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Encouraging Movement Through Musical Feedback for Elderly People with Very Low Physical Activity

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ABSTRACT

In the current conditions, when the aging of the population is a certainty, it is very important that older people continue to have an active, comfortable and independent life for as long as possible. As the accelerated technological progress of recent years, elderly people tend to be isolated, either through self-isolation (inability or disinterest to keep up with new discoveries; refusal to represent a burden on family or other people) or through various external factors (geographical situation, busy families, limited social assistance).

Keywords— *Cognitive Ageing, Aging, Ageing and Health, loneliness, well-being, physical health, mental health, musical biofeedback, creativity.*

I. INTRODUCTION

The improvement of health care in the last century has contributed majorly to the increase of the life expectancy of the population and implicitly of the fragility of the elderly. Fragility is a geriatric concept regarding increased vulnerability to stressors and the precarious balance between needs and the ability to cope. It has biological, physiological and psychological components. Another consequence of the aging of the population besides the increase of fragility is the increase in the share of neurodegenerative diseases (dementias, Parkinson's disease, amyotrophic lateral sclerosis, etc.) or psychiatric (anxiety, depression, personality disorders, etc.). Often persistent sad mood leads to depressive disorders that are in most cases the preamble of dementias from different syndromes or diseases. Depression affects an estimated 350 million people globally, according to the World Health Organization. More than half of them do not receive treatment because they are not diagnosed.

The number of strokes in elderly people with depression is double that of those without this disease. Dementia is a syndrome characterized by impaired brain functions such as memory, thinking, orientation, understanding, learning, language, judgment. The most common form is Alzheimer's dementia which accounts for up to 70% of all of them. Patients have affected the quality of life especially in the middle and advanced stages.

The beneficial role of lifelong experiences such as exercise, meditation (including mindfulness, concentration, yoga and tai chi practices) and music (including play and instrumental dance) on the brain and cognitive health in older adults is demonstrated by various studies. Their role must be well studied and extrapolated, in order to be able to manage the crisis of the future caused by the decline of cognitive function. There is an unprecedented increase in the global population but also in people aged 65 and over, with an increase from 8.5% in 2015 to 16.7% in 2050. Cognitive disorders are characterized by problems in thinking, memory, language and judgment, which are greater than cognitive ones, changes in normal aging, which range from mild to severe. One in two people over the age of 85 will be diagnosed with dementia while the estimated prevalence of mild cognitive deficit among people aged 60 and over is 5-36% in 2015 [1].

1.1 Degradation of affective (emotional) state and pathology of depression

Loneliness and social isolation are significant problems among the elderly population. 40% of all elderly people experience loneliness, which has been linked to various health problems, including increased risk for cardiovascular disease and death. The loneliness of the elderly is an important area of development for the computational models of emotions, because the feeling of loneliness is the affective response to social isolation. Automated systems that can identify and intervene on the feeling of loneliness in the elderly can have a significant positive impact on society.

Current methods of emotional engagement - therapeutics - use passive communication media, such as the images contained in the International System of Affective Images. However, a complete emotional engagement requires active participation. Studies have shown that the use of a virtual agent in attracting people to interact has much more effective results in combating loneliness than if the virtual agent waits for people to initiate interaction. Thus, an "affective agent" that can identify and intervene on the affective state represents a promising technology, which has a real potential in maintaining the independence and health of the elderly.

1.2 Attracting the elderly person to physical activity through creation and music.

The idea that old age and creativity are mutually exclusive is as familiar as it is erroneous. Recent cognitive studies have shown that intelligence in the elderly does not deteriorate as they age. The decline found in some cases is determined by diseases as well as by the lack of stimulation of existing capacities. In addition, elderly people have the opportunity to use skills that, before, they did not have the time, energy or opportunity to develop.

Studies show that the actual participation of the elderly in the creative act has the following advantages: 1. increasing self-confidence and self-esteem, 2. adopting new directions regarding identity and role in life, 3. improving cognitive functions, the ability to enjoy and find pleasure in everyday life, 4. the perceived progress as well as, often, exceeding one's own expectations regarding the results, ensures a positive mental state, the pleasant diversification of daily activities. A creative person is more receptive to the new, processes information more easily and has the permanent ability to accommodate new knowledge.

Music is a form of sensory stimulation, which causes reactions due to the familiarity, predictability and feelings of safety associated with it. Research in the field of music therapy has proven its effectiveness in various fields, such as: physical rehabilitation and facilitation of movement, increased motivation in observing a treatment, emotional support, facilitating the expression of feelings. The viability of music therapy has been proven even in people who resist other treatments [2].

Listening to music requires the integration of complex sensory information with motor control processes, coordination, working memory and performance monitoring. While seniors frequently use their bodies and movement as tools with which they experience moods, new ideas and facial expressions appear, through dance, in parallel with the modification of biochemical parameters [3].

Musical training has shown that it increases neuroplasticity throughout life, which has led to considerable interest in the use of musical activities as a means of improving different neurological and neurodegenerative conditions. As a therapeutic intervention, many studies have investigated the effects of neuroplasticity of musical activities. Several cognitive areas have been shown to benefit from musical activities, including sound processing, language, intelligence and inhibitory control [4]. Several retrospective studies have noted that people with extensive music experience hold more cognitive advantages at older ages. For example, trained older musicians have a superior ability to perceive speech, especially in noise conditions, and exhibit superior neural activity for vocal perception and encoding. There is also evidence indicating a reduced loss of gray matter in trained musicians in relation to naïve older adults. Consequently, it has been found that music significantly reduces the likelihood of dementia and cognitive impairment in older ages.

II. Music as a motor rehabilitation tool

Of particular significance in the context of motor rehabilitation is the notion that musical rhythms can train patterns of movement in patients with movement disorders, serving as a continuous time reference that can help regulate the time and rhythm of movement.
Rhythm is the basic pattern or grid in which musical notes move and flow. The beat is the tempo that remains consistent throughout the piece. Rhythm can be best described as the repetitive pattern of beats and timing in a song. Rhythm can change within a piece of music, but the beat remains consistent. It's also the main differentiating factor between different musical genres.

The response to the rhythm and how it differs is completely inextricably linked to movement. When listening to rhythmic music, there was spontaneously a desire to respond through movement. Even when the music stops, we can make dance moves, synchronizing with an internally generated rhythm. A special characteristic of people is the training phase, the few seconds in which we try to read the rhythm, and then synchronize, generating an internal beat and then initiating the rhythmic movement. To highlight the areas of the brain that activate in response to rhythm, MRI scans were performed. During the scan, the participants were asked to stand still. The images obtained show the work of the auditory cortex, which is responsible for sound processing. But the confirmation of the desire to respond to the rhythm is confirmed by activating the areas responsible for the processing of the movement, respectively by the selection, control and initiation of the movement. The additional motor area, the premotor cortex and the basal ganglia deep in the brain are active. This result suggests that music is not just about sound, but fundamentally it is about movement [5].

That means we can actually use music to change activity in the motor areas of the cricket. The potential for therapeutic applications is of great importance, considering that these motor areas of the brain are frequently affected, both by stroke and by degeneration. An example of this is Parkinson's disease, in which patients have difficulty initiating movements and often freeze in the middle of performing an extra movement in addition their movements can be unstable or slow. The results of the tests are spetaculous, especially, when the patient chooses his own melody or rhythm according to his preferences. The question is what characteristics of music are responsible for the different response to music of the patient. The degree of spontaneous movement for a particular piece of music depends on a combination of musical or acoustic factors (syncopation, tempo) and subjective factors (pleasure, familiarity) [6].
Groove is the feature that indicates to us how much the chosen music makes us want to move. Groove music usually has a high tempo and a clear beat. Another factor, but with a much less influence on the desire for movement, is the desire to listen to a song known in his youth and loved. There is evidence to support the idea that the ability to predict a sequence of beats or the rhythmic progression of a song is related to the extent to which a listener enjoys a particular piece of music [7].
Another approach to the rhythm-movement relationship is that of Dr. Ayelet Landau, who emphasizes the rhythmic nature of our perceptions. Rhythmicity is a hallmark of the brain [8] [9]. In recent years, neural as well as cognitive exploration have revealed rhythmic reasons in the mechanisms that govern attention and perception.
People have a wonderful ability to choose only the things relevant to their needs.
This is what we call "attention." When we pay attention to something, different parts of the brain, which process it, actively communicate with each other (brain discussions)
Even when we focus on one thing, it turns out that attention does not work continuously at the same level. These transitions, between moments of attention and inattention, occur about 8 times per second. It's the rhythm that shapes our experience. phase of a cerebral rhythm of ~8 Hz. [10]. Behavioral changes as well as neural signatures have been investigated in response to stimuli containing a rhythmic temporal structure. In the laboratory, applying regular rhythmic stimuli, both a

brain response and a behavior that follows the rhythm of stimulation were obtained. This means that in the neural response, a frequency modulation can be revealed, the same as that of the rhythmic stimulus. This phenomenon is called neural training and can produce rhythmic modulations of behavioral performance [9].

Bayesian brain theory, a computational approach derived from the principles of predictive processing (PP), provides a mechanical and mathematical formulation of these cognitive processes. This theory assumes that the brain encodes beliefs (probabilistic states) to generate predictions about sensory input, then uses prediction errors to update its beliefs. [H Bottemanne et al.]. Consistent with this theory it can be stated that the perception of rhythm is a predictive process. And the activity of the motor regions in the brain, regions that help to plan motor movements, is also part of a predictive process of synchronization and simulation of movement. Maybe this is why we say we feel the rhythm of the music [11].In the brain beat perception is not just an auditory phenomenon it's an auditory motor phenomenon.

Professor Aniruddh D. Patel makes a connection with another skill we have that connects auditory and motor processes, called voice learning (imitating complex sounds when we learn a language) and hypothesizes the existence of a neural specialization and the possibility that some of the mechanisms we use to process rhythm music are also used to process language.

Viewed from the perspective of physical activity, dance represents a viable alternative for the elderly. For these, dance is a familiar concept, which was integrated into everyday life in the past to a much greater extent than it is nowadays.

But dance has a multifaceted nature, involving physical, cognitive, musical, emotional and social aspects, which all have a role in the overall physical and mental well-being.

Dance is classified as a 3D exercise, because it involves a constant movement, in a controlled, fluid, repetitive way, in all 3 spatial planes.

Dancing can be an effective intervention that synergistically combines both cognitive and physical benefits. Dance is composed of complex elements, such as synchronizing movement with music, memorizing sequences step by step, social interaction, having a beneficial effect on knowledge. In the last decade, dance is gaining popularity as a therapeutic activity to improve the cognitive capacity of the elderly, for example, dance therapy for Parkinson's and dementia. Dementia, including Alzheimer's disease, as we already mentioned, is a progressively degenerative disorder that affects several areas of cognitive ability. In the early preclinical stage, dementia often manifests itself in the form of a mild cognitive impairment (MCI), with deficits in cognition and memory that are greater than expected for the age of the individual, but that do not yet affect the person's ability to live independently. As symptoms progress into dementia, these deficiencies expand to include executive functions such as planning and organization, which limit an individual's ability to perform the basic tasks of independent living; in its later stages, the symptoms of dementia include additional dysfunctions in mood, personality and affect. As these symptoms worsen, patients require an increased level of assistance in terms of their personal care and safety.

Dance, music, creativity can induce neuroplasticity in the brain, through synaptic and dendritic receptor growth increases and changes in neuronal growth factors.

Clearly, it is essential to identify what activities and behaviors (life habits) can enhance cognitive reserves and promote healthy brain aging. Exercise, meditation and music, can improve neurological health as evidenced by some research, already.

III. PROJECT SENTIR

Smart wearable for assisting Elderlies in fighting loNeliness, improving fiTness and empowerIng cReativity

The premise of our project is that elderly people who spend the day without having someone by their side are inclined to unwanted physical and mental states. The concept of the project is based on an intelligent device to help these people, offering them an alternative through which to cope more easily with loneliness (relieving loneliness) and to contribute to maintaining the state of health through a regular program of appropriate physical exercises (improving fitness), all this motivated by the satisfaction of creating musical pieces based on the movements performed (stimulating creativity).

Specifically, the proposed device consists of a bracelet system, a computing unit and a display (touch screen). The bracelet contains intelligent sensors (accelerometer, gyroscope, etc.) for determining alarm situations (fall or major imbalance), sensors for monitoring physiological parameters (pulse, oxygen, muscle activity) to determine the emotional state. A module of communication with a unit of calculation. It receives physiological and audio parameters from the bracelet and based on them detects the emotional state of the user. It also contains a video camera that detects facial expressions, but also the movements performed by the person in question. Facial expressions are used to determine the affective state – so the recognition of emotions is done through a multimodal method, the final emotion being determined by the fusion of the results of the 3 methods – facial expressions, voice, physiological parameters. The device will be connected to the touch screen so that the person also has visual feedback. It is envisaged to add the option to connect to a TV or a monitor that the person already owns.

From a functional point of view, the device primarily fulfills a role of correcting the negative state and maintaining the positive state. but it also has a second purpose, equally important, namely the announcement of the owners in case of detecting an unpleasant event (a fall, a hit, ec.). The bracelet notifies the user when he has to take his medicines, reminds him of certain activities that he has to do (if these are defined), sends an alarm message to the basic device in case of detection of an emergency situation (e.g. the user has fallen) and takes the initiative (thus having a pro-active behavior) to suggest to the person concerned to do the necessary physical exercises daily in front of the device. Of course, the user can take this initiative himself, performing physical movement whenever he wants, and the device will memorize the working session. When the person starts his exercises, the device detects the movements and creates a specific soundtrack. Music is generated using specific algorithms for the user's current state of mind, starting from parameters that define his movements (speed, amplitude, trajectory).

There are three cases of operation of the device, which are independent of each other. Fig. 1 presents the main function of the device, that of maintaining the well-being of the user, both physical and mental. Thus, using the sensors incorporated into the bracelet, a first detection of the emotional state is made from physiological parameters and voice. A negative affective state suggests that the bracelet may recommend the user to do some exercise. However, this decision is not made before checking other parameters. The first parameter is given by the history of physical activities: when the person last exercised and how many times on the current day – physical exercises are good, but with measure, without exaggeration. The second parameter depends on the user's preferences, predefined in the system. For example, the person may have another activity set within the given time interval. But if all three parameters (emotional state, history of physical activity, user preferences) suggest the need for physical exercise, then the bracelet will make this recommendation to the user. He may or may not choose to take into account the recommendation. If it is decided that it wants to do exercises, it will have to move in front of the basic device, and the music generation module will start automatically, once the physical exercises begin by the user.

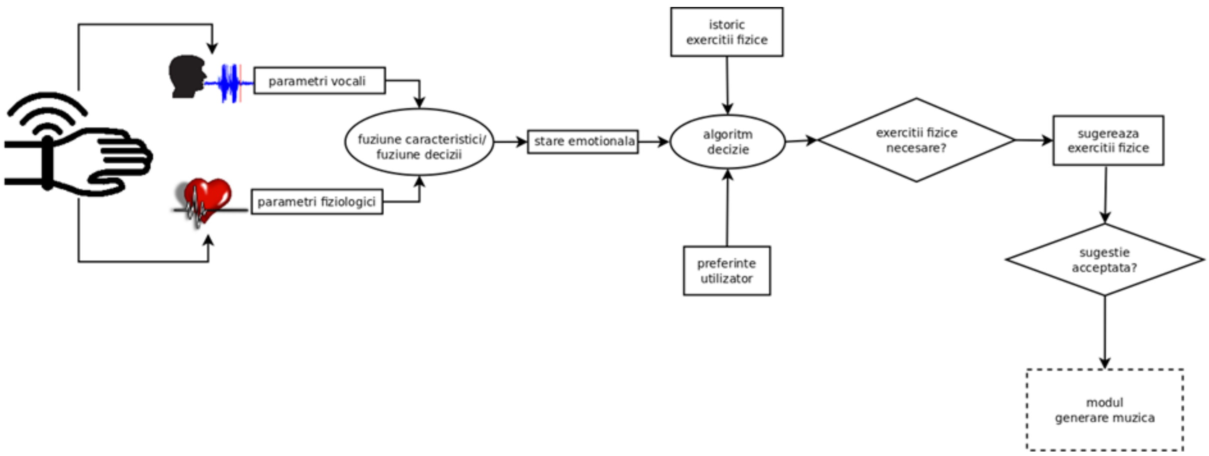

Fig. 1. Case 1 of operation – maintaining well-being through movement and music

The case presented in Fig. 1 is the main function of the SENTIR device: that of bringing well-being/entertainment/amusement into the lives of elderly people without activity or with minimal activity. The device thus has a pro-active behavior, making sure the decision whether or not it is the case to recommend to the user the physical exercises at the given time. The module that is triggered automatically at the beginning of the fixture exercises is that of "music generation" because, as seen in Fig. 4 and will be detailed below, based on the movements and affective state of the user, a musical passage is synthesized.Even if well-being is the main function, a device dedicated to the elderly must be useful and two other situations that we have considered necessary: the one in which the person is in an emergency situation and the one in which he needs to be reminded of something.

Fig. 2 presents the second case of operation, the detection of the fall. Using the accelerometer and gyroscope, it is detected if the person has had an accident and in this case the contact person is notified (predefined through the graphical interface of the basic device). Optionally, the bracelet first warns the user that it will send the alarm message and waits a few seconds, during which the user, if nothing serious has happened, can cancel the sending of the message. It is thus taken into account the preservation of the independence of the elderly person, who has the right to live life with dignity, without considering it to be a burden for those who take care of it and without inducing the feeling of powerlessness and uselessness.

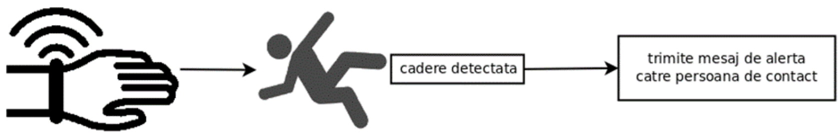

Fig. 2. Case 2 of operation – alerting the contact person in case of emergency

Fig. 3 presents the third case of operation, the one in which the bracelet reminds the user of a certain action that he has to do, predefininta through the graphical interface of the basic device. For example, at a set time the person must take certain medications, in certain quantities. The system starts from the assumption that the user fails to take his medication due to the fact that he does not remember. It is not taken into account the case in which he deliberately refuses to take the medicines, because it is considered that it is not the duty of the device to force the person to one activity or another.

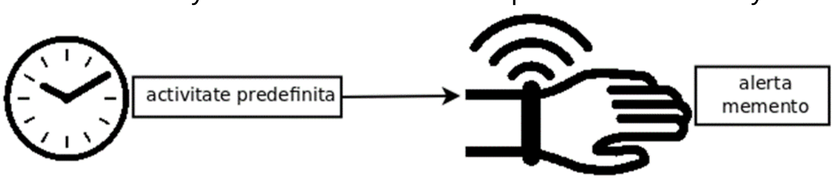

Fig. 3. Case 3 Operation

Returning to the main function of the device, that of improving and boosting the performance of physical exercises by generating music, Fig. 4 presents the module for synthesizing musical pieces. The generation algorithms take into account the user's affective state, but also the movements he makes. The affective state is determined both from voice and physiological parameters (as in case 1 of functioning), as well as from facial expressions. It requires a fusion of results. For this, both the merger of decisions and the fusion of characteristics will be tested. The resulting emotion, along with the detected characteristics of the movements performed by the user, will be the basis of the music synthesizing algorithms.

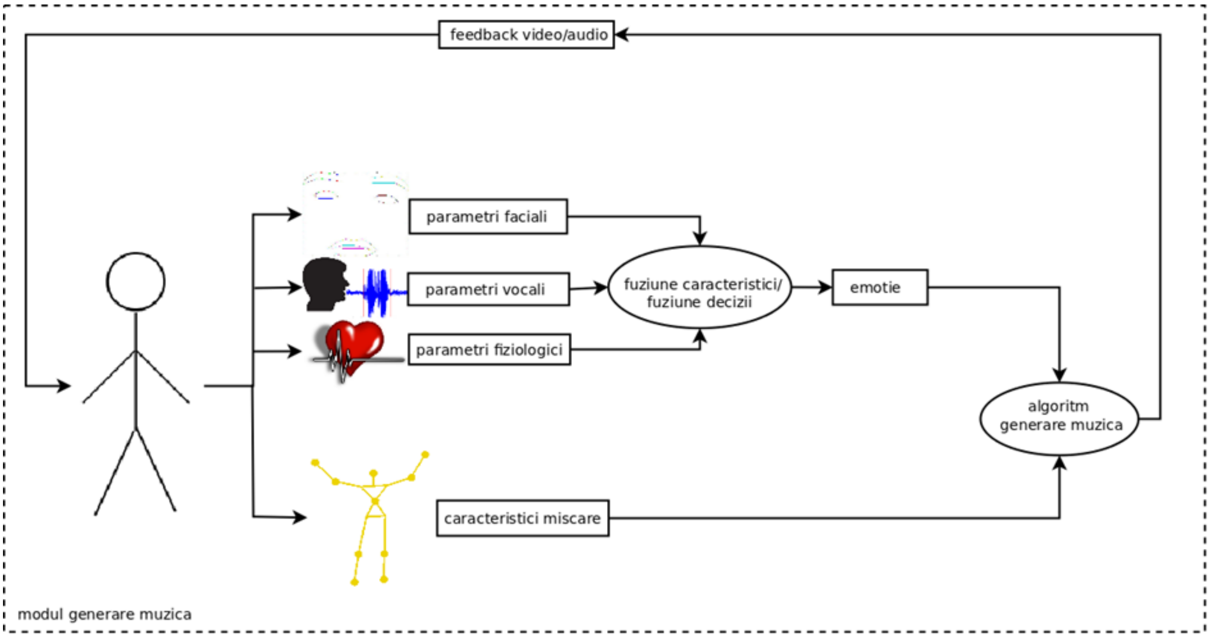

Fig. 4. Music generation module

Fig. 5 incorporates all 3 functions in the architecture of the developed intelligent system.The music generation module was written in Max MSP, which is a high-level graphical programming language, providing an interactive programming environment with extensive libraries of pre-component algorithms. The code is automatically generated from graphic configurations. It is specifically intended for real-time computer music applications. Max also allows the creation of independent applications, as well as expansion by including so-called external objects written in C and Java.

The Max MSP SENTIR application contains several "Manager" modules, such as the UDP module or the rhythm module. These, in turn, are made up of sub-modules that contain various objects or data processing functions as well as predefined lists of values (for example, values of MIDI instruments in the form of "Program Change").

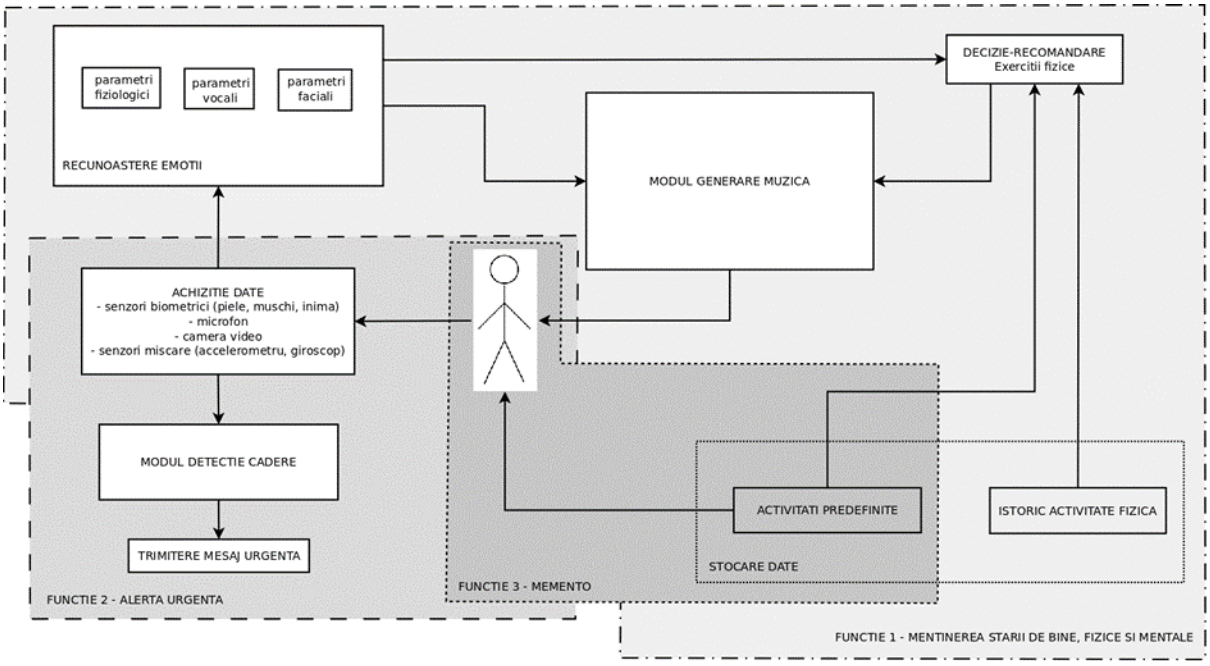

Fig. 5. Device architecture

Innovation consists in the immediate feedback that older people receive in audio form, being thus an element of motivation to perform the physical exercises necessary to maintain health, transforming or augmenting the pleasure of exercising with the pleasure of creating. Because music is generated based on physiological parameters, it helps users to improve their psychomatory performances, learning to control and relax their muscles. This concept is called biofeedback and is used to relieve certain pains or anxiety.

Loneliness, sadness, the feeling of helplessness towards uselessness are not treated by any doctor at the individual level, and the pills are undesirable. In the best case, the person is advised to exercise and have an active life, but without effective monitoring that measures the degree of compliance with this advice. The proposed project supports the fact that well-being can be practiced through movement (which can turn into dance) and through the satisfaction of creating something new, pleasant. It is envisaged to expose the musical creations created by each individual on an online platform, in case they turn out to be pleasant to be listened to by other people.

IV. Conclusions

The concept of the SENTIR project uses the therapeutic strategies through dance, music and creativity, in order to achieve the proposed goals, namely the stimulation of the user's movement, with positive consequences in terms of improving the effects of loneliness. Specifically, the developed application contains three different modules that interact to create a system that provides a unique musical response for the user and his state of mind.

The video information processing module takes the images coming from the camera and calculates a set of motion parameters through which the dance and/or gestures of the subject in front of the camera are described as faithfully as possible. The process is complex, involving the detection of the silhouette, the extraction of the skeleton from the current frame, its adaptation to the previous frames, and only then the calculation of the parameters. Skeleton extraction is the most resource-consuming stage, because iteratively searches for those coordinates in the image for which the historama is as close as possible to the histogram of the desired joint. A set of trusts is calculated for each of the 14 joints that define the skeleton, and the modification of the coordinates of one aritculation influences the trust for the other joints. However, the results are acceptable hiar and in less promising environmental conditions.

The automatic detection module of the user's affective state contains two sub-modules: one that does the recognition using physiological parameters, another that makes the recognition using motion parameters. Physiological parameters are purchased from the SENTIR-BS wearable device and refer to the activity of the heart, skin conductance and skin temperature. The three types of signals make up a time series that must be analyzed both statistically and in the frequency field, in order to make a more accurate characterization of these signals, so that the existing differences for different affective states can be extracted. Similarly, the sub-module for detecting emotions in motion parameters works, but the calculated features refer to distances, velocities and accelerations of the body joints.

The music generation module takes the data from the first 2 modules and composes a song that changes dynamically depending on the user's movements. The mapping is not direct, but the acceleration or slowing of the movement, the amplitude, the shape of the body, the effort made, all bring their contribution to the created sound effects. All musical parameters are further processed to maintain the cohesion of musical notes, the sounds being in the same range, without sudden changes of rhythm or accompaniment.

The interaction of the three modules takes place in real time, so that the response of the system is perceived simultaneously with the input provided, so the user hears the music generated with the movements made, the response received thus stimulating him to try new and new variants.

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