Elderly Fall Forecast Based on Adapted Particle Swarm Optimization Algorithm

Stan Ovidiu, Liviu Miclea, and Anca Sarb

***Abstract*—The proposed paper is based on an integrated planning system for mandatory and regular assessment of the elderly's state of being and, if necessary, their telemonitoring and assistance. Consequently, the scope and the purpose of this paper is to provide a new type of treatment (medicine), based on connectivity, collaboration, personalization and computing. The presented paper issues an adaptation of the Particle Swarm Optimization Algorithm to forecast the next episode of an elderly's fall.**

***Index Terms*—Elderly fall risk, elderly fall prediction, PSO.**

I. Introduction

Due to the United Nations statistics' and reports', the population on the entire globe is engaged in an unprecedented aging process. Although the most affected country is China, Romania does not take exception of this rule [1], [2]. In all areas of the globe, elderly people catch a series of diseases caused by the fall accident/episode. This is the most important factor of the health risk that diminishes the quality of life of the elderly persons.

Falling is defined by the World Health Organization as being the event that results in a person resting unintentionally on the ground. If a person has more than two such events per year, the World Health Organization defines this as being a recurring fall [3].

After such an episode, they can no longer take care of them with respect to their daily work, this leading to a significant increase in the national and international health systems' costs.

This issue has begun to be investigated and solved over the last periods taking into consideration all sorts of means. The most common method is to use sensors on the bearer, and when a fall event occurs, the device automatically sends a message or provides an alarm button for the user to use[4], [5]. However, these methods are limited because if the person that falls lost consciousness, then he can no longer activate the alarm signal by pressing the button. In addition to this, other methods are based on devices that use voice or sound recognition [6], [7]. Unfortunately, this method is directly dependent on device performance and costs are very high. In the market, there are also methods that use video processing and monitoring of the patient's home, but this method cannot detect the fall event of victims when they leave their home or whenever they are in a private room (bathroom, bedroom, etc.)[8].

This paper proposed another method, based on big data analysis, through a modified Particle Swarm Optimization Algorithm and its forecast of the next episode of fall without needing other sensors or devices. It is based on the periodic data gathered by the geriatric doctors after an episode of evaluation occurs. The gathered data results in the five geriatric evaluation tests: Mini Nutritional Assessment (MNA) [9], [10], Katz Index of Independence in Activities of Daily Living (ADL)[11], Fall Risk Assessment and The Geriatric Depression Scale (GDS) and The Mini Mental State Examination (MMSE)[12], [13].

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II. Core Concepts

A. Geriatric Evaluations

All the geriatric evaluations listed at the end of Section I are used by the geriatric doctors in order for them to evaluate the health status of an elderly persons.

The Mini Nutritional Assessment (MNA) is used to identify older adults who are at risk of malnutrition. MNA is a clinical completed instrument with two components: screening and assessment. The use of this tool eliminates some of the invasive tests like blood sampling and gathering of information regarding anthropometric, personal, dietary and overall evaluation through a series of only 18 questions.

TABLE I: Katz Index of Independence in Activities of Daily Living

Activities Point (1 or 0)	**Independence:** (1 Point) **NO** supervision, direction or personal assistance	**Dependence:** (0 Points) **WITH** supervision, direction, personal assistance or total care
Bathing	Self-bathes completely or needs help in bathing only a single part of the body such as the back, the genital area or the disabled extremity.	Needs help with bathing more than one part of the body, getting in or out of the tub or shower. Requires total bathing.
Dressing	Gets clothes from closets and drawers and puts on clothes and outer garments completed with fasteners. May have help tying shoes.	Needs help with self-dressing or needs to be completely dressed.
Toileting	Goes to toilet, gets on and off it, arranges clothes, cleans genital area without help.	Needs help transferring to the toilet, self-cleaning or uses bedpan or commode.
Transferring	Moves in and out of bed or chair unassisted. Mechanical transferring aides are acceptable.	Needs help in moving from the bed to the chair or requires a complete transfer.
Continence	Exercises complete self-control over urination and defecation.	Is partially or totally incontinent of bowel or bladder.
Feeding	Gets food from the plate into the mouth without help. Preparation of food may be done by another person.	Needs partial or total help with feeding or requires parental feeding.

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The Katz Index of Independence in Activities of Daily Living (Table I), commonly known as the Katz (ADL), is the most appropriate instrument to assess functional status of an individual, as a measurement of the patient's ability to perform activities such as independently daily living. Its ranking of performance of capabilities to fulfill six basic functions, like: bathing, dressing, toileting, transferring, continence, and feeding through 6 questions.

The Mini Mental State Examination (MMSE) is used to systematically and thoroughly assess the mental status of a patient. It is based on six questions and manages to separate patients with cognitive impairment from those without cognitive impairment.

The Geriatric Depression Scale (GDS) may be used on healthy patients, medically ill ones and mild to moderately cognitively impaired older adults. It is composed of 30 questions. It basically manages to present how the elderly felt during the administration day of administration into the hospital. While this test takes place they get a score. Scores of 0 - 9 are considered normal, 10 - 19 indicate mild depression and 20 - 30 indicate severe depression. The GDS is not a substitute for a diagnostic issued by a mental health professional, but it is a useful screening tool in the clinical setting to facilitate the assessment of depression in older adults, especially when baseline measurements are compared to subsequent scores.

TABLE II: FALL ASSESSMENT TOOL

Client factors	Date	Initial score	Date	Reassessed score
History of falls		15		15
Confusion		5		5
Age (over 65)		5		5
Impaired judgment		5		5
Sensory deficit		5		5
Unable to ambulate independently		5		5
Decreased level of cooperation		5		5
Increased anxiety/emotional liability		5		5
Incontinency/urgency		5		5
Cardiovascular/respiratory disease affecting perfusion and oxygenation		5		5
Medications affecting blood pressure or level of consciousness		5		5
Postural hypotension with dizziness		5		5
Environmental Factors				
First week on unit [facility, services, etc.]		5		5
Attached equipment (e.g., IV pole, chest tubes, appliances, oxygen, tubing, etc.)		5		5

The Fall Risk Assessment Tool (FRAT) includes the patient and the environment as factors that contribute to falls. The tool should be administered on admission to the elderly facility or elderly agency and again at specified intervals and when warren of changes in health status. It is based on 15 questions and manages to detect those individuals that are situated at a highest risk for falls. The series of question that these persons are required to answer while completing this test are presented in Table II, considering matters from history of falls to confusion, to age and even medication that effects the blood pressure or consciousness.

The results from the tests are sent in real time to the server through a previously developed application [14]. This is used by the geriatric doctors in order to see the evolution of a certain patient. Basically, the mobile application is used by 64 patients, since January 2016, and we have assigned two medical staff to them. All this information has been digitized (demographic information, medical information, medical history, all hard paper records with the geriatric testes presented above) in order to avoid time-wasting and energy wasting when unnecessary. The way this application was created is not the subject of this article. This article presents how the gathered data, together with the application is used to predict the next fall episode of an elderly person.

B. Elderly Falls - Causes

A falls episode can appear in different scenarios, like falling from a chair, falling when the patient is holding a standing/walking pole or even falling from walking, standing or climbing down the stairs. Factors leading to the forth bringing of an episode of falling can be grouped into three main dimensions: the health of the elderly person, the extrinsic factor caused by the elderly's environment and factors related to the individual behavior (Fig. 1).

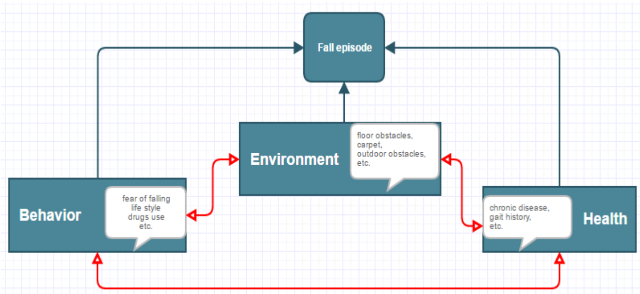

Fig. 1. Fall risk classification.

One of the most recognized causes from the literature review that leads to a fall episode or to an increased risk of falls is chronic disease [17]. Of those that have the most important decision-making factors, the ones worth mentioning are: cardiovascular disease, diabetes, arthritis, mental illness such as cognitive disorders or depression, asthma, any form of cancer, multiple sclerosis, epilepsy and osteoporosis [17], [18].

Factors that are correlated with the environment and that need to be mentioned here are also considered to be extrinsic. Some of the more extrinsic fall factors that have been mentioned in literature are related to the lack of stair handrails or to the bad stairs' design, lose or improper shoes for the age of the elderly, slippery surfaces, improper quality of light, and the lack of grab bars around the places where elderly move and live.

III. PARTICLE SWARM ALGORITHM

The particle swarm optimization (PSO) [15], [16] is a random optimization approach/technique, grounded in a population of individuals. The algorithm is easy to control because it has a small number of parameters. Basically, in a particle swarm optimization, the particles (or individuals of the population) motion through a specific designed space while finding and pursuing to reach the best of the particles (or individuals of the population). While exploring the space, the individual remembers its best position. The best position is the position where it has reached its best results.

Furthermore, besides having this information, it has the information on the position of the best individual in the swarm. Taking into consideration this information, a change in position and velocity of everyone happens; this way the search space exploration is created. In addition, unlike other heuristic optimization methods, it has the flexibility to enhance the exploration and exploitation abilities.

When considering a N-dimensional search space, the position vector of each particle (x_i^k) is updated by the (1) formula. The process is also presented in Fig. 2.

$$x_{k+1}^i = x_k^i + v_{k+1}^i \tag{1}$$

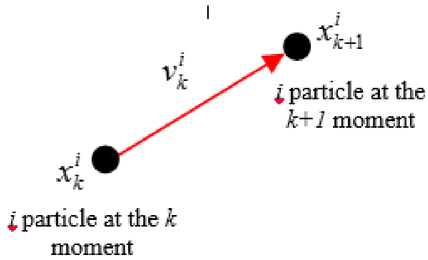

Fig. 2. Particle position updating process.

where,

x_{k+1}^i	New position of the particle *i*
x_k^i	Current position of particle *i*
v_{k+1}^i	New velocity of the particle *i*

$$v_{k+1}^i = \omega * v_k^i + c_1 * r_1^k * (pbest_i - x_k^i) + c_2 * r_2^k * (gbest_i - x_k^i) \tag{2}$$

How the new velocity of a particle is obtained is presented in equation (2), where: ω represents the weight of the inertia, the acceleration constants are introduced in the above formula through c1, c2; r_1 and r_2 represent the acceleration which is a random value between [0, 1] and represents the contraction expansion and controls the convergence speed of the algorithm; $pbest_i$ and $gbest_i$ are the best local, respectively global position of a particle *i*.

IV. The Proposed Approach

To solve the prediction problem with PSO, this study proposed a network parallel PSO algorithm and applied it to all the classifications of the geriatric evaluations included in the application.

The parallel processing approach presented in Fig. 3 effectively reduces the impact of the diversity and complexity of the sample in order to improve the algorithm's performance.

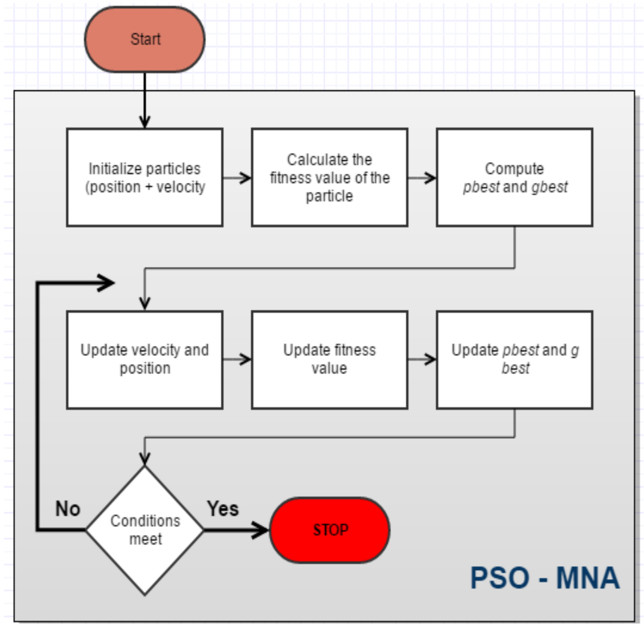

Fig. 3. PSO applied on data gather through the mini mental state examination.

The flow of the algorithm is presented further on. In the first stage, the PSO parameters, like position, velocity, population size are initialized. Even though Figure 3 presents just the method of how the data gathered through the Mini Mental State Examination is evaluated through PSO algorithm, the system calculates all of this in parallel, like it is showed in Figure 4. The fitness function used to calculate the x_i individuals is defined as:

$$F_i = \sum_{j=1}^{M-1} (\bar{z}_i - z_i)^2 (i = 1, 2, \cdots, n) \tag{3}$$

For each particle, the fitness value is calculated and then is computed the Population's fitness value.

Each individual's optimal fitness is updated into *pbest* and the position is stored. If any current fitness value of a particle is smaller than the optimal *pbest*, then this value is used to update the optimal fitness value and its position. The population fitness value *gbest* is then updated with the best value *pbest* of the winning particle. By updating the speed and the position of particles a new population is generated. This is constantly updated with equation (2). The solution obtained is constantly compared to the registered episode of fall of all the patients enrolled within the application.

When the satisfying condition is obtained, the algorithm training phase concurs. First, the network algorithm is initialized with a value for the structure and for an expected output. The PSO algorithm provides information for the training phase such as the initial weight and threshold of the algorithm's network. The layers of the network are calculated, and, if the error satisfies the requirements and the expectations, an alarm is set through our application to the geriatric doctor assigned with the elderly patient.

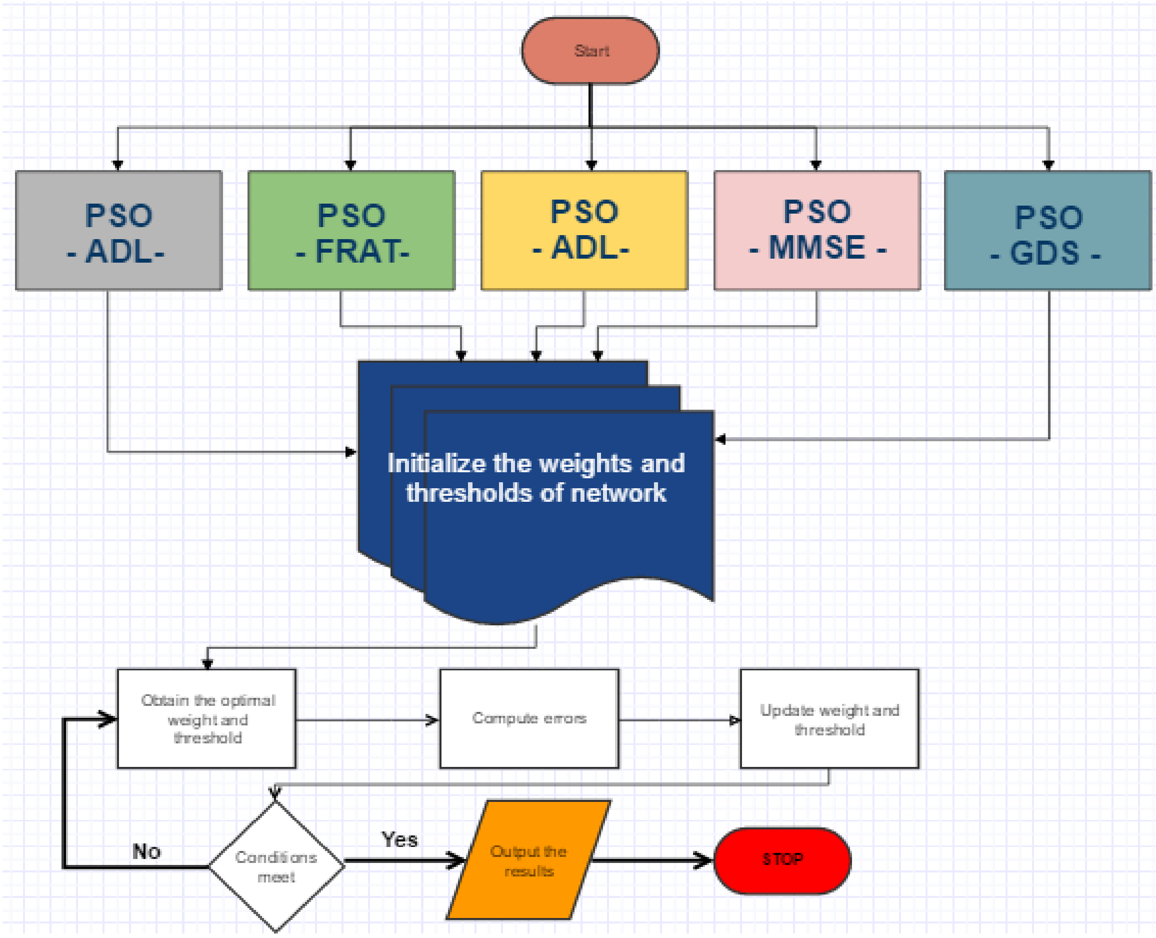

Fig. 4. PSO applied on data gather through the mini mental state examination.

In Fig. 5 is detailed the basic neuronal network used in order to develop and to generate the forecast algorithm. In the middle part there is presented the hidden layer, while the left and the right part represent the input (Z1, Z2, …, Zn), respectively output (Y1, …, Ym) of the neuronal network.

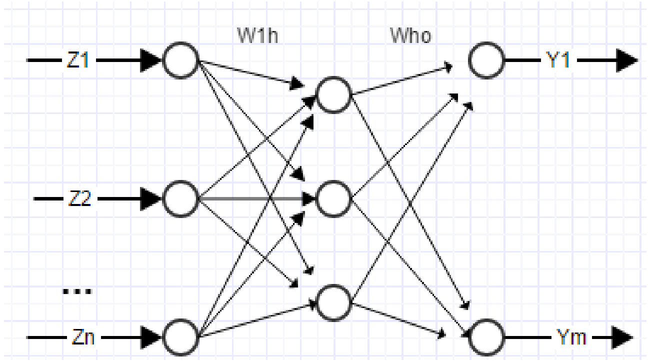

Fig. 5. Neuronal PSO adapted network proposed.

Basically, because the input and output value are independent variables, but also they are dependent to the function, the network can be considered as a nonlinear function. The hidden layer uses the nonlinear transfer function. Basically, the structure of this network is based on three layers (input, hidden, output) is:

$$Ym = purelin[Who * \tan sig(W1h * Z1 + Bh) + B0] \qquad (4)$$

Bh and *B0* represent the threshold from input to hidden layer, respectively from hidden to output layer.

We use this kind of neuronal network due to its properties, such as rigorousness in derivation with high level of precision, a low level of error function through the solving process of the minimal function and, furthermore, a high level of precision. The network training process constantly updates and adjusts the network parameters, such as weight and threshold. that leads to a convergence with a low speed and minimal steps to solve the problem. This concurs to an easily adapted algorithm and, also, to its improvement.

V. Conclusion

The project's innovative outcomes can be used in the exploitation of an elderly's health, disability, dependability, quality of life and it is used for longitudinal data collections and cross-sectional analysis. Its use is not limited by physical boundaries of a country. It can be implemented within European countries, while also in the non-European ones, without changing its initial purpose - identifying and monitoring trends of healthy aging and addiction, until reaching the next fall forecast. The solution will provide well founded and reliable scientific evidence, comparable between different regions of a country or between countries, to research and develop policies on aging and dependability. Our solution is now used in two elderly centers from Alba Iulia, Romania. It is used for monitoring and tele-monitoring and gathering data of the elderly persons and to facilitate the bond between patient and doctor. Moreover, this leads to a decrease in the time spent by a doctor with an elderly patient and vice-versa in a pointless way. Based on the gathered data we have managed to create and implement an evolutionary and innovative neuronal algorithm in order to forecast the next fall episode of an elderly person based on personal's patient gathered data and on the history data gathered from the patients that are already a registered part of the application.

The goal of the presented method is to anticipate the fall before the episode of fall happened so that we can provide a safety mechanism to alarm the geriatric doctors and the elderly person in order to avoid any wounds associated with the fall and to avoid or foresee any costs involved with the recovery of the elderly.

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