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Geriatric Agility Detection Using Python and OpenCV

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***Abstract*: Early and accurate detection of frailty in the older population is essential to determine early falls and loss of muscle movement. This allows early intervention as deemed fit by the healthcare providers and prolongs muscle functioning. After the Covid-19 outbreak, a large population of older people have been confined to their homes which has affected their physical health to a great extent. These effects have been magnified in the elderly largely due to extended lockdowns, travel restrictions and loss of social support. The study attempts to design a system to help elderly self-assess their frailty levels by early and precise Geriatric Agility Detection using 30 second chair stand test. Geriatric refers to medical care of older adults and Agility, referring to the ability to move freely and swiftly, is closely linked to reduction of falls in the older population.**

***Keywords*: Geriatric, agility, frailty, reduction of falls, 30 second chair stand test.**

1. Introduction

According to WHO, the number and proportion of people aged 60 years and older will increase to 1.4 billion by 2030 and 2.1 billion by 2050[1]. Therefore, proper diagnosis and rehabilitation programs need to be designed to prevent immobility and postural instability, decreasing the risk of falls and downstream decline on a frequent and consistent basis. With the ongoing pandemic, the likelihood of age-related cognitive and functional problems have increased significantly due to decrease in physical activity and lack of accessing services [2]. Thus, we introduce an economical and easy to use method to help the older and frail population self-assess and deal with such problems without the requirement of a healthcare provider.

The method revolved around the results obtained after performing the 30 second chair stand test [3] to help determine the level of agility of a user according to their age and gender. This test is part of the Senior Fitness Test Protocol, and is designed to test the functional fitness of seniors. The user sits in the middle of the seat, with their feet shoulder width apart, flat on the floor. The arms are to be crossed at the wrists and held close to the chest. From the sitting position, the subject stands completely up, then completely back down, and this is repeated for 30 seconds. We count the total number of complete chair stands (up and down equals one stand) [4]. The advantage of this test is that it is simple to perform and can be done even at home without any technical assistance. It is a measurement that assesses functional lower extremity strength [5].

In order to achieve this, we suggest a novel approach using a method of Computer Vision where we detect the alternate color variation in the background and foreground where foreground being the subject as opposed to the traditional method wherein, we detect pressure changes with the help of pressure plates and gyroscope. The color of background is registered in the form of BGR values [6] using color detection and conversion in OpenCV and the subject stands in the foreground setting the camera at the recommended position, initiating a 30 second timer and the test. The color of the background is stored in a multidimensional array and the color of the background in the rectangular frame is compared with the foreground with a wait time of 10 milliseconds in between. The comparison is made within a specific deviation of magnitude of 40 in BGR values and hence detecting change eventually leading to increase in the sitting phase. Similarly, the process is repeated for the stand-up phase of the whole iteration. Hence, we are able calculate the total count of standing and sitting phase and the resultant count is half of the previous sum to give the total number of repetitions performed in the stipulated time of 30 seconds.

The objective of our study was to apply the current strategy to detect frailty and make it accessible to the larger population of old people. The approach is hassle free, self-accessible and allows a user make comparative study without the need of a technician making them more independent. The software can be used on a laptop or camera and can be viewed as a form of cumulative solution to achieve better physique and reduce potential risks of injury.

2. Literature Survey

In paper, *Automatic Evaluation of the 30-s Chair Stand Test Using Inertial/Magnetic-Based Technology in an Older Prefrail Population by Nora Millor*, discusses the relevance of the 30-s Chair Stand Test as an important parameter to discriminate among healthy, prefrail and frail populations using sensors such as accelerometers and gyroscopes. The whole test is divided into three phases namely - Impulse, stand up and sit down. This paper, suggests the use of body-fixed sensors as a powerful tool to analyse the test results as it not only calculates

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the duration of test but also evaluates how the movements have been carried out [7].

In paper, *Measurement of the Chair Rise Performance of Older People Based on Force Plates and IMUs, by Sandra Hellmers*, discusses how technology can be used to support a well-known test in geriatric field. The measurements were taken using the inertial measurement unit (IMU), a Kinetic camera and a force plate and hence documented to provide a table which shows the agility score of adults as related to time duration of test. In this 5 CRT test in comparison to other geriatric tests it also determines duration of cycles [8].

In another study of, *An evaluation of the 30-s chair stand test in older adults: frailty detection based on kinematic parameters from a single inertial unit, by Marisol Gómez*, discusses how various performance tests such as the 30-s Chair Stand test can be used to predict co-morbidities and mortality of older populations. Test subjects were asked to perform this test while their trunk movements were measured by a sensor unit at vertebra L3. It would also detect failed attempts by using acceleration and orientation information. The results are a preliminary step toward the development of a user-friendly, simple automated tool to help clinicians assess the 30-s CST in an objective manner based on movement-related parameters [9].

The Paper, *Agility-based exercise training compared to traditional strength and balance training in older adults: a pilot randomized trial, by Eric Lichtenstein*, have an aim of the current study was to apply the agility framework to an exercise training intervention and compare the efficacy to a traditional exercise training intervention particularly targeting strength and balance in older adults. Agility-based exercise training seems at least as efficacious as traditional strength and balance training in affecting selected physical performance indicators among community-dwelling healthy seniors [10].

Patent *Self-Evaluation Tool and Diagnostic Method for Healthy Aging, by Jean-Pierre MICHEL (Geneva)*, claims to be a self-assessment tool, application program. This report is used to assist doctors in diagnosing the person in order to suggest remedial actions. Out of many tests, balance and flexibility /agility tests are also suggested as part of the application program [11].

A. Comparative Study

All the approaches as cited by the studies involve the use of expensive hardware to capture and evaluate the results of the 30 CST. These hardware components do provide a deep understanding of the results obtained when the geriatric test is performed by various participants. But their major drawback is that it makes these tests difficult to perform without technical assistance and in a clinical environment.

On the other hand, our model makes use of the 30 second chair stand test (30 CST), part of the Fullerton Functional Fitness Test Battery [12], to help detect early signs of weakness in the home environment. The approach uses camera and BGR Colour variation algorithms in OpenCV to detect body movements and feed it as input to the rest of the processes. It also suggests an agility-based training program to the user after calculating the test results and allows graphical visualization of their progress from time to time. The results thus obtained by using this model are in accordance with the standard evaluation done with the standard evaluation done with the help of body sensors and Inertial force plates.

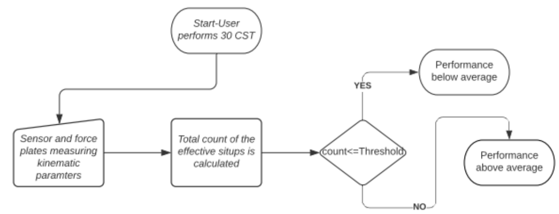

Fig. 1. Flow diagram of traditional geriatric test using pressure plates and sensors

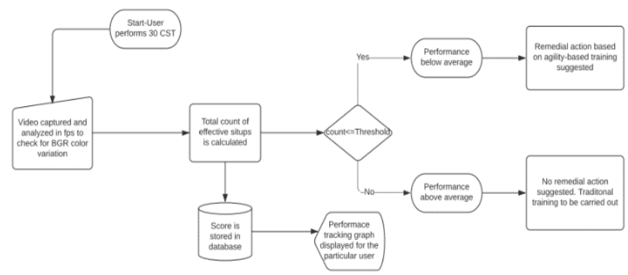

Fig. 2. Flow diagram of geriatric agility test using computer vision

3. Methodology

The method followed in this process of geriatric agility test detection is broken down into three processes to make representation accurate and less complex. The first process 1 (P1) which involves calculation of the number of sit-ups done, second process 2(P2) suggests the user agility-based exercise based on their performance score and third process 3(P3) graphically represents the data collected over the time for the user.

A. Process 1 (P1)

It is related to evaluation of the total repetitions of the 30 CST. A user logs in and enters name and age and starts the test. Background registration begins by capturing the video through the camera. A timer begins counting down to 30 seconds and simultaneously detects changes in the BGR colour of the reference frame to evaluate the total number of sitting and standing phases. The result shows the number of repetitions done along with the performance analysis data. The method involves using the concept of multi-threading to achieve both the video capturing and initiation of a 30-sec timer.

Algorithm:

- Step-1: Start
- Step-2: Register the name, gender and age of the user.
- Step-3: When the user presses the button to start the test, countdown begins in 30 seconds and import cv2 package from OpenCV to allow video capturing.
- Step-4: Create a 2D matrix to register background colours in BGR values in a rectangular frame directly identified in front of the camera.

- Step-5: Create a function to return the count of complete chair stand repetitions performed. A loop is used to analyse video in the form of frames and colour of the foreground is registered in BGR values in the same rectangular frame. Here, foreground refers to the user.
- Step-6: A loop is used again to actually look for change in the box by comparing with the already stored background. A Boolean construct is used to check the colours pixel by pixel. Every time the current value of a pixel is different from the colour registered for background implies changes in the background and hence, we need to increase count of the sit-ups.
- Step-7: Once the total count is obtained, we refer to the Table 1 and Table 2 to display the result of the test and is also stored in the database for it to persist.

Table 1
Male test subject [13]

Age	Below Average	Average	Above Average
60-64	< 14	14 to 19	> 19
65-69	< 12	12 to 18	> 18
70-74	< 12	12 to 17	> 17
75-79	< 11	11 to 17	> 17
80-84	< 10	10 to 15	> 15
85-89	< 8	8 to 14	> 14
90-94	< 7	7 to 12	> 12

Table 2
Female test subjects

Age	Below Average	Average	Above Average
60-64	< 12	12 to 17	> 17
65-69	< 11	11 to 16	> 16
70-74	< 10	10 to 15	> 15
75-79	< 10	10 to 15	> 15
80-84	< 9	9 to 14	> 14
85-89	< 8	8 to 13	> 13
90-94	< 4	4 to 11	> 11

- Step-8: END

B. Process 2 (P2)

The results obtained from process 1 are fed to process 2 to suggest an agility-based training routine to improve overall strength and endurance of the lower extremities. The suggested routine depends on the session number and includes the exercises, duration and its variations.

Algorithm:

- Step-1: Start
- Step-2: The track of the number of attempts is kept. According to the session number and results obtained after performing the chair stand test, an agility-based exercise training routine is suggested to the user.
- Step-3: If the user's agility score is below average, the training routine is displayed according to the table 3 [14].

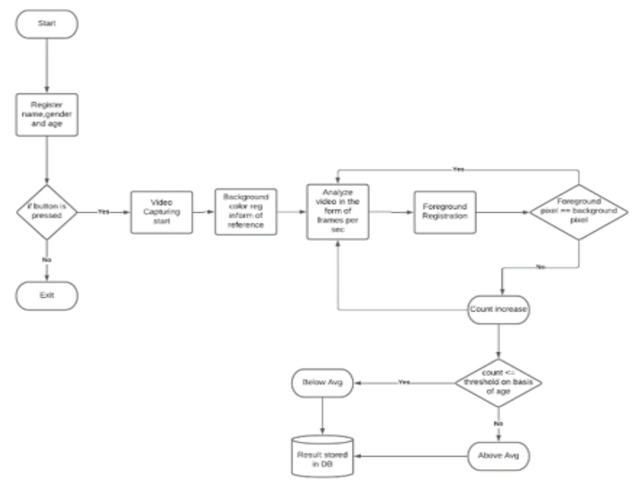

Fig. 3. Flow diagram to calculate agility score by counting no. of sit-ups (Process 1)

- Step-4: If the user's agility score is average, a training routine is displayed according to the table 4.
- Step-5: If the user's agility score is above average, a user is suggested to continue the same training routine as before.
- Step-6: End

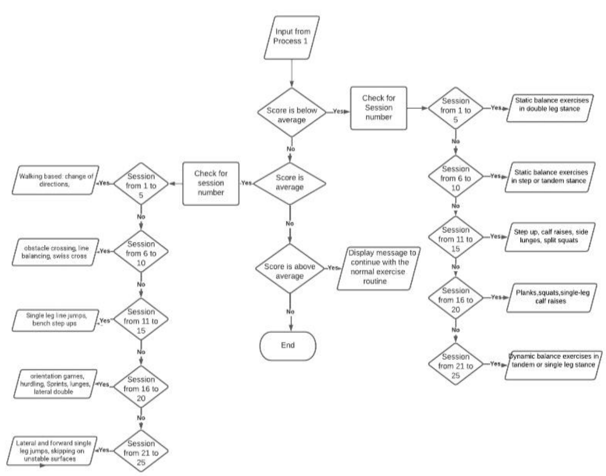

Fig. 4. Flow diagram to suggest rehabilitation program based on agility score (Process 2)

C. Process 3 (P3)

This process is initiated when a user wants to visualize the progress made throughout. The data collected and stored in the database-Mongo DB is used as the raw input to graphically represent the progress made, if any using matplotlib [15]. Since our database should be scalable, Mongo DB is an ideal choice. In matplotlib.pyplot various states are preserved across function calls, so that it keeps track of things like the current figure of the test score and plotting area, and the plotting functions are

Table 3

Session 1 to 5	Exercises Duration Variations	Walking based: change of directions, cuts, obstacle crossing, bench balancing. Double leg line jumps, bench step ups ~30sper exercise,2 rounds, 5 exercises Elevated balancing, obstacle height, speed, plane of moment
Session 6 to 10	Exercises Duration Variations	Walking based: change of directions, cuts, obstacle crossing, line balancing, Swiss cross and combinations of these. Unstable lunges, ball dribbles. ~30 s per exercise, 2 rounds, 7 exercises. Color coding of movement directions, all of the previous
Session 11 to 15	Exercises Duration Variations	Walking based: change of directions, cuts, rotations, obstacle crossing, line balancing, swiss cross and combinations of these. Single leg line jumps, bench step ups, orientation games ~30 s per exercise, 3 rounds, 7 exercises Sound coding of movement tasks and directions, walking modes, all of the previous.
Session 16 to 20	Exercises Duration Variations	Walking based: obstacle crawl and crossing, catch through the course, beam balancing, orientation games, hurdling, Sprints, lunges, lateral double leg jumps, bench step-ups. ~30 s per exercise, 3 rounds, 8 exercises All of the previous
Session 21 to 24	Exercises Duration Variations	Walking based: Song with coded tasks on words, catch through the course, orientation reaction games. Lateral and forward Single leg jumps, skipping on unstable surfaces, lunges, ball throw and catch exercises. ~30 s per exercise, 3 rounds, 8 exercises Cognitive tasks, ball dribbling while performing the tasks, all of the previous.

Table 4

Session 1 to 5	Exercises Duration Variations	Static balance exercises in double leg stance Squats, calf raises, supported split squats 30s exercise,30 s pause,3 rounds,8 exercises Perturbations
Session 6 to 10	Exercises Duration Variations	Static balance exercises in step or tandem stance Squats, calf raises, side lunges, split squats, crunches 50s exercise, 30 s pause, 2 rounds, 8 exercises Perturbations Strength exercises o slightly unstable surface
Session 11 to 15	Exercises Duration Variations	Static and dynamic balance exercises in step or tandem stance Step up, calf raises, side lunges, split squats 35s exercise,30 s pause,3 rounds,8 exercises Cognitive tasks, unstable surfaces, arm balance Strength exercises on slightly unstable surface
Session 16 to 20	Exercises Duration Variations	Balance exercise in step on tandem stance Planks, squats, single-leg calf raises, side lunges, split squats, Bulgarian 40s exercise,20 s pause,3 rounds,8 exercises Cognitive tasks, perturbations, arm balance
Session 21 to 24	Exercises Duration Variations	Dynamic balance exercises in tandem or single leg stance Squats, single-leg calf raises, step-ups, Bulgarian split squats 55s exercise,20 s pause,3 rounds,8 exercises Unstable surfaces, perturbations, arm balance

directed to the current axes. Thus, data can be better understood when presented by a graph than by a table because it reveals a trend and/or comparison.

Algorithm:

- Step-1: Start
- Step-2: The application is connected to the database and data stored in the database is used as the raw input. Importing PyMongo and Axes3d and Matplotlib is essential and the client is connected using "pymongo.MongoClient(course_url)".
- Step-3: Set the query to filtering conditions and criteria by removing outliers that are clearly bad data and convert cursor into a list.
- Step-4: We use the data from the list to plot the graph and can also be used to set titles and legends.
- Step-5: End

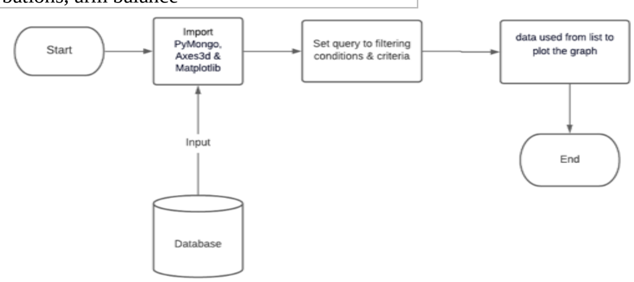

Fig. 5. Flow diagram to graphically represent user's performance over a time periods (Process 3)

4. Conclusion

We suggested a self-assessment designed specifically keeping in mind the interests of the elderly during the pandemic. It is hassle free, easy to use and an accurate method to detect frailty in older adults and suggests a time-efficient alternative for exercise training and allows visualization and analysis of results over a period of time. A long-term investigation needs to be carried out to overcome difficulty of correct posture detection to ensure that the person does exercise properly and include other tests to gauge agility of senior people. This automation makes it easier to run tests without any technical knowledge and makes an attempt to reduce human errors. Thus,it makes it a feasible approach that can be used in clinical as well as home environments. Not only it warns the user about the potential dangers but also suggests remedial actions that can be taken to mitigate them.

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