Autonomous and Remote Controlled Humanoid Robot for Fitness Training

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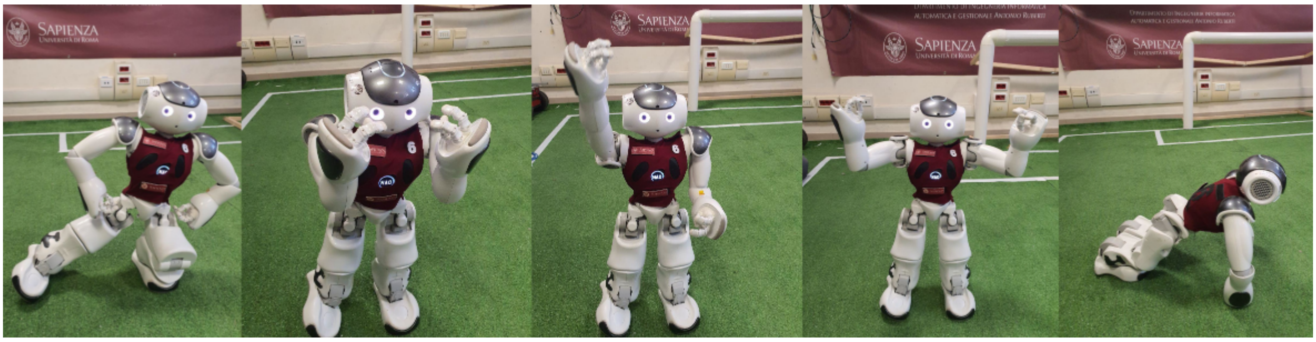

Figure 1: Some of the poses of the NAO robot during exercises.

ABSTRACT

The world population currently counts more of 617 million people over 65 years old. COVID-19 has exposed this population group to new restrictions, leading to new difficulties in care and assistance by family members. New technologies can reduce the degree of isolation of these people, helping them in the execution of healthy activities such as performing periodic sports routines. NAO robots find in this a possible application; being able to alternate voice commands and execution of movements, they can guide elderly people in performing gymnastic exercises. Additional encouragement could come through demonstrations of the exercises and verbal interactions using the voice of loved ones (for example, grandchildren). These are transmitted in real time to the NAO which streams the video of older people exercising, bringing the two parties involved closer together. This proposal, realized with the robot NAO V6, allows to have a help at home ready to motivate, teach the exercises and train the elderly living alone at home.

CCS CONCEPTS

• **Robotics**; • **Social robot**; • **Healthcare**; • **Personal Trainer**;

KEYWORDS

Robotics, Artificial Intelligence, Sport, Personal Trainer

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1 INTRODUCTION

One of the most noticeable changes in the world's social fabric is the increase in the elderly population. According to the most recent statistics, by 2050, it has been estimated that the percentage of people over 65, today at 8.5%, should be around 17% [10]. This growth leads to the responsibility of investigating this phenomenon more closely, and increase knowledge about promoting the health of the elderly using the various resources that research provides us, including artificial intelligence. The role played by different factors for the well-being of the individual has been investigated in the population group in question, whose vulnerability factors will concern both the physical and psychological dimensions: physical activity [18] and the social support network [3] are among them. More specifically, the research has highlighted the inversely proportional relationship between physical activity, disability, and mortality in this population group [13, 14], which nevertheless continues to represent the least physically active. At the same time, it was seen that, to increase adherence to a training program, a supportive coach was particularly indicated [16, 22]. This variable is, in fact, positively correlated with an increase in the participants' motivation, but also with the quality and satisfaction associated with the performance, that are underlying and characteristic elements of intrinsic motivational processes [8]. More specifically, if intrinsic motivation is what makes it possible to perform any activity for the simple pleasure of practicing it, extrinsic motivation is dependent on the rewarding return that a promise of rewards would bring [5]. Both are determinants in the sports experience and represent not only subjective psychological processes, but also dimensions influenced by external inputs as, in the present case, the one concerning the coach-athlete relationship. It is not only the trainer's presence that will determine a greater involvement of the athlete, but the personalized attention and communicative style adopted by the trainer. It has been demonstrated that a supportive attitude and incentive to autonomy on the part of the coach, positively correlates with the motivational processes described above [4], and with a greater probability of continuation of the sports practice in the long term [2]. There are also benefits associated with involvement in activities in which social interaction is expected [21], loneliness represents a further negative prognostic factor for chronic organic diseases, and it is one of the most represented risk factors in old age [3, 23, 24]. In the view of the above studies, robotic systems would also represent a further tool to support the goal of promoting well-being; having also confirmed the importance of interaction and the relational component in stimulating the motivational dimension of the person, the remote control could make an important contribution in this sense.

2 RELATED WORK

During the recent past, the advance in the robotics field led to a considerable improvement in the interest in robot use during human sports training. Several works have shown different approaches to exploit a robot as an assistant for people with special needs, such as elders or people who need rehabilitation procedures. In [12], authors present ADLER, a robotic system meant to help people regain functional tasks during rehabilitation after a stroke. The system is based on sensors' use to track the patient movements to send them into a wireless connected display. ADLER's main focus was on people with a need for rehabilitation after handicap diseases such as hemiparesis. Much work has also been done in socially assistive robots, particularly for older people. In [17] is presented a robotic system for tracking human movements and give feedback for every exercise executed by the user. In this work, the robot captures the postures of the human, then compares them with a database of possible activities and, after finding the most similar motion, gives feedback about the execution's correctness. In [19] an approach similar to the previous one is introduced, but firmly centered on the use of mobile robots capable of following the human movements during the training. In [20] an assistant robot for performing exercises is also proposed, but in this case, the presence of bio-feedback sensors for the human that executes the exercises is included. The agent takes the sensors' feedback, and using these data adapts the exercise routine to the most suitable for the given person. Also in [15] a robot that can access a complete exercise database is presented, select exercises to perform for elderly people, and then track, with the use of a depth camera, the performance in the exercise execution, then gives feedback to the user. All the approaches discussed so far are based on the use of wheeled mobile robots that could not actually execute the movement. An alternative and interesting variation is the use of humanoid robots to perform the motion required by the exercises and illustrate them to the user. In [9] an approach for learning the execution of exercises imitating the gestures of a human trainer is proposed. The gesture acquisition is performed using a depth camera (RGB-D) with the use of the OpenNI software. After the acquisition of the motion, the system translates it to the robot configuration; then, if the action is feasible, it adds the movement to an exercise database, otherwise, it corrects it to make it doable on the robot configuration and then adds it to the database. Similar to this work, there is the one discussed in [7]. In this paper, the authors describe a system based on a wheeled humanoid robot controlled with the use of a controller by the human. This robot can execute arm movements and illustrate them, then track the action execution of the user and give feedback based on the quality of the performance. The approach proposed in this paper is strongly related to [7] and [9], but in this case we propose a method that is entirely self-contained into the robot, allowing for the execution and the tracking of movements using only the NAO robot camera. The use of the NAO robot also allows for the implementation of leg movements and guarantees better mobility for the robot itself. All the work discussed so far are related to fully autonomous robots without human intervention. Our work is slightly related to creating a hybrid agent that can both be used in autonomous mode, and a remote controlled mode. The first one uses recognition of movements and acquisition of bio-feedback inputs for creating and evolving the training session. The second one involves a trainer (for instance a relative like a nephew) that can administrate the exercise routine leading the elder using the NAO robot and receiving suggestions from the system about the recommended exercises. The presence of a relative that controls the robot in remote can be a plus for the training's execution during the time. It may also be useful for connecting people in a shared activity even in the presence of limitations for the physical presence as the ones experienced during the recent COVID-19 lockdown, or for people with mobility issues.

3 PROPOSED METHODS

The NAO Robot is a humanoid robot that performs complex motions thanks to its 25 degrees of freedom. For this task, the robot version chosen is the NAO V6[1]. In this version, it embeds a quadcore CPU manufactured by Intel. The computation capabilities combined with the set of sensors already on board of this robot allow it to be suitable for several tasks and, hence, become a trainer Fig.1. The onboard sensors include two cameras, four microphones, IMU, touch

[1]www.softbankrobotics.com/emea/en/nao

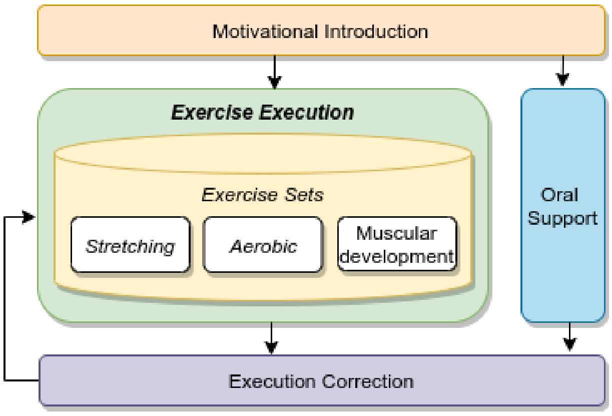

Figure 2: Schema of the autonomous training routine. This procedures has been designed for a scenario where the robot has to play the trainer role. The execution is fully monitored and supported. At the end of the execution, the robot chooses to go ahead or to repeat the current execution.

and force sensors, and sonars. The manufacturer's SDK allows to take control of the hardware and to design behaviors easily. The interaction with the user can happen using the robot microphones and speakers. The training routine proposed in the current work has been carried out combining all these tools. There are two training modalities: (1) the NAO is used as a personal trainer, and it autonomously supervises the exercises of the person in front of it, (2) the NAO is remotely teleoperated, it receives commands about the exercise to perform and sends back the video and the audio taken from the environment.

A video example of the two modes implemented on the NAO V6 robot can be seen at: **https://youtu.be/7lQZd3w-zl4**

3.1 Autonomous Mode

In the first mode, the routine is mainly composed of a motivational introduction and a set of exercises shown by the robot, as shown in Fig. 2. When the human executes the exercise, the robot supervises and corrects the inaccurate repetitions. An oral motivation from the robot is given during the repetitions of the exercises. Exercise supervision is implemented using only the robot cameras. The movement is tracked using the NAO robot's built-in face tracking algorithms and custom integration of the TensorFlow mobile posenet. Three sets of exercises have been prepared: Stretching, Aerobic and Muscular development. The set choice relies on the exercises suitable for the trained person based on its characteristics. The robot can supervise the exercises' execution by using its camera and a custom system to detect human postures. The human posture detection is fundamental to help and cheer up the person who is performing the exercises. Hence, the robot perceives the state of the current routine's execution, can count the repetitions of a specific activity and can set breaks or cheer up the trainee when needed. Furthermore, this can be extended by connecting the robot to wearable biometric sensors that allow monitoring the trainee health status during the routine execution. In this modality, the robot has to engage the training session autonomously without the remote human teleoperation. To this end, we developed a routine capable of ensuring the correct interaction with the human. This fixed routine is composed of the explanation of the exercise and the robot execution. Then, human performance is monitored by using the cameras, and it is evaluated. If the execution is too fast or incomplete, the robot can assign a new series of exercises and motivate the human by using positive feedback.

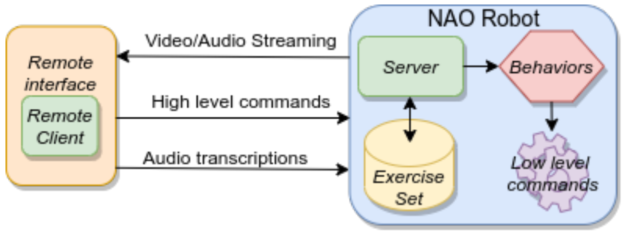

Figure 3: System architecture in the remote avatar modality. The robot receives audio transcriptions and high level commands from the remote client and sends back a continuous video streaming taken from the NAO's cameras and microphones.

3.2 Remote Avatar Mode

In the second mode, the robot is used as a remote avatar by a human trainer or a trained person's relative. In this case, a graphical interface has been prepared for having real-time streaming caught from the robot cameras and microphone and a set of tools to control the robot. In fact, the remote control interface allows the robot to: walk in a specific direction moving it to have a better camera placement, choose the exercises to perform, and speak with the person in front of the NAO by using the NAO speakers. Technically, this is managed by having an active server on the robot that receives commands through the network. The remote client sends the commands that, in the robot, are mapped to pre-programmed routines. In Fig. 3 the architecture of this approach is shown.

In fig. 4, we can see an example of the Graphical User Interface that the remote operator uses for controlling the robot. It is worth noticing that the NAO robot can perform the aforementioned operations without the extra hardware and using only the onboard sensors and the embedded CPUs.

4 CONCLUSION AND DISCUSSION

In the presented work, the NAO robot V6 has been used as a trainer for people who cannot reach gyms. We proposed two modalities, both implemented by using only the hardware available on the NAO robot V6. The two modes have been developed to also involve a human trainer in the process or not. All the perception and the computations have been carried out by using the NAO on-board hardware. All the developed routines have been designed to provide a supportive attitude to have a better engagement and, hence, a higher probability to give continuity of the sports practice in the long term. The NAO robot is provided with stretching exercises [1] for warming up the trained person. Also, it can execute aerobic activities [6], such as running and steps. Finally, the robot can also perform and illustrate muscular development activities [11]

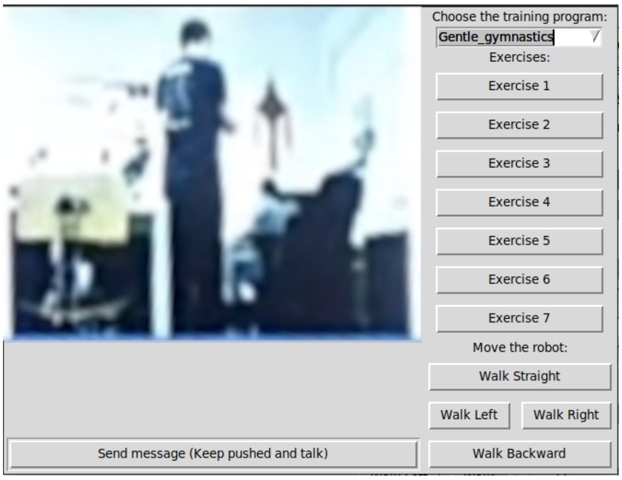

Figure 4: Using a Graphical User Interface an operator can control the robot in the remote avatar mode. The external operator can see what the robot sees using the camera streaming, then he can choose one of several option between: speaking with the trained person, adjust the robot position using walking commands, or execute one of the desired exercises.

as squats or push-ups. In Fig.5 several movements executed by the robot are shown.

We set up the environment to future improvements. One possible addition is the interface with personal biometric sensors that the person on training can wear. This feature can lead the robot, or the remote trainer, to a better awareness of the training status and lead to more customized training sessions, that can improve the training experience and effectiveness.

At the time of writing of this article, the experimentation on a sample of the reference population is being planned.

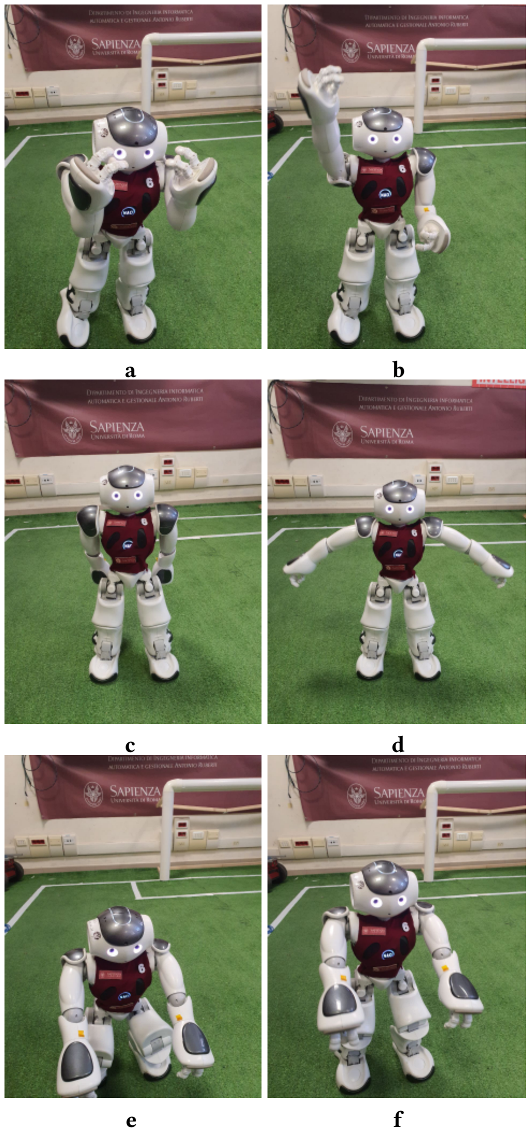

Figure 5: The NAO robot can perform a large variety of exercise activities such as: aerobic (a,b), stretching (c,d), and muscular development (e,f)

REFERENCES

[1] Michael R Bracko. 2002. Can stretching prior to exercise and sports improve performance and prevent injury? *ACSM's Health & Fitness Journal* 6, 5 (2002), 17–22.

[2] LB Brawley and RJ Vallerand. 1985. Effects of informational and controlling fitness leaders on participants' interest and intention to pursue engagement in a fitness program. *Unpublished manuscript, University of Waterloo, Waterloo, Canada* (1985).

[3] Emilie Courtin and Martin Knapp. 2017. Social isolation, loneliness and health in old age: a scoping review. *Health & social care in the community* 25, 3 (2017), 799–812.

[4] Edward L Deci, Haleh Eghrari, Brian C Patrick, and Dean R Leone. 1994. Facilitating internalization: The self-determination theory perspective. *Journal of personality* 62, 1 (1994), 119–142.

[5] Edward L Deci, Richard M Ryan, et al. 1985. The general causality orientations scale: Self-determination in personality. *Journal of research in personality* 19, 2 (1985), 109–134.

[6] F Dimeo, M Bauer, I Varahram, G Proest, and U Halter. 2001. Benefits from aerobic exercise in patients with major depression: a pilot study. *British journal of sports medicine* 35, 2 (2001), 114–117.

[7] Juan Fasola and Maja J Matarić. 2013. A socially assistive robot exercise coach for the elderly. *Journal of Human-Robot Interaction* 2, 2 (2013), 3–32.

[8] Katrien Fransen, Filip Boen, Maarten Vansteenkiste, Niels Mertens, and Gert Vande Broek. 2018. The power of competence support: The impact of coaches and athlete leaders on intrinsic motivation and performance. *Scandinavian Journal of Medicine & Science in Sports* 28, 2 (2018), 725–745.

[9] Binnur Görer, Albert Ali Salah, and H Levent Akın. 2013. A robotic fitness coach for the elderly. In *International Joint Conference on Ambient Intelligence*. Springer, 124–139.

[10] Wan He, Daniel Goodkind, Paul R Kowal, et al. 2016. An aging world: 2015. (2016).

[11] Mary Josephine Hessert, Marilyn R Gugliucci, and Heath R Pierce. 2005. Functional fitness: maintaining or improving function for elders with chronic diseases. *FAMILY MEDICINE-KANSAS CITY-* 37, 7 (2005), 472.

[12] MJ Johnson, KJ Wisneski, J Anderson, D Nathan, and RO Smith. 2006. Development of ADLER: The activities of daily living exercise robot. In *The First IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics, 2006. BioRob 2006.* IEEE, 881–886.

[13] I-Min Lee and Ralph S Paffenbarger Jr. 1999. Do physical activity and physical fitness avert premature mortality? *Healthy Aging: Challenges and Solutions* (1999), 63.

[14] Suzanne G Leveille, Jack M Guralnik, Luigi Ferrucci, and Jean A Langlois. 1999. Aging successfully until death in old age: opportunities for increasing active life expectancy. *American Journal of Epidemiology* 149, 7 (1999), 654–664.

[15] Ahmad Lotfi, Caroline Langensiepen, and Salisu Wada Yahaya. 2018. Socially assistive robotics: Robot exercise trainer for older adults. *Technologies* 6, 1 (2018), 32.

[16] Geneviève A Mageau and Robert J Vallerand. 2003. The coach–athlete relationship: A motivational model. *Journal of sports science* 21, 11 (2003), 883–904.

[17] Dominic Mallinson. 2019. Robot as Personal Trainer. US Patent App. 15/705,167.

[18] Jamie S McPhee, David P French, Dean Jackson, James Nazroo, Neil Pendleton, and Hans Degens. 2016. Physical activity in older age: perspectives for healthy ageing and frailty. *Biogerontology* 17, 3 (2016), 567–580.

[19] Hong-Seok Na, Youn-Sik Choi, and Tae-Soo Park. 2009. Mobile robot for personal exercise training in ubiquitous healthcare environment. In *Proceedings of the 2nd International Conference on Interaction Sciences: Information Technology, Culture and Human*. 742–744.

[20] Jaime Andres Rincon, A Costa, Paulo Novais, Vicente Julian, and Carlos Carrascosa. 2019. Towards a Robotic Personal Trainer for the Elderly. In *International Conference on Intelligent Data Engineering and Automated Learning*. Springer, 238–246.

[21] Angel Rodriguez-Laso, Maria Victoria Zunzunegui, and Angel Otero. 2007. The effect of social relationships on survival in elderly residents of a Southern European community: a cohort study. *BMC geriatrics* 7, 1 (2007), 19.

[22] Joanne M Sommers, Fredrick F Andres, and James H Price. 1995. Perceptions of exercise of mall walkers utilizing the health belief model. *Journal of Health Education* 26, 3 (1995), 158–166.

[23] Andrew Steptoe, Natalie Owen, Sabine R Kunz-Ebrecht, and Lena Brydon. 2004. Loneliness and neuroendocrine, cardiovascular, and inflammatory stress responses in middle-aged men and women. *Psychoneuroendocrinology* 29, 5 (2004), 593–611.

[24] Andrew Steptoe, Aparna Shankar, Panayotes Demakakos, and Jane Wardle. 2013. Social isolation, loneliness, and all-cause mortality in older men and women. *Proceedings of the National Academy of Sciences* 110, 15 (2013), 5797–5801.