statistics of extracted image region such as; centroid, bounding box and blob count. Among other features blob count is related to image differencing level. The amount of pixel that builds the cluster in binarized image should be in-between threshold values in order to continue executing algorithm steps. Do the clustered pixels contain an individual or a dog? That is considered according to maximum minimum blob analysis' interval.
Other important point here is the tolerance to illumination changes over time or reflection of light change due to motion of focused person. Reflective surfaces results in different

intensity values, as a consequence of a motion in the scene. In differencing, illumination changes may result in monitoring mistakes that, where is the location of to be followed pixel cluster. In this point the experimental data is taken and the difference matrix is considered. From the experimental matrix an optimum threshold is found as $5*10^{-2,}$ as a measure of intensity differences. If the measures of pixel's intensity values below that threshold then algorithm ignores this area. Gaussian blurring is used because when we take difference a shell forms in differenced image. As told before the total pixel amount that can be clustered as a region is important for the algorithm. So with Gaussian blurring that is a 3X3 matrix the noise has been reduced. We can think this step as eliminating irrelevant data points. Following section will cover binarization part of the algorithm.

2.4. BINARIZATION

A binary image B can be attained from a color or gray-scale image through an algorithm or an operation. In binarization the algorithm or the operation, will be denoted by F from now on that extracts a subset of the image and assigns that subset as foreground or background and leaves the rest of the points disregarded. Therefore this operation F can be a thresholding operation with setting a boundary or an interval for intensity levels and extraction of a blob can be executed through or the operation could be a complex algorithm that selects a subspace of image through a set of rules.

Each pixel that represents an image has a *pixel value* which describes how bright that pixel is, and/or what color it should be. In the simplest case of binary images, the pixel value is a 1-bit number indicating either foreground or background [72]. For grayscale images, the pixel value is a single number between 0 and 256 that represents the brightness of the pixel.

Binary images require less storage space, less processing and computing time. Therefore binary images used in many application areas such as Object recognition, face recognition, motion analysis, image segmentation, scene analysis etc.

Binarization of a gray level image can be thought as a clustering problem. We have to find appropriate cluster centers in the image space. The pixels nearest to any cluster center will be assigned the value of the cluster center. But herein, binarization problem has clustering arguments due to illumination changes according to day-night circle, weather changes, or artificial lightening of indoors.

ABSys deals with the illumination problem with clustering. After image differencing [72] if the generated clusters, that is going be taken as human region cannot be labeled as human because the area of cluster is less than threshold value, then the cluster gets eliminated and algorithm goes back to image differencing step. This is also called Blob Analysis and Blob analysis is used to access statistics of extracted image region such as; centroid, bounding box and blob count. Among other features blob count is related to

image differencing level. The amount of pixel that builds the cluster in binarized image should be in-between threshold values in order to continue executing algorithm steps. Do the clustered pixels contain an individual or another object? That is considered according to maximum-minimum blob analysis' interval.

Herein the threshold value is used, and as explained the threshold is differences in pixel intensity values. Yet still the foreground extraction is performed and value 1 is assigned to found foreground pixels and a modified binarization is performed. In the former section, the algorithm makes use of image differencing to find human region in the vision area. That is assigned as foreground and the rest is ignored.

After picking up the human area, for processing time, the image is binarized. The human region will be pointed out with number one and other regions will be aborted with number zero. One assigned areas is white. Binarization is important not just because of computing time but also helps to accurate choice while programming the algorithm.

2.5. MINIMUM BOUNDING BOX

A minimum bounding box is a rectangle that has vertical and horizontal sides. These sides encompass the region that contains the objective field on the image with its topmost, leftmost, bottommost and rightmost points. This region should be as minimum range as possible. The axes of the bounding box should be aligned with the image aspect not with the axes of the extracted object. Extreme points take place in opposite duos. Each pair of duos generates and defines the axis.

Along with other features of bounding box can be utilized to detect fall of a person in binarized image as will be considered later in this section. Due to simplicity of rectangles when utilized in the recognition process, segmentation is needed in order to transform clustered pixels into meaningful information.

Imagine these points on a Cartesian grid; here the algorithm simply takes the minimum and maximum of coordinate points. The axes are orthogonal to visionary axes. This method can be called also axis-aligned bounding box.

If bounding box is rotated aligned with the polygon's edges to any arbitrary angle, the box may be smaller. This is called optimal bounding box. In order to detect fall here optimality condition is not needed because afterward, the algorithm considers only the ratio of short edge-long edge, the angle and object center height.

Second step is to check the MBR ratio [72]. MBR ratio is fraction of long edge to the short edge. Here the logic is that any standing person can be bounded by a square at most. The threshold value has been chosen as one. Because of the inherent characteristic of human anatomy, the long edge or height of MBR always should be along with monitoring axes-y.

2.6. ANGLE AND CENTROID

The angle which is used as a control parameter for discriminating fall from everyday activities is calculated through minimum bounding box. The parameter used to distinguish fall is the slope of diagonal line of minimum bounding box. Moreover the angle between diagonal line and the edge which is parallel to x-axis is used as another control parameter.

If 90 degrees minus arctangent of (θ) angle is bigger than 45 degrees as seen in equation 2.2, this is another indication that a fall might have occurred [72].

$$90° - \arctan(\theta) > 45° \tag{2.4}$$

The next paragraph of algorithm simply controls center point and checks if there is any sequential decrease. In order to detect sequential decrease, algorithm takes differences between frames. Sequential decrease means recovery from fall, basically standing up. For this variable also there is a threshold value, taken experimentally as 700.

At the end of this process, decision tree algorithm decides to call for help or not. To decide if there is a fall or not algorithm makes use of control parameters; MBR ratio, angle (θ) and center point. If the conditions meet at the same frame then algorithm sends an e-mail to primarily concerned person.

2.7. IMPLEMENTATION

2.7.1. Object Oriented Programming

Object-oriented programming is to combine the functions that operate on data and the data itself to form a single unit. That means on the contrary to procedural languages that are a list of instructions carried to be by the computer, objects have functions it selves. And if the software or the user wants to read the data, data is accessible only through objects.
In object oriented programming a programming problem will be divided into objects. In OOL's there are classes that assist as a plan or a blueprint. Classes specify what data and what functions will be included in objects of that class. A class can be thought as a description of containing objects.

At least, an object is often a set that has a unique individuality, some state and some manners. For the purposes on this work, an object's identity will likely be its deal within memory space. An object's state will likely be formed from gathering named grounds, which get values as well as object identities — therefore, an object may hold a reference to another object, or even itself. Where a new field will not hold this type of reference, its importance is reportedly 'null'. An object's behavior will likely be formed from gathering named approaches, which contain commands which, amongst various other actions, operate on the object's grounds. An object's grounds and approaches together style its list of attributes. By means of references, an object method might access the actual attributes associated with other objects in addition to the attributes of its object: one way always is aware of the identity with the object to which that belongs, often known as a reference to self. Generally, the target of your message invocation is referred to as the receiver with the technique call.

2.7.2. Why MATLAB

MATLAB has built-in libraries and an image processing toolbox which includes reference-standard algorithms. Reference standard algorithms help to use functions that have been already in-use. What is meant by “use functions” is that stages of ABSys have been in use in literature. The toolbox has functions that allow manipulation of different image and video formats. Therefore toolbox helps implementing an algorithm period shorter. For instance with the function “imread” the image becomes a matrix as shown in Figure-6 that involves intensity values along with coordinate data for a grayscale image. Other example of a useful function is “colorspaceConverter” which transforms an RGB image into a grayscale image with the intensity values ranging from 0 to 256. Also shapeInserter function is very practical while implementing an algorithm. With shapeInserter function any shape, a rectangle in this case, can be inserted into image as an overlay. This is a convenient function while debugging because the output of the implementation can be monitored simultaneously. To sum up MATLAB empowers when compiling software with no recompilation.

Moreover MATLAB is really effective for picture transformations. This qualification outstands along other vision programs. Briefly with MATLAB rapidly comprehending results in any part of coding is quite practical.

Computer graphics is the subject when manipulating image. In thesis algorithm uses raster graphics that is pixels rather than vectors. In Matlab basic data elements are vectors and everything is presented in matrixes. For better understanding how Matlab stores images three-dimensional matrixes should be presented. A presentation of three-dimensional matrixes is shown below 2.4. In these matrices first entry is row and second entry is column and the third is extra dimension.

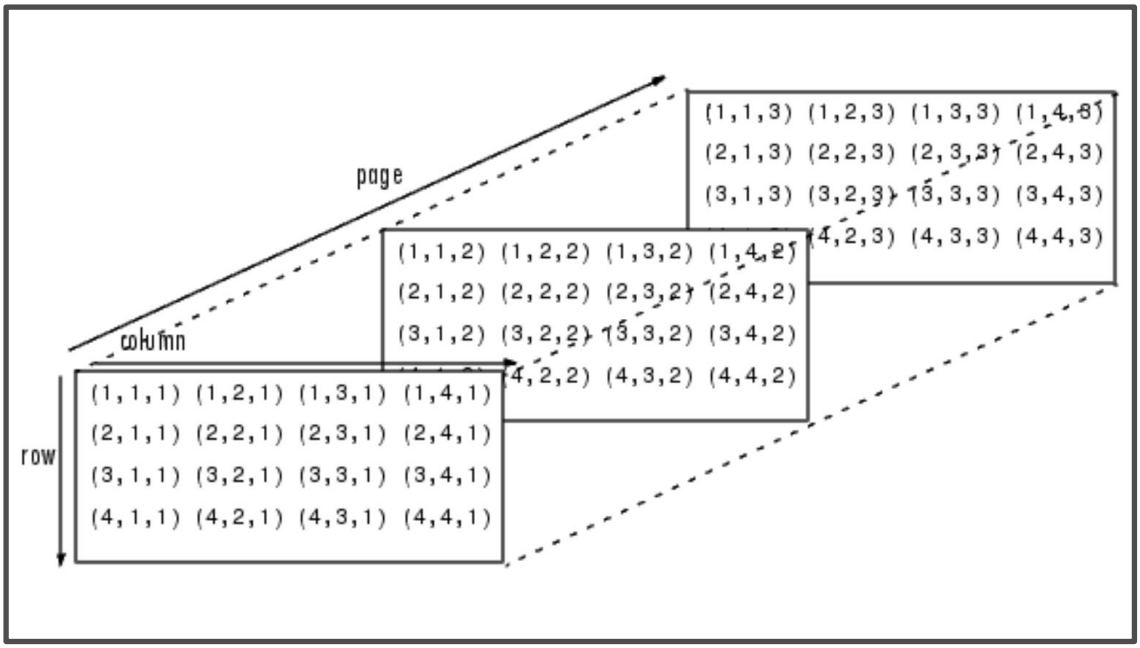

Figure 2.4. Presentation of three-dimensional matrices

In MIT an optimized image processing language called HALIDE is being composed for the image processing purpose only. Halide is an optimized language as means of pipelines and scheduling. For further information see [73].

2.7.3. MATLAB Code

Vision.BlobAnalysis; can be seen as an object analysis that measures the clusters' pixel amount and area of the bounding box. As this can be foreseen, if a moving object that is out of our interest (i.e. dog, vase etc.) the algorithm doesn't take into account if the cluster is not between somewhere 10000, 50000 pixels-wide. In these experiments the blob analysis' maximum and minimum area was taken experimental, but ABSys should take samples for setup. Minimum blob area should be considered as when the distance to camera maximum and vice versa.

The objects above: hVideoOrig, hVideoFg, hVideoRes are for screening purposes only. The numbers are the coordinates of the pop-up viewer on the computer's screen. The above code's output is, when processing, demonstrating the original video, binarized video and bounding box video.

With System objects, the method that actually implements the algorithm is called step(). In other words, step() is what processes the data. But step does much more than that, step() handles initialization, and if there are states involved, it manages the state information as well. So step() takes care of a lot of processing that prior to System objects. The step() call invokes a method on objects contained in the toolbox.

Here the system takes images into account if in time space the number of the frame is bigger than three. In order to take differences of frames, algorithm uses i^{th} and $i\text{-}3^{th}$ frames. Then Gaussian filtering is implemented because after frame differencing a shall of the moving person in time forms in binary image. For the algorithm to be able to make a blob analysis and understand that that shall is to be analyzed, Gaussian blurring was needed. Gaussian blurring is used for noise reduction in images, but in here it helps to make blob analysis in the aspect that the two shells are connected. Then another calibration takes place in the algorithm for illumination changes and to ignore if the frame difference intensity value is below $5*10^{-2}$ because in frame differencing even reflections of bright surfaces effects binarized image.

Then as you can see in the code, initialization and creating objects of ratio for bounding box, ratio that parallel to y axis divided to edge that is parallel to x axis. As explained in the algorithm section the angel between diagonal of minimum bounding box and the edge that is parallel to x axis, is considered next. If 90 degrees minus arctangent of that angle is bigger than 45 degrees, this is another indication that a fall might has occurred. Also for center point of minimum bounding box an object is used as can be seen in the algorithm called “merkez”. For this variable also there is a threshold value, taken experimentally as 700. After a coincidence of all features, the algorithm starts to study center point and the indices of coincidences. If the three features exceeds thresholds for just one time, ignores the situation, also if the thresholds are exceeded in more than one indices and if the center point is increasing; the total number of these events that is exceeding thresholds plus center point increase is smaller than 5 algorithm again ignores the situation because the situation shows that there is recovery, if not fall decision is made and e-mail is sent to primarily concerned person.

The next paragraph of algorithm simply controls center point and if there is any sequential decrease. In order to find sequential decrease, algorithm takes differences between frames. Sequential decrease means recovery from fall, basically standing up.

At the end of this decision tree, algorithm decides to call for help or not. This decision is made up of three features excessing thresholds in exactly the same frame. If the conditions meet at the same frame then algorithm sends an e-mail to primarily concerned person.

2.7.4. Scenarios for the Evaluation of Fall Detection ABSys

The scenarios of falling are very various so one must test the devices with a limited number of situations of falls (positive situations) as well as of ‘pseudo’ fall situations (negative situations) [74].

As most falls occur during intentional movements initiated by the person, they happen mainly in the anteroposterior (relating to both front and back) plane, forward or backward: stumbling on an obstacle during walking, backwards slip on wet ground, transfer ‘Stand-To-Sit”. If the person gets to be unbalanced inside the forward direction, s/he may try to recover with a few steps ahead, so this action amplifies the fall pattern, and also he/she may finally fall whilst projecting his/her arms forwards intended for protection. S/he can also drop herself onto the knees. If loosing balance befalls backwards, the person will try to sit down to possibly reduce the intensity of the shock effect. But in some cases, the fall occurs sideways, either during a badly controlled "Sit-To-Stand" transfer, or if the person, when becoming unbalanced, tries to grip the wall [74].

There are also daily life movements during which the amplitude or intensity of the movement can be similar to that encountered in accidental situations: the action of lying down, or of sitting down, if carried out "quickly". One can also encounter situations of fall initiation with recovery which is called stumbling. For evaluation of ABSys reliability following scenarios is used and all of the cases with explanations can be seen in Table 2.1.

Table 2.1. Scenarios for fall and outcomes of the algorithm

Category	**Name**	**Outcome**	**Outcome Measures**
Backward fall (both legs straight or with knee flexion)	Ending sitting	Fall	True Positive
	Ending lying	Fall	True Positive
	Ending in lateral position	Fall	True Positive
	With recovery	-	True Negative
Forward Fall	On the knees	-	True Negative
	With forward arm protection	Fall	True Positive
	Ending lying flat	Fall	True Positive
	With rotation, ending in the lateral right position	Fall	True Positive
	With rotation, ending in the lateral left position	Fall	True Positive
	With recovery	-	True Negative
Lateral Fall to the Right	Ending lying flat	Fall	True Positive
	With Recovery	-	True Negative
Lateral Fall to the Left	Ending lying flat	Fall	True Positive
	With recovery	-	True Negative
Syncope	Vertical slipping against a wall finishing in sitting position	-	True Negative
Neutral	To sit down on a chair then to stand up (consider the height of the chair)	-	True Negative
	To lie down on the bed then to rise up	Fall	False Positive
	Walk a few meters	-	True Negative
	To bend down, catch something on the floor, then to rise up	-	True Negative
	To cough or sneeze	-	True Negative

The fall types are categorized as fall-happening planes. As in Table 2.1. categories are named as; backward, forward, lateral and syncope and natural. Name column shows how act of fall ends. For example on the fifth row fall happens in posterior plane with an ending on the knees. In the outcome column cells are showing the output of the algorithm. If algorithm makes a decision of fall, “Fall” is written on the cell otherwise “-“sign is seen in the cell.

Outcomes measures are named as general binary classification. False positive is an error that an alarm initiates but actually fall does not happen. Also true negative indicates that a

condition (fall) is not present and in reality this indication is true. And lastly the true positive outcome corresponds to a real fall case with an alarm output.

A series of scenarios of fall is presented and for each category a sample was recorded. Scenarios are a total of 20 with 4 recoveries and 5 fall-like cases. Among them only 9 are real fall cases and they are all detected as true positives besides one. The rest 11 cases are either with recovery or fall like cases and only one of them gives a false positive alarm. Hence the true positive percentage is 100 per cent while the false positive ratio is 11, 1 per cent.

3. ABSys in SYSTEMS ENGINEERING

The Figure 3.1 below shows the waterfall system design model. The waterfall model was chosen to develop the system: ABSys, because compared to highly detailed and comprehensive software projects, ABSys is a small-scaled project and has certain requirements.

ABSys is a small-scaled project because the system is already a sub-system of smart homes. Elderly care at home includes many sub-systems such as help with activities of daily living, drug intake, coordination of outside services etc. Moreover waterfall model is easy to understand and each phase of the model has specific outcomes along with identifiable review processes. Also when technical and technological requirements are understood no overlapping phases of development is needed.

Determining the **system requirements** is the first step for a typical sequential progress of software design and implementation under the waterfall model. These requirements include determining the components for building a system; identifying the hardware requirements and software tools.

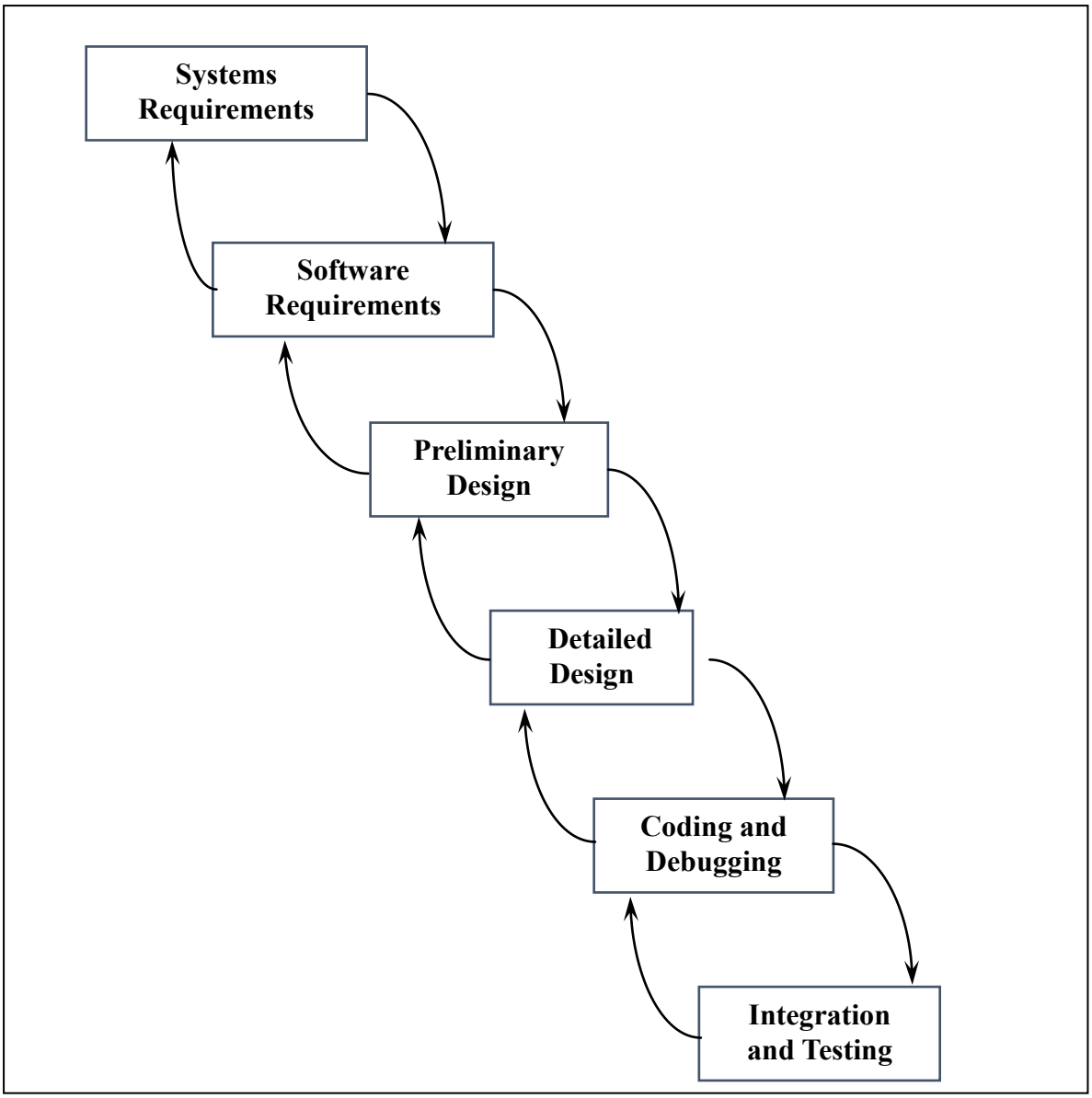

Figure 3.1. Waterfall model of software engineering

The hardware requirements for ABSys are decided as follows: for the processor an İ7, 2.4 GHz and as operating system a 64-bit Windows 8.1. Other configurations were tested and to balance the expense of the configurations and computational time these hardware components were found optimal. For coding software MATLAB is chosen. MATLAB has built-in libraries and an image processing toolbox which includes reference-standard algorithms. Reference standard algorithms help to use functions that have been already in-use. What is meant by “use functions” is that stages of ABSys have been in use in

literature. The toolbox has functions that allow manipulation of different image and video formats. Therefore toolbox enables implementing an algorithm period shorter.

Moreover MATLAB is really effective for picture transformations. This qualification outstands along other vision programs. Briefly with MATLAB rapidly comprehending results in any part of coding is quite practical.

Second step in the waterfall model as seen in Figure 3.1 is **software requirements**. Proposed ABSys software missions to satisfy the following requirements: The system shall monitor an elder/disabled person who lives alone. The system shall send an emergency e-mail to concerned center/person if a fall occurs. The designed algorithm of ABSys shall take frames from the video sequence as an input, and should determine if there is a fall. In addition to this decision, the system shall transform the fall indication into an emergency e-mail.

Preliminary design is conducted via literature research. In systems engineering software design, this stage is essential in order to ensure that selected system is conforming to design and performance specifications. Software design specifications are taken as the basis for preliminary design to perform functional and non-functional requirements. In preliminary design stage a non-invasive system implementation was decided. Performance measures in fall detection systems are based on true and false alarms of the system. The structure of the algorithm is designed accordingly. Also other alternative approaches to fall detection systems are investigated. There are three approaches for fall detection algorithms and three approaches for systems. For algorithm implication simplicity of the approaches was examined. For system application available methods advantages and disadvantages were explored. Although there are other ideas asserting that vision based approaches are intrusive, since ABSys is not recording anything, employment of a vision based fall algorithm considered optimal for customer use.

Detailed design is the next stage in waterfall model. A software development starts with a top-down approach with basics then design goes into detail. Each module of the software is specified precisely. For functional capabilities such as accuracy or capacity design

specifications are added to algorithm. Reliability of the design is one of the most important characteristics of fall algorithms because the only mission is to accomplish to initiate an alarm when needed. Distinguishing human in the scene was a result of preliminary design. In detailed design illumination problem and also irrelevant pixel problem in the differenced image is solved. In other words necessary technical details are added to algorithm.

In coding and debugging stage the implementation of the code is started. Implementation process should be planned in the software requirements stage because all programming languages have advantages and disadvantages. After implementation the fall algorithm debugging took place with two sample videos taken from the internet. For example Gaussian blurring was applied to binarized image at first. Eliminating irrelevant points in the binarized was first planned in this step. And theoretically it seemed possible to multiply all the pixel values which are 0 and 1 with a random Gaussian function and round the values to nearest number. But as a consequence of testing the code, this step is changed and blurring procedure is applied to differenced image.

Integration and testing are the last stages in the waterfall model, in some cases they are seen as separate stages, in others they are seen as a whole. Integration stands for larger projects to integrate subsystems software as a whole. Since ABSys is a small scaled project, it does not contain subsystems. Testing is an important step in software design. For ABSys a total of 20 videos are recorded for testing stage and results can be seen at the section scenarios for fall evaluation.

A system is a collection of hardware, software, and people gathered in order to accomplish some common purpose. The systems thinking practice is to see the all parts as a whole as distinguishing that which parts are interacting, adapting. Furthermore systems thinking can be resolved scientifically to think about events, situations, meaning that perceiving the system as an individual and learning about its behaviors. As an application of systems thinking, in fall detection all of the components will be explained later in this section.

In order to define ABSYS in terms of systems engineering, we must first start with the section on quantity. When defining quantity items, the documentation should state relevant

answers to “How many”. The system that is called ABSys is monitoring (without recording/intervening privacy) an elder/disabled person who lives alone and if there a fall occurs sends an emergency e-mail to concerned center/person. Besides all of the information above, the quantity information associated with “How many” questions [75] is directly related to input and output data of the system. In this case it is important that the input and output data of the system which helps to define quantity of the system to be clear. The designed algorithm of ABSys obtains frames from the video sequence as an input, determines if there is a fall and as an output transforms the fall indication into an emergency e-mail. The first step of functional requirements is design motives. ABSys design is motivated by the desire of the elderly wanting to age at their home. With all this information quantitative requirements can be determined. Although the system assumes that the focused person lives alone and if there is more than one person that person is eligible to get help, fall of more than one person can happen simultaneously. In this case the pixel amount of the moving cloud may exceed the algorithm’s specified threshold. To be more precise; the algorithm draws minimum bounding rectangle around intensity changing area and along with other parameters uses rate of change of this rectangle to decide if there is a fall. Moreover the algorithm uses threshold values of minimum and maximum pixel amounts to distinguish focused person from pets or other possible fallen objects. Two or more people falling closely in the same image may generate a bigger amount of moving cloud more than allowed pixel threshold resulting in a false negative.

Another question of “how many” of the system is the user amount [75]. The first user of the system (focus on the person) is elderly or disabled people who want to live alone in the house. Second level users are the people who are expected to respond the emergency call, which is the primarily concerned person. The number of users in the second level can be more than one. Because the system is for emergencies, respond to emergency may come from a relevant center.

The second phase of identification of functional requirements is to determine the metrics of quality of the system, which is how to measure the quality. Measuring system quality can be made as follows. In the literature fall algorithms uses results of experiments to measure quality. These studies generally determine true positives. In other words the experiments

measure the percentage of fall situations, if done properly. In this study 25 different fall and fall-like videos are recorded to measure the competence of ABSys. Detailed information containing experiment videos can be found at the section 2.7.4. In addition, the frequencies of false alarms of the algorithms are as important as true positive. Although other studies in the literature does not attach importance false positive, ABSys is adding a new feature to success measurement with including this feature.

Other point to discuss is timelines [75]. With timeline, the intended notion is the answer to the question “How long”. In order to be precise in defining timelines remembering the user’s expectations is helpful. First user is people who want to age in their place and the second is defined as the responsible person for the elderly. The first user's request to maintain life in the home, knowing they could get help when they need it, while other user's request or expectation of the system is to be aware of the emergency. With these two user’s expectations, the conclusion can be drawn as fall algorithm should be available 24-hour a day.

The applicability of the system is also important. Compliance [75] can be defined as the ability to respond when input repeats. The input in the system is everyday activities of focused person or fall of this person. Besides all of these the reason that this system exists is that the fallen person cannot stand up because they are either elder or disabled person. But the effort to stand up can only result in sending multiple e-mails. Other than multiple notifications, there isn’t any other inconvenience when input recurs.

In requirements analysis, design constraints are an important title to go over. Design constraints help us to define the feasible areas of the system [75]. Here titles are environmental conditions or limits and the system’s ability to defense against internal or external threats. Work environment of the system is designed as indoors (home). In addition to this because none of the images are recorded and there isn’t any option to re-watch any past videos, the system can also be used in bathroom and toilets. When the frequency of falls in the bathroom considered it is clear that for elder people this number is high and this is one of the powerful features of ABSys. Algorithms that can adapt to any room size are suggested in the literature for the design constraints. These methods develop

algorithms that can distinguish a person in the horizon. Unlike those, ABSys only takes into account the moving cloud. Also ABSys can be applied to all interior sizes. However for experiments a view angle of 3x2x4 dimensions was used and algorithm was adjusted to this vision of field accordingly. Therefore the thresholds should be adjusted based on the environment size to be used.

When the system is considered in terms of system threats, ABSys is found to be vulnerable to power-cut. Adding a power generator against this threat would eliminate the power outages problem. That would increase the cost. The external threat is the need of low price.

Requirements loop [75] was obviously seen when designing ABSys. First pulled out requirements were insufficient as seen in verification level. For verification step sample videos were recorded and that led to a better understanding of reflection of physical conditions on algorithm. With these understanding of physical conditions new requirements were produced. More specifically, before applying Gaussian filtering to the differenced image, the algorithm was unable to distinguish intensity change on a particular pixel if the user/focused on person wears a mixed-patterned outfit. This issue is solved by applying a 3x3 mask matrices. The reason behind that it is called a mask matrix that the matrix visits each pixel on the image. Here the process is visiting each pixel individually and calculate an average of that pixel and surrounding eight pixels, and as a result removing all zeros or illumination change effects. Gaussian filtering is used different from literature because the noise of illumination reflection and mixed pattern problem has not mentioned. This is a distinctive feature for ABSys.

In addition to physical requirements described until now, software requirements must be considered along with other requirements [75]. ABSys includes a laptop/PC, a camera, a generator and a software platform that has image processing built-in libraries and toolbox. Systems engineering design loop was experienced again when these requirements were formed. An average computer with 4GB RAM and i4 processor was considered sufficient before the experiments. Also another insufficient point was the camera's pixel numbers. All of these requirements are upgraded according to experimental videos.

Last topic in the requirements analysis is project and enterprise constraints [75]. Because the investment on project is preferred to be low, infrared camera that enables night-vision and Kinect that can be used for ground-floor identification is not added to the system. Actually in such a system, ground-floor identification is a requirement analysis result in order to reduce false positive percentage. At measures of performance level fall-like scenarios (section 2.7.4) were recorded and performance level was measured as 11 per cent. Also at customer expectations level [75], the need to function without illumination or at low illumination was revealed. The false positives were not considered fully because of project constraints. Therefore they are partially measured. However positive levels are not affected by these constraints and the performance level is very high.

4. LIMITATIONS OF THE STUDY

ABSys detects falls if there is an image available, and since the simulation of the world is not something possible in the aspect of furniture for every situation, the detection is present in an ideal furnished room, that has no behind place could be fallen and stay hidden.

ABSys needs improvements in different two aspects. This study was conducted to detect fall. But for an elderly this fall detection surveillance system is needed at home at all times. ABSys does not work while individual sleeps in his/her bedroom and also without power of the light. Light problem could be solved with infrared cameras with just remote sensing of heat, and of course algorithm should be calibrated with the heat image.

Other area to improve is the bedroom and sleep times. While sleeping has four phases, there is no indication of health or if help needed in REM phase. In REM phase, as REM stands for rapid eye movement, only the pupils have movement. This part strongly constraints remote sensing idea that the only indicator of health while sleeping is the blood pressure and pulse.

Also in experiments the specificity and sensitivity statistics are not given. A simulation was needed to represent those numbers. Since in real life application of experiments, for say 100 times replication of a single fall is devastating to human body, one sample of each experiment has been able to be given. For future work an alias of human should be considered or a virtual tool that enables accurate human modeling should be used. There are commercial software that simulate and optimize human models but they are expensive to buy.

5. FUTURE WORK

ABSys is a fall algorithm and like other fall algorithms it is designed to detect human falls. In addition to the detection of a fall situation, it is also important to discriminate everyday activities that mimic a fall and can be miss classified as so. However ABSys is not always capable of distinguishing between a fall and a horizontal position that the person in focus takes deliberately. That is when the focused person lies/transfers to a horizontal position on a bed, sofa or a similar surface it is not always possible to distinguish his/her position from a fall case.

There are two significant distinguishing factors that helps to distinguish the deliberate transition to a horizontal position from a real fall. These are the acceleration rate of the position change and recognition of the surface that the event occurs. Second distinguishing factor means that if an algorithm can discriminate between whether the surface is ground-floor or otherwise.

Ground-floor identification problem has different approaches in literature. Most promising approach among these is Microsoft's Kinect Box. Although Kinect is designed as a game console, this product has multi-usages. Solving ground-floor identification problem with Kinect can help to develop other algorithms about elder disabilities in the future. For instance pace and gait exercises can be done with Kinect assistance properly. Kinect can also perceive depth information of indoor places as well as its ability to differentiate a standing person's joint points. In development of ABSys, depth information perception can be used instead of joint recognition ability of Kinect.

Depth information is obtained by v-disparity method. V-disparity method uses exactly human brain-eye depth sensing principle. In the game console there are two cameras placed on same axes. First the system has information of the two cameras focus axes distance to each other. Second information needed is the corresponding pixels distance. What is meant by corresponding pixels is that the same point on the image in two cameras is envisioned from different points. Consequently the system uses these distance

information using similarity of triangles and finds pixels depth information. Finding corresponding points in two images is a complex problem.

A huge sample library is built for Kinect in order to be able to perceive joint points. With perceived human body, the samples are compared through decision trees to find most suitable joint points. Although producing fall algorithms with Kinect has high reliability, the cost of placing Kinect console every room in a household is practically not manageable.

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APPENDIX A: COMPUTER QUALIFICATIONS

Table A.1. Computer qualifications

Processor	İ7, 2.4 GHz
Coding Software	Matlab R2012a
Operating System	Windows 8.1, 64-bit

Once video sequences are processed into MATLAB, a detection algorithm using minimum bounding ratio and blob analysis will analyze through motion estimation and image analysis and classification of data to detect whether or not it is a fall.

APPENDIX B: CODE

Algorithm A.1. Fall Detection

```
clear all

% filename = 'Falls_in_elderly_people_1.avi';
% filename = 'backwardfall-with recovery.avi';
filename = 'backwardfall-ending lying.avi';

hvfr = vision.VideoFileReader(filename, 'ImageColorSpace', 'RGB');
hcsc = vision.ColorSpaceConverter('Conversion', 'RGB to intensity');
% % Create System object for drawing the bounding boxes around detected moving
person.
hshapeins = vision.ShapeInserter( ...
        'BorderColor', 'Custom', ...
        'CustomBorderColor', [0 255 0]);
hblob = vision.BlobAnalysis( ...
                'CentroidOutputPort', true, ...
                'AreaOutputPort', true, ...
                'BoundingBoxOutputPort', true, ...
                'OutputDataType', 'single', ...
                'MinimumBlobArea', 10000, ...
                'MaximumBlobArea', 50000, ...
                'MaximumCount', 1);

sz = get(0,'ScreenSize');
pos = [20 100 360 600];
hVideoOrig = vision.VideoPlayer('Name', 'Original', 'Position', pos);
pos(1) = pos(1)+320; % move the next viewer to the right
hVideoFg = vision.VideoPlayer('Name', 'Binarized', 'Position', pos);
pos(1) = pos(1)+320;
hVideoRes = vision.VideoPlayer('Name', 'Results', 'Position', pos);
i=1;
ratio_fall=1.5;
counter=0;
counter1=0;
```

```
while ~isDone(hvfr)
   image = step(hvfr);

   y{i} = step(hcsc, image);

   image_out = image;
if i>3
       diff_image=y{i}-y{i-3};
       h = fspecial('gaussian',[3,3]);
       diff_image = imfilter(diff_image,h,'replicate');
       bin_image=abs(diff_image)>(5*10^-2);


       [area, center,bbox] = step(hblob, bin_image);
      image_out = step(hshapeins, image_out, bbox);
       step(hVideoOrig, image);          % Original video

       step(hVideoFg, bin_image);

       step(hVideoRes,  image_out);


       Idx = bbox(:,2) > 1.2;
       ratio = zeros(length(Idx),1);
       ratio(Idx) = single(area(Idx,1))./single(bbox(Idx,3).*bbox(Idx,4));
       ratiob = ratio > 0.3 ;
          bbox(~ratiob,:) = int32(-1);
          if ~isempty(bbox)
       teta(i)=(90-atand(single(bbox(:,4))./single(bbox(:,3))))>=45;
       ratio_fall(i)=single(bbox(:,4))./single(bbox(:,3));
       merkez(i,:)=center;
          end
end
     i=i+1;
end
control1=(ratio_fall<=1)&(teta==1);
   control2=control1&(merkez(:,2)>700)';
    q=find(control2==1);
a=diff(q);
b=find([a inf]>1);
c=diff([0 b]);
merkez1=merkez;
indices = find(abs(merkez)==0);
   merkez(indices) = [];
   merkez1=reshape(merkez,length(merkez)/2,2);
```

```
e=diff(merkez1(:,2));
e1=find(e<0);
e2=diff([0 e1']);
if any(c>=2) && (sum(e2==1))<=5

 fprintf('Fall \n')

sender= 'elifcanyasa@gmail.com';
 psswd = 'celal1uzun';

setpref('Internet','E_mail',sender);
setpref('Internet','SMTP_Server','smtp.gmail.com');
setpref('Internet','SMTP_Username',sender);
setpref('Internet','SMTP_Password',psswd);
% setpref('Internet','SMTP_Username','myaddress@example.com');
% setpref('Internet','SMTP_Password','mypassword');

props = java.lang.System.getProperties;
props.setProperty('mail.smtp.auth','true');
props.setProperty('mail.smtp.socketFactory.class', ...
                  'javax.net.ssl.SSLSocketFactory');
props.setProperty('mail.smtp.socketFactory.port','465');

recipient='elifcanyasa@gmail.com';
subject='Emergency';
message='Fall';
sendmail(recipient, subject, message);
end
```