

A Computer-Based Support System for Cooperative Tasks in Nursing Homes

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ARTICLE INFO

Article History

Received 12 Nov 2018

Accepted 13 May 2019

Keywords

Computer-based support tool
Group formation
IT Applications in Health Care
Coalition structure
Cooperative groups

ABSTRACT

Different studies have shown the benefits of a cooperative activities programme for the elderly. Members of a group with similar abilities or disabilities are often encouraged by having the opportunity to share their experiences, knowledge, or opinions. Nevertheless, when caregivers try to plan specific cooperative activities, different aspects, as the individual needs of each person, should be taken into account, which notably increases the complexity of that planification. This paper proposes a computer-based support tool for recreational therapists which facilitates the management task of grouping elderly people into cooperative groups for existing activities. To do this, an iterative learning process is proposed allowing the formation of proper distributions of elderly people into activities.

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1. INTRODUCTION

Group work is a widely used modality of work among older people to achieve different objectives such as (i) socialization therapy, education, and recreation, (ii) service and advocacy, (iii) support, (iv) therapy, and (v) family care and care-giver assistance. This type of work greatly improves the social interaction and adaptation of the elderly. Cooperative activities play a significant role in nursing homes as they help elderly home residents to adapt to a new way of life. These activities are essential to progressively achieve therapeutic, educational, or social goals in settings such as hospitals, elder-care centers, nursing homes, and social organizations.

One of the results obtained through participation in cooperative activities is the achievement of a sense of accomplishment and the opportunity that elderly home residents have to develop their skills, which provides them with an improvement in self-esteem and satisfaction [1]. Nursing homes and more specifically caregivers that work in these institutions have to carry out an activity planning where the characteristics of the potential participants (i.e., the residents) should be considered. These characteristics are the physical abilities, social relations, antecedents, and interests of the residents. In general, in most scenarios, the social interaction that is generated in cooperative activities is more important than the activity itself [1].

Nevertheless, only a few works have tried to analyze which is the best way to organize older people into activity groups. Typically, groups are randomly formed or organized by the caregivers that use their common sense. Members of a group with similar abilities are often encouraged to share their life experience, knowledge, and general views and opinions with their peers and carers.

The recreational therapist has a great challenge in planning activities for residents. This challenge consists on distributing residents in the different activities in the most appropriate way (i.e., physical and cognitive capacities of the residents correspond to those required in the activities) [2–4]. In order to reach the expected goals through cooperative activities, recreational therapists also have to work together with the residence nursing staff. Nursing staff helps the recreational therapist to select the activity that will be most beneficial to the needs of each individual resident.

1.1. Questionnaire

This work was validated by workers of daycare centers in the northern area of Portugal, like the *Centro Social Irmandade de S. Torcato*. The validation was performed through a questionnaire that was done to the caregivers (registered nurses and medical personnel), identifying their needs and expected results of helping tools. Two questionnaires were responded by 12 persons, one before the tool was presented to them, being used as a requirements analysis; and the other questionnaire was post-operation of the tool, providing a

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validation of the operation. The questionnaire was designed simple and using most of the time Likert scales to represent the responses of the questioned people. This reduces the spreading of the possible responses and linearizes the attained values.

In Table 1, we confirm that most of the daycare centers contacted have some kind of computer software that tracks the residents information. The type of information that it is available is unknown, but at the least there is a basic knowledge about who are the clients of the daycare center. Table 1 also shows that all the questionnaire participants know how to operate a computer, thus a technological barrier does not exist.

In Figure 1, the opinions are distributed between a social service technician and a social assistant, while the rest of opinions were attributed to the family or others, meaning that the workers feel that the family should have a say in the planning of the activities. In this specific environment, the social service technician has a rank above the social assistant and has more expertise about the activities and their impact to the users. Therefore, it is implied that most of the questionnaire participants believe that the task of scheduling activities should be performed by a highly qualified person. Four people have chosen not to participate on this question.

In the response of Figure 2 the respondents have reduced the importance of activities planning, putting this task as only moderately important.

Figure 3 presents the amount of collaboration the residents do on the activity planning. This means that the person that is in charge of the planning knows that the opinion of the people that perform the activities matter, and having them choosing the next activity results

Table 1 Usage of computer systems.

	Yes (%)	No (%)
Is there an information system where residents' data and activities are stored?	91.7	8.3
Do you feel comfortable working with computers?	100	0

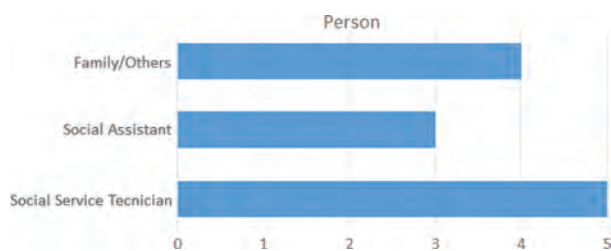


Figure 1 In your opinion, what is the professional profile that the person responsible for carrying out planning activities should have?

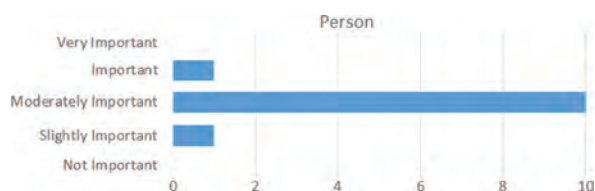


Figure 2 How would you classify the statement: "Is activity planning a big problem at residencies?"

on the increase of happiness level. Therefore, the personality and likes of the residents play an important part in activities planning.

Although the questionnaire respondents have affirmed that the planning of activities do not have a critical importance, they vehemently affirm that they would like a tool that helps them in activities planning, showed in Figure 4.

In Table 2 the respondents have showed a clear tendency to spend large amounts of time (over 1 hour) dedicated to planning activities, thus it is clear that it is a relevant task on the daycare operation.

In this questionnaire the personal opinion of the caregivers was also measured. This measures provides a better insight to the planning task and how the caregiver feels about it. Furthermore, the personal experience is gathered, being vital to understand what are the relevant resident's features to take into account in the tool.

In Table 3 the respondents divide their opinion in three topics, being one common critical issue is the economic means available. It is clear that without funding the daycare centers are limited to tasks that they have the means to organize, thus there is a high level of activities repetition.

In Figure 5 it is clear that the activities are limited by the budget but to perform activities there is not the need to have a large budget. Like stated before, the lack of resources limit the variety of the activities. This factor may lead the residents to moments of boredom and in compliance.

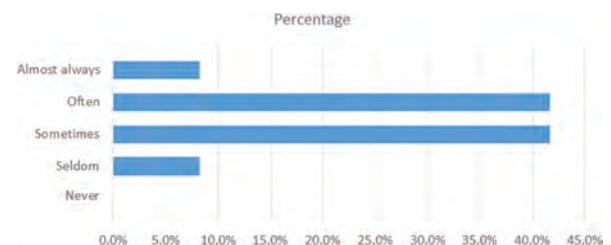


Figure 3 How much do residents collaborate in the selection of activities?

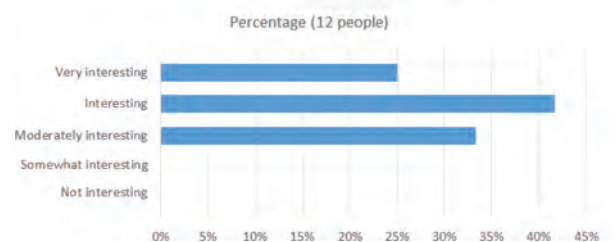


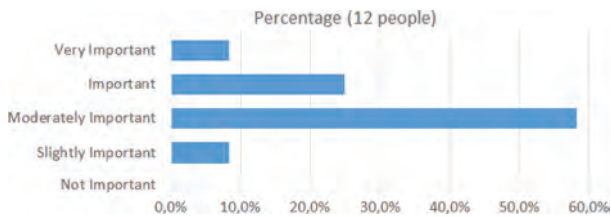
Figure 4 Do you find it interesting to have a tool to help you plan activities?

Table 2 How much time takes to plan a group activity, accounting the residents' interests and limitations?

<1 hour	25%
1 to 4 hours	60%
4 to 8 hours	0%
>8 hours	15%

Table 3 | What factors not related to residents are taken into account when planning activities?

Staff, time, and means	71.6%
Economic availability and activities that go against the preference of all participants	14.2%
Economic availability, accessibility, availability, and swimming activities	14.2%

**Figure 5** | Do you think monetary restraints strongly influence planning activities?

In Table 4, the respondents do not believe that a heterogeneous group of people is important for an activity, nor they affirm that similar people should be bundled together. Additionally, they affirm that the residents should be inquired about how they felt about the performed activity, being the caregivers able to make an informed decision about what activities they would like to perform next.

This questionnaire validates our initial idea about the necessity to improve the organization of older people into activity groups, and the responses highlight features that should be used on the algorithms. The social and work experience of the questionnaires are invaluable, and with this knowledge we are able to build a decision support system that helps the caregivers to plan activities and make groups of people that are happy to perform them.

This paper builds on a computational teamwork theory to identify opportunities for technology to support the creation and coordination of groups for activities that enable and enhance existing approaches. Specifically, the paper proposes a tool for recreational therapists and caregivers which facilitates the management task of grouping elderly people into optimal groups for existing activities. The proposed tool relies on the profile of the elderly people, coalitional structure generation, and an iterative learning process which allows forming proper distributions of elderly people into activities. This tool should be used as a support system, being the results supervised by the recreational therapists and caregivers, thus alleviating the effort and time that they dedicate to activities planning.

The rest of the paper is structured as follows: Section 2 presents different previous works that try to analyze the benefits for older adults with active participation in different types of activities and

the importance to correctly identify groups that can perform specific activities. Section 3 analyses in detail the problem that we try to solve. Section 4 shows the proposed model for group generation. Section 5 presents a case study. Section 6 describes the experiments and the proposal validation, and, finally, in Section 7 some conclusions are exposed.

2. RELATED WORK

As stated above, there are some studies that show the sociological connection between active life promoting activities and elderly people. In [5] a study is presented analyzing how well-being can be enhanced modifying exercise classes and increasing participation. Moreover, in [6] the importance of physical exercise in older people is studied. The authors tried to predict the level of physical activity required to ensure that a person's physical status was in the range between clinically favorable or healthy.

Other studies were centered in a specific type of activities, like leisure activities. Leisure participation has been proven to be beneficial and has a positive link to successful ageing, generating a greater involvement in leisure activities. This involvement was associated with better health in older age [7]. The work presented in [8] showed how the promotion of active participation in diversified leisure activities should also be emphasized in view of the possibility of greater benefits gained from its involvement. Moreover, [9] remarks the importance of developing community-based programs to facilitate physical activities for older people with a chronic diseases.

Undoubtedly, the influence of engagement in mental, physical, social, productive, and recreational activities refrains, and in some cases reduces, the dementia incidence in older people [2]. Energetic activities that involve mental or psychosocial components may act as stimuli to preserve cognition [2].

Another important issue is the use of social activities by caregivers. Informal social activity has accumulated the most evidence of an influence on well-being. In this sense, some studies have analyzed the importance of the group to improve well-being. As an example, the study presented in [3] investigated the capacity for group decision-making to build a sense of shared social identity among elderly care home residents and thereby increase their social engagement, well-being, and cognitive performance. In the same line, in [4] it was tested how nursing home populations engagement was highest among residents with adequate functioning in activities of daily living (ADL) and cognition.

There are several software and tools, like AccuPoint Med and CareVoyant, that are within the elderly care realm but are only

Table 4 | Planning configuration opinion.

	Very Important (%)	Important (%)	Moderately Important (%)	Slightly Important (%)	Not Important (%)
Do you think it is important to mix people with different cognitive or physical problems in their activities?	16.7	16.7	41.7	8.3	16.7
Are the participants' opinions about each activity taken into account when planning the next activities?	41.7	41.7	8.3	8.3	0

designed to manage the institutions and the staff, thus, not to manage the activities or time of the care-receivers. Therefore, they lack the essential features that could enable the provision of the active aging paradigm. There are also other projects directed to the elderly and their caregivers that fall under the Ambient Assisted Living (AAL) domain such as [10–13]. AAL projects produce systems and products that help its' users to become independent and provides aid on ADLs, and at the same time, create a secure and safe environment. The focus is to improve the quality of life and stabilize the health condition.

Moreover, we can find specific software and services which are directed to professional caregivers, but concentrate on private companies. This is the case of Hometeam, Tabula Pro software, and Sagely. These platforms show that there is a large investment in terms of solutions to monitor and care for elderly people, whether they are at home or at residencies. Most of them are almost purely administrative, and easy the bureaucratic process that is keeping the personal health record updated as well as keeping track of the activities and general well-being of the care-receivers. From our point of view, it is clear that these applications require that the caregivers spend a large amount of time interacting with them and do not have any automated decision support system that helps them when planning activities or detect any decay of the care-receivers health condition.

However, there are not very many studies that focus on the key issue of how to create cooperative groups for elderly, which is a task that requires a considerable amount of time to compose well-balanced groups (i.e., how to distribute elderly people into activities in a way that all the people in each activity satisfy the required conditions to do it). More specifically, when there is a large number of older people and different grouping criteria, the task of forming teams to promote successful outputs (i.e., well-being, engagement and involvement in the group) is considered an exponential problem. Moreover, activities in groups or teams can bring positive and negative consequences (i.e., positive: social engagement, well-being and negative: lack of interest, lack of motivation, tense social context), making the task of team formation a complex one. Several factors like personality, health, and human behavior can interfere with the performance of the group during an activity [14]. Therefore, it is of crucial importance to identify groups that can perform correctly an activity.

There are areas such as human resources management and collaborative learning where the problem of generating groups according to a set of predefined criteria (i.e., knowledge and experience, personality, learning/thinking style) has been thoroughly studied. In these areas, computational proposals have been developed in order to automate the process of group formation in cases where it was not manually viable. An example of automation of the process of group formation is presented by Lin *et al.* [15]. The authors present an algorithm that takes into account two criteria for the creation of learning groups: the levels of understanding and the interests of the students. Another proposal that uses a computational model is presented by Cavanaugh *et al.* [16]. The authors consider criteria such as gender, skills, and schedules of students for automatic generation of groups through a web tool. Wi *et al.* [17] present a proposal based on genetic algorithms whose goal is the generation of groups in R&D-oriented institutes. The algorithm proposed uses a fuzzy model to collect information about candidates'

knowledge and experience on certain topics related to a project. Another aspect considered by the algorithm is the social network of the candidates in order to establish their suitability for project management positions.

Taking into account all of these, as far as we know there is no work which tries to help caregivers to analyze how to group older people in order to enhance activity engagement and well-being. Our proposal presents a decision support tool that generates a more accurate distribution of care-receivers over activities. In order to generate the groups of each activity, the tool takes into account care-receivers' physical state, activity preferences, social relationships, and previous activities already performed. After each activity, care-receivers provide feedback about the activity (i.e., their preferences) and the relationships with other members of the group. The activity is also added to their historical activity profile to avoid monotony of activities. As the number of activities performed increases (i.e., there is more information available about care-receivers), the tool is able to learn from this information to improve the distribution of activities that better fits with care-receivers' expectations.

3. PROBLEM DESCRIPTION

Nursing homes, and institutions that care for elderly people, have difficulties in creating an harmonious environment that can provide the required attention that their care-receivers demand. Most of these places try to provide an active and healthy lifestyle by promoting different cooperative activities that stimulate them in terms of the physical and psychological aspects. These activities can be simple tasks such as reading and table games or advanced tasks such as dancing and theater enactment, designed to engage with them and sooth their likes.

The most common issues highlighted by the care-receivers are the lack of interesting and different activities and their general disinterest [3,4]. These issues originate from four elements: the lack of caregivers [18], high number of physically and/or psychologically challenged care-receivers [3,4], lack of events [19], and poor activities management [20].

In terms of personnel, most of the European countries have established rules that define the minimal personnel that certified institutions must have [21], while some just establish a social approach like "having a number of people attributed to each nurse that is not overwhelming". For instance, Portugal establishes the following personnel for resident homes (where residents live permanently) [22]:

- A part-time social assistant (or recreational therapist);
- One registered nurse and an assistant for every 40 care-receivers;
- One nursing assistant for every 8 care-receivers;
- A direct care nurse for every 20 elderly and night surveillance.

Establishments that care for highly vulnerable seniors require the following personnel ratio:

- A full-time social assistant (or recreational therapist);
- A registered nurse for every 20 elderly;

- A nursing assistant for every 5 seniors;
- A direct care nurse for every 15 elderly.

These personnel requirements are the bare minimum possible to maintain a harmonious environment while monitoring the care-receivers. The issue with this environment is that it leaves no space for individual care and the number of activities that can be performed become limited to ones that include a large amount of people and that are easy to be monitored.

The lack of events and appropriate planning means that the institution does not provide plans that are indicated for the care-receivers and/or lack funding to host complex activities that require additional funding, for example, museum visits.

Some of the institutions have a recreational therapist that manages the global and personal tasks that creates activities plans according to the institution limitations (as stated before) and the users likes. Furthermore, the activities are designed to be inclusive, meaning that they can serve a large amount of people, being the issue that a large part of these activities may not be of the interest of the care-receivers, thus being emotionally negative to them. Meanwhile, the role of the recreational therapist is crucial as it coordinates with the registered nurses, nursing assistants, and direct care nurses the immediate needs and the likes of the users, but most of the time the activities are not optimized due to several social and monetary problems.

In recent studies [23,24] two issues were outlined: the medical and the organizational. Both require different levels of decision that may collide, according to the relevance and impact on the care-receivers and on the institution. Focusing on the organizational issue, there are three levels of operation: the strategic level, the tactical level, and the operational level. Each of them has a great impact on the institutions operations, being the operational level transversal to the care-receivers, since it is related to the human resources and care activities scheduling problems, and daily inventory management. They reveal that the number of constraints (relative to the number of human resources and the number of activities) directly affects the complexity of achieving an optimized solution (or if it is even achievable). [5] shows that to maintain an active life, the elderly should perform activities that concentrate in their cognition, physical, and social life. Also, care-receivers have responded positively to the experiences in the tests made in [5], and that they had improved the elderly emotional state even if they do not have actively participated in those activities.

But there is an issue in terms of organizing various activities. The United Nations [25] have established that elderly people (65 years old and over) have medical, physical, and social requirements that are not easy to be met. Therefore, most of the activities that day-care centers do are safe and have a low physical impact. The issue is that the day-care residents frequently report high levels of dissatisfaction about activities repetitiveness [3,4].

Accounting for all requirements of the care-receivers, law, environmental, and monetary is complex and requires researching all the possible combinations that comply with the hard and soft requirements. For instance, if an institution wants to organize a trip to a museum it has to account for the care-receivers that will be able to go (according to their psychological and physical abilities), if there is enough staff to care for them, how can the care-receivers can be

paired (according to their social connection), what activities can be performed, among others requirements. Thus, the underlying difficulty undermines the promotion of these events and their execution. The use of computational systems that may facilitate this process may provide the help that the institutions require to give their care-receivers joyful activities and promote an active life and harmonious environments.

These evidences were found on the research process of the Cognitive Life Assistant (CLA) [26,27]. The CLA is a cognitive assistant platform inserted in an AAL environment. The core aim is to provide assistance in ADLs by providing information about the daily events that the users have to perform, connecting with relatives and friends and promoting the active aging initiative. It also supports embedding external modules, such as users emotion detection [28] and persuasion recommendation [29].

On the development of tools to aid the caregivers (relatives, assistant nurses, registered nurses, or private services companies) keep track of the events, whereabouts, and health state of the care-receivers it was found that there was a severe lack of other solutions to them. The ones that existed were managing tools designed to keep track of personnel and accounting. One outstanding complaint from the caregivers with multiple care-receivers assigned was the lack of groups management. Therefore, group managing and multiple people events became one of the aims of the CLA.

The objective is to create a solution that can be easily integrated with the CLA and that bridges the task of group creation and event choosing with the caregivers, relieving the stress of the caregivers. Moreover, it will increase the range of the CLA aid to the care-receivers by promoting activities that they enjoy and with people that they like. The following section shows the model needed to achieve this.

4. PROPOSED MODEL

In this section, we describe our policy for dividing care-receivers into groups to perform activities each day during a period of time. This policy relies on the profiles of care-receivers (i.e., preferences, health, friendship), the profiles of activities, and the coalition structure generation. First, we describe how dividing care-receivers into optimal group is equivalent to a Coalition Structure Generation Problem.

The Coalition Structure Generation problem refers to partitioning the components of a set into exhaustive and disjoint coalitions so that the global benefits of the system are optimized. In our problem, the components of the set are the care-receivers that take part in cooperative activities proposed by a senior residence center.

Definition 1. Let $E = \{e_1, \dots, e_n\}$ be a set of care-receivers where each individual e_i is described by set of features F_i that describes his/her profile.

Definition 2. Let $A = \{a_1, \dots, a_m\}$ be a set of activities planned for a period of time (i.e., several weeks or months depending on the senior residence center). Each activity is defined by a set of requirements for being carried out.

We define $G_j \in E$ as a subset of E called *group* of individuals that participate in the same activity. Considering a group G_j , its value is given by a characteristic function $\nu(G_j) : 2^E \rightarrow \mathbb{R}$ that assigns a

real-valued payoff to G_j . The value of a group $v(G_j)$ is calculated as a linear combination of p functions ϕ that calculate different types of matching depending on different input parameters (e.g., the features of each individual, the specific activity):

Function: ϕ_i

Input: p_1, \dots, p_l : list of parameters

Output: r : real $[0..1]$

And the value of a group $v(G_j)$ is calculated as follows:

$$v(G_j) = \sum_{\phi_i \in G_j} \alpha_1 \cdot \phi_1 + \alpha_2 \cdot \phi_2 \dots + \alpha_p \cdot \phi_p. \quad (1)$$

where each α_i represents a weight associated to the function ϕ_i in order to give more or less relevance to this function for the calculation of the value of the group. Given all these weights, the following property must be fulfilled: $\sum_{i=1}^p \alpha_i = 1$.

Definition 3. A group structure $S = \{G_1, G_2, \dots, G_k\}$ is a partition of groups such that $\forall i, j (i \neq j), G_j \cap G_i = \emptyset, \bigcup_{G_j \in S} G_j = E$. The value of a group structure is denoted by $v(S)$, where $v(S)$ is an evaluation function for the group structure. In this work, we consider that the value of each group is independent of other groups. Therefore, we can calculate the value of the group structure as $v(S) = \sum_{G_j \in S} v(G_j)$.

The goal of the algorithm that solves our problem is to determine an optimal group structure for the organization of activities $\argmax_{S \in 2^E} v(S)$.

It turns out that partitioning a set of elderly individuals into disjoint groups while optimizing a social welfare function corresponds to the formalization of coalition structure generation problems. In order to solve this problem, we formally define the coalition structure generation problem as a linear programming problem [30] and solve it with the commercial software *ILOG CPLEX 12.5*.

4.1. Workflow

The proposed model for dividing care-receivers into groups to perform activities based on coalition formation strategy is the basis for a software application. The main goal of this application is to facilitate the management task of grouping care-receivers into optimal groups for activities. During the planning of the activities of several months in eldercare centers, a recreational therapist may carry out several activities that require the formation of groups. In this section, we describe the general workflow and the most important features of the proposed tool to generate coalitions for each activity.

As a general outline (Figure 6), the application relies on the profile of the elderly person, coalition structure generation, and an iterative learning process to form proper assignments of elderly people into activities in a period of time. In the following paragraphs, we explain how these elements are put together to provide an adequate web tool for facilitating the planning of several months of activities to elderly (see Figure 7).

The tool has been developed to be integrated in web platforms, where actors (i.e., recreational therapists and care-receivers) can interact with the system. The starting point of the application corresponds with the recreational therapist (or other member of the nursing staff) that will register all the care-receivers and their physical profiles in the system (1). Once all the potential participants have been registered in the system, the recreational therapist creates the available activities during the planned season (i.e., this period could be several weeks or months depending on the availability of resources for the activities). The recreational therapist fills out all the information about the activities (e.g., activity description, duration, physical requirements). Moreover, the recreational therapist should determine the number of activities and the number of people per activity. Note, that these initial tasks could be avoided if the eldercare center already has an Information System that stores information about residents and activities.

Considering all of this information, the group formation mechanism is ready to start the automatic generation of groups for activities of each day of the planned season. If it is the first time

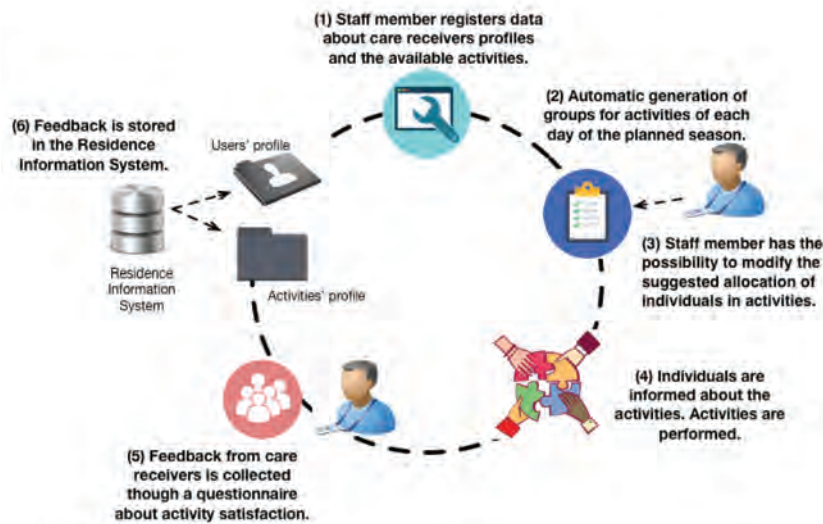


Figure 6 | Workflow of the decision support tool.

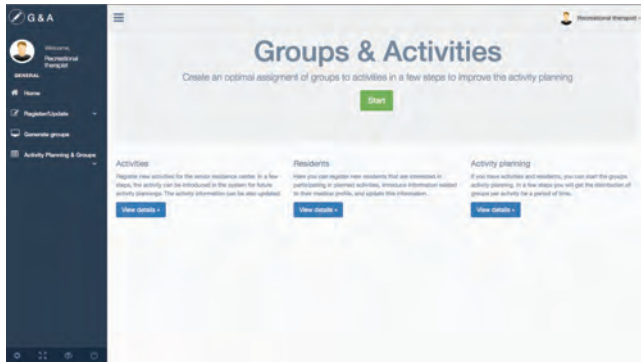


Figure 7 | Main page of the web application for activity group generation.

that the tool takes as input a group of care-receivers, there is no feedback about previous experiences of the individuals (e.g., friendships, preferences about activities, historical activity profile). Therefore, the tool only considers the profile of the care-receivers, the characteristics of the activities, the number of activities, and the number of days of the planned season as input for the algorithm that generates the groups for the activities. Otherwise, the algorithm can also consider information provided by care-receivers as feedback from previous activities. As more activities are performed by the same population, more information will be available about their feedback. Note that the caregiver has the possibility of modifying the weights of each of the features considered to generate a suitable allocation of individuals in activities. This fact allows the model to adapt to different scenarios. Then, the algorithm will provide a suitable allocation of individuals in activities which will improve the overall satisfaction of the groups (2). At this stage, the caregiver has the possibility to modify the suggested allocation of individuals in activities according to his/her professional criteria and experience (3). Once the groups are created to perform an activity, each individual is informed (4).

When an activity finishes, each participant has the possibility to log in the application in order to provide feedback through a questionnaire. This questionnaire collects information about his/her satisfaction related to the activity (e.g., if he/she considers appropriate to update his/her preferences about activities, and if he/she wants to update his/her relationship with the group members that he/she has interacted with during the last activity) (5). All this information is stored in a database (6). If the participant cannot log in the application, the caregiver in charge of the activity can collect this information to fill the questionnaire. Note that this information is optional, the system does not require this information to perform the activity planning, but it provides more information for a more accurate solution.

As new planning of activities is carried out, new information is gathered and accumulated so that this information can be used in future group activity assignments.

5. CASE STUDY

In this section we present a Case Study from a real dataset. The test subjects were created through the use of real data collected by a Portuguese institution called *Fundao Manuel Francisco Clérigo* and presented on their annual report (of 2015). Following, we describe

how the data was instantiated by considering the model described in Section 4.

5.1. Specification

The data obtained was anonymized for the protection of the participants, thus keeping the results unbiased. From the complete information about the several housing and services that the institution has we have focused on the permanent residents. This decision was done based on the direct impact and the capability of complete monitoring of the participants in future tests with real subjects. Furthermore, these subjects are the ones that are more exposed to interactions with the other residents, as the most of the activities require that they participate. The report is constituted by the following information:

- The general distribution and characteristics of the population, like the following:
 - Age and gender and their distribution;
 - Distribution of the diseases (without relation to gender);
 - Distribution of activities preferences;
 - Physical resources and personnel resources;
 - Dependence level of the participants (independent, partially dependent, and fully dependent);
 - Distribution of friendship relationships;
 - Education level and former profession.
- Planned activities according to the dependence level;
- Planned activities by month (one year).
- Executed activities monthly (with data of January to April).

Due to being anonymous, the information was detached from the participants, thus we were unable to correlate the diseases, gender, age, and so on, with the specific participants. To have a dataset of test subjects a procedure of correlation was implemented. This procedure consisted in taking the available data and correlate randomly the data available and generate *personas* (a generic projection of people). In terms of associating diseases with the generated personas it was done by a random process with two constraints: dependence level and gender. For instance, if a specific user is classified as independent no limiting disease (like Alzheimer) is attributed, the same with mastectomy that was attributed to the female gender (although it is possible of a male to suffer this disease it is highly improbable, as mastectomy reports indicate). The procedure was performed in the following way:

1. Name and gender correlation according to the number of the participants (24 females and 19 males);
2. Correlation of the previously generated personas with the dependence levels (5 independent, 17 partially dependent, and 21 fully dependent);
3. Clustering and correlation with diseases, with a mean of three diseases per test subject and in accordance to the previously mentioned constraints;

4. Association between the personas. Friendship levels that are likes, dislikes, and indifferent, thus following a fuzzy logic pattern. The friendship connection holds the symmetric relation;
5. Mapping of the activities performed each month and their dependence leveling.

The outcome of this process is a dataset representative of the possible patients of a nursing home. Although the randomization can be debatable, the information provided required some kind of association process and it is our opinion that the most unbiased way to do it was to generate personas that were generated by a constrained random process.

In order to determine the factors taken into consideration when assigning a person to an activity, we asked the workers of daycare centers about this issue. As it can be observed in Table 5, the likes, the physical, and the psychological conditions are the factors that are the most considered when the participants are chosen to do an activity (i.e., they are considered as very important by over the 60% of the caregivers). In second come other factors such as the relationship with the residents, the activity control, the frequency, the personality, and if needs a caretaker.

These responses may provide a bias to the algorithm in the decision support system, as they establish the priorities and what needs to be considered first. Responses like the sphincter control and special medication may prove that some consideration is given to these issues but are not so relevant, although we do not know if the activities already contemplate these issues, or if the residents or caregivers are prepared for these issues' contingencies.

For the sake of simplicity, we select only some of the most relevant factors in order to define the profile of each individual for the experiments. We select those factors described as "very important" by over the 60% of the caregivers (numbers 2, 3, and 5), and those factors described as "very important" or "important" by over the 80% of the caregivers (6 and 9). Note that the model proposed in Section 4 would allow to add other factors if needed. These factors are grouped into the following features:

- **Physical and psychological status** refers to the physical and psychological conditions of the individual and can take three values based on his/her medical profile: independent, partially independent, or dependent. Depending on this status, there are some activities that are most suitable for an individual. This

factor is assumed to be known from the beginning and remains almost constant during his/her stay in the center.

- **Preference of activities** refer to the first choices of a person related to an activity, that is, how appealing is an activity for an individual. This feature can take three values: appealing, neutral, or nonappealing. We assume that an individual has not preferences until he/she participates in a planned activity. After his/her participation, the elderly has an opinion about this activity and provides feedback about his/her preference.
- **Friendship relationships** represent the social network of the senior residence center. Nodes represent the individuals and links are considered as weighted bidirectional relations between individuals and can take three values: nonfriends (i.e., the individuals consider each other annoying), neutral (i.e., the individuals are indifferent with each other), or friends (i.e., the individuals are friends). Initially, information of friendship relationships is not available. After each activity, individuals provide information about his/her relationships with other activity members.
- **Historical activity** profile stores the sequence of activities already performed by the individual during the planned period. This information is considered in order to avoid the repetition of activities during a specific period of time.

After the participation in each activity, new individual preferences and friendship relationships are learned and historical activity profiles are modified. All of this information is considered in future group activity configurations (see Figure 8).

The requirements associated to an activity are the **type** and the **number of participants** (see Figure 9). We consider two types of activities based on their requirements to perform them: psychological and physical. Psychological activities include table games, artistic expression, reading, or religious party among others. Physical activities include dancing, walks, gardening, or culinary lessons among others. The number of participants is represented as a range of numerical values that defines the minimum and maximum of individuals required for an activity.

According to the features that describe the profile of each individual, we define the following four ϕ functions to calculate the value of a group:

Table 5 | Responses to "What factors do you consider important to assign a person to an activity?"

	Very Important (%)	Important (%)	Moderately Important (%)	Slightly Important (%)	Not Important (%)
1. The age	33.3	25	33.3	8.3	0
2. Physical condition	66.7	8.3	25	0	0
3. Psychological condition	66.7	8.3	16.7	8.3	0
4. The personality	16.7	58.3	16.7	8.3	0
5. Likes the activity	75	16.7	8.3	0	0
6. Rarely performs the activity	8.3	75	16.7	0	0
7. If the participants are in control of it	25	50	16.7	8.3	0
8. Its character in relation to the activity (participative, passive, etc.)	8.3	41.7	50	0	0
9. Relationship with the residents	16.7	66.7	8.3	8.3	0
10. Possess sphincter control	0	50	50	0	0
11. Is aggressive	16.7	41.7	33.3	8.3	0
12. Is dominant or submissive	8.3	41.7	50	0	0
13. Needs special medication	16.7	25	33.3	25	0
14. Needs a special caretaker	16.7	50	25	8.3	0

Figure 8 | Resident view of the feedback questionnaire.

Figure 9 | Recreational therapist view of the activity group generation.

- Function $\phi_1 = phy(e_i, a_j)$ calculates the degree of match between the physical and psychological status of an individual $e_i \in G_j$ and the physical and psychological requirements of the activity $a_j \in A$.
- Function $\phi_2 = act(e_i, a_j)$ calculates the match between the personal preferences of each individual $e_i \in G_j$ for the activity $a_j \in A$.
- Function $\phi_3 = fri(e_i, X)$ calculates the degree of friendship of an individual $e_i \in G_j$ with other members of the group $e_k \in G_j : i \neq k$ considering their friendship relationships in the social network X .
- Function $\phi_4 = his(e_i, a_j, d)$ is used to penalize the group formed if an individual $e_i \in G_j$ has the activity $a_j \in A$ in his/her historical activity profile in the last d days.

Given the above functions, the value of a group is calculated as follows: The parameters α_1 , α_2 , α_3 , and α_4 described in this equation are firstly specified with the same weight (0.25):

$$v(G_j) = \sum_{e_i \in G_j} \alpha_1 \cdot phy(e_i, a_j) + \alpha_2 \cdot act(e_i, a_j) + \alpha_3 \cdot fri(e_i, X) + \alpha_4 \cdot his(e_i, a_j). \quad (2)$$

6. EVALUATION

In this section, we present some experiments to test and validate the application. First, we present empirical experiments that were carried out in order to evaluate the performance of the algorithm proposed. Then, we show some results about the opinion of the caregivers regarding the tool developed.

6.1. Experimental Setting

In order to analyze the performance of the tool regarding the different criteria used for group formation, we simulated several scenarios from the dataset. The value of each individual group was measured according to the Equation (2). Therefore, the physical and psychological status matching for an activity, the personal preference for an activity, the friendship relationships, and the historical activity profile had all of them the same influence for computing the value of a group.

For each experiment, we simulated different scenarios in which individuals were grouped during 30 days. For each day, we calculated the value of the group structure, considering that each individual could carry out a single activity per day. The size of each group ranged from three to five people per group, and the number of activities was 20. It must be pointed that some activities could be carried

out by different group sizes while others must be only carried out by a specific number of group size. We simulated the following grouping strategies depending on the information that is provided to the tool:

- **Random (RDM):** Individuals were grouped randomly every day without considering any information related to the physical and psychological status of each individual, the personal preference for activities, the friendship degree, and the historical activity profile.
- **Status (STA):** Individuals were grouped by considering the matching between the individual physical and psychological status and the physical and psychological requirements of the activity. The information regarding the historical activity profile was also stored in order to penalize the repetition of the same activity in the next three days. The information regarding the personal preference and the degree of friendship was not considered for group formation.
- **Activity preference (ACT):** Individuals were grouped by considering the status matching and the personal preference for an activity. The historical activity profile was stored similarly to the previous strategy in order to penalize the repetition of the same activity in the next three days. Initially, the system had not any information related to the preference of each individual for each activity, but after participating in an activity, this information was stored in order to be considered in the forthcoming days. This process simulates the workflow in a real environment in which after completing an activity, each participant would have provided feedback by using the web tool. The information regarding the friendship degree was not considered for group formation.
- **Friendship degree (FRI):** Individuals were grouped by considering the status matching, the personal preference for an activity, and the friendship degree among the individuals of a group. Similarly to the two previous strategies, the historical activity was stored to penalize the repetition of the same activity in the next three days. Apart from the information related to the preference of an individual regarding an activity, the friendship degree among the individuals that were grouped in the same team was also stored after each iteration. Similar to the previous strategy, this simulates the workflow that would be carried out in a real environment by using the web tool.
- **Optimal (OPT):** This grouping criteria represents the optimal grouping in which all the information is already known at the beginning of the experiment (the status matching, the personal preference for an activity, and the friendship degree). The historical activity profile was stored in order to penalize the repetition of the same activity in the next three days. This strategy is used as the upper bound to compare the rest of the strategies.

6.2. Group Formation Strategies

In the first experiment, we focused our interests on analyzing the performance of the group structure depending on the specific formation strategies. To do this, we simulated scenarios in which all the participants were grouped according to the above strategies during

30 days. Figure 10 shows the results of this experiment, in which the value of the group structure is represented for each day during the whole execution. The Fitness function follows Equation (2). The execution of each strategy was repeated 10 times, showing the 95% confidence interval, and performing Students t-tests to assess whether the differences among the different strategies were significant. The upper bound of the highest value of the group structure is also represented as a continuous line above all the strategies.

As it can be observed in the figure, as the more information was considered for group formation, the higher the value of the group structure was. Thus, *FRI* was the strategy that had a performance closer to the optimal, while *RDM* showed the worst performance. However, only *FRI* and *ACT* strategies were able to notably improve the performance during the 30 days. As an example, in the *FRI* strategy, the value of the group structure was near 0.40 in the first day while this value was around 0.70 in the day 30, which was very close to the optimal value. Actually, the differences between this strategy and the *OPT* strategy got smaller and the mean value of each 3-day period (which is the period established to penalize the repetition of the same activity) was not significant from day 14 on. This can be explained by the fact that new information associated to friendship and activity preferences was added after each day. Hence, the amount of information available for group formation was quite more considerable in day 30 than in day 1. In contrast, the *STA* strategy showed a similar value of the group structure during the 30 days since the information that was considered for group formation was not updated. The differences between the *FRI* and *ACT* strategies become significant after day 1, and between the *ACT* and *STA* strategy after day 7. Thus, it can be observed that the amount of information learned in the first days is eventually large enough to make significant the differences between strategies.

In order to measure this issue, Figure 11 shows the evolution of friendship relationships and activity preferences for the two strategies that incorporate new information every day (*FRI* and *ACT* strategies). This figure shows the percentage of these that were learned after 5, 10, 15, 20, 25, and 30 days. It can be observed that the increase of the learned information was high during the first 10 days, in which almost the 50 or even 60% of these parameters were learned. In contrast, the learning process was getting stable on time, showing that very few information was learned in the last 5 days of the simulation. This may suggest that very few new information

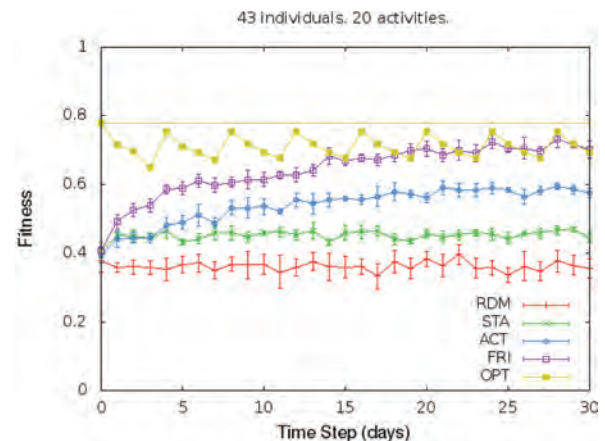


Figure 10 | Forty-three individuals and 20 activities.

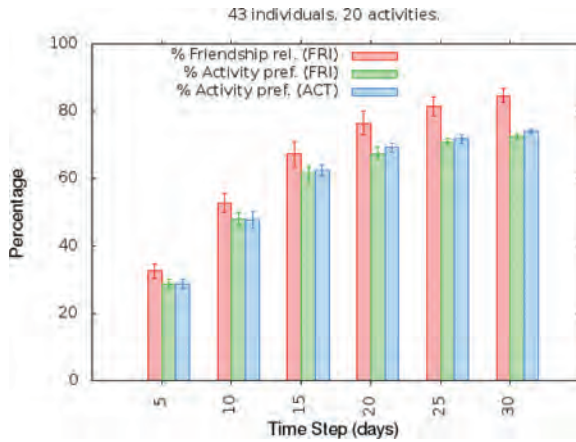


Figure 11 Percentage of friendship relationships and activity preferences learned.

would have been learned if the experiment would have extended the number of days. One of the factors that might explain the fact that some friendship relationships and activity preferences remained still unlearned is the number of days that was considered of penalization if the same activity was repeated. In this experiment, this value was established in 3 days. Thus, after 3 days, activities can be repeated without any decrease in the value of the group structure, which might cause that some local optimal groups were found and not any further combinations were explored.

6.3. Days of Penalization to Repeat the Same Activity

In order to measure the possible influence of the factor mentioned above, we carried out two different experiments that considered 6 and 9 days of penalization to repeat the same activity. Figure 12 (top-left) shows the value of the group structure for the *FRI* strategy applied with both configurations together with the original of 3 days of penalization. The Fitness function follows Equation (2). It can be appreciated that, as the number of days considered for penalization increased, the value of the group structure decreased since better combinations cannot be repeated so often. Thus, for the three configurations, periods of 3, 6, and 9 days were required for repeating a quite optimal group formation. This can be appreciated in Figure 12 (top-right), which shows the corresponding *OPT* strategy for 3, 6, and 9 days of penalization.

For the experiments shown in Figure 12 (top-left), we also calculated the percentage of friendship relationships and activity preferences that were learned by the three configurations during the 30 days, which is shown in Figure 12 (bottom-left) and 12 (bottom-right). Apparently, the number of days of penalization had some influence in the percentage of information that was learned since this percentage was slightly higher when the number of days of penalization was also higher. However, differences among the three different configurations were not significant to establish a solid conclusion.

6.4. Friendship Relationships

The following experiment was aimed at comparing the grouping strategies depending on the friendship relationships of the

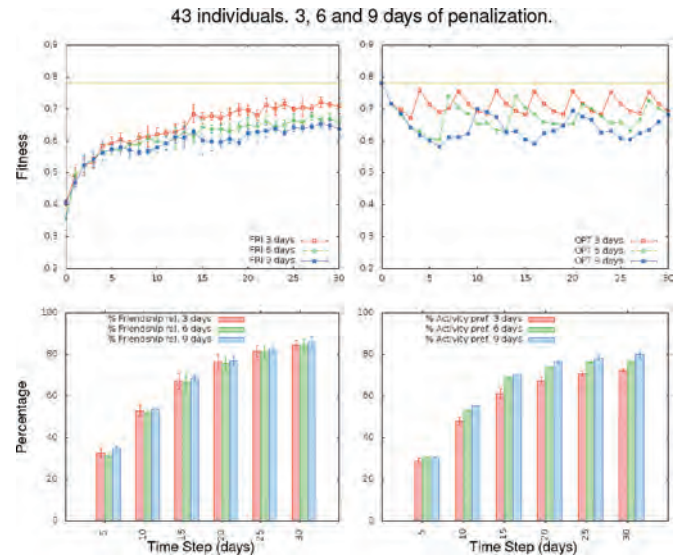


Figure 12 *FRI* str. for 3, 6, and 9 days of penalization (top-left), *OPT* str. for 3, 6, and 9 days of penalization (top-right), percentage of friendship relationships learned (bottom-left), and percentage of activity preferences learned (bottom-right).

individuals. From the whole population, we created sub-population of 20 individuals with strong friendship relationships (i.e., the 20 individuals with the largest number of friends) (Figure 13 left) and a sub-population of 20 individuals with weak friendship relationships (i.e., the 20 individuals with the shortest number of friends) (Figure 13 right). The Fitness function follows Equation (2). As it can be observed in both figures, since friendship relationships are related to the value of the group structure, the performance of all the strategies was higher in the scenario with strong friendship relationships. This causes that a more days were required to obtain nonsignificant differences between the performance of *FRI* and *OPT* strategies. Specifically, the differences between these both strategies were significant in 3-day period until day 14 for the experiment with the least friendly individuals, while these differences were significant until day 18 for the experiment with the most friendly individuals. Regarding *FRI* and *ACT* strategies, differences were significant for every day in day 16 and 17 for both configurations, respectively. Therefore, it can be observed that the evolution of the strategies were similar in both scenarios.

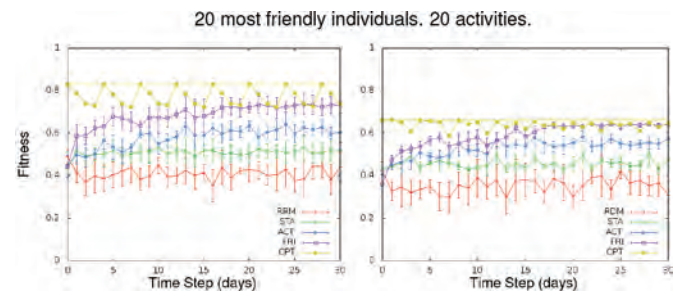


Figure 13 Twenty individuals with strong friendly relationships (left) and 20 individuals with weak friendly relationships (right).

6.5. Preference of Activities

Having compared the strategies depending on the friendship relationships, in the next experiment we tested the performance of the grouping strategies by considering the whole population of 43 individuals but with different subsets of activities. Specifically, in Figure 14 (left), the individuals were grouped by considering only the 10 activities that were the most preferred, while in Figure 14 (right) the individuals were grouped by considering the 10 activities that were the least preferred. The Fitness function follows Equation (2).

As it should be expected, the performance when only the most preferred activities were considered was greater for all the strategies. In both configurations, the differences between *FRI* and *ACT* strategies were significant from day 1 on. However, the differences between *ACT* and *STA* strategies were significant much more earlier when considering the 10 most preferred activities (day 11) than when considering the 10 least preferred activities (day 27). Therefore, it can be observed that the type of activities had a special influence when using these strategies.

6.6. Influence of Parameters

In the following experiment, we tested the influence of the parameters α that are associated to the functions defined in the Equation (2). This would allow us to determine how these changes affected the different strategies. We did not focus the parameter associated to the historical data since this is equally applied by all the strategies. This represents scenarios in which the different parameters had not the same weight and therefore, some of them were more critical than others. Specifically, in Figure 15 (top-left) it can be observed the performance of the grouping strategies when function ϕ_1 was given more importance over the other functions (0.55 instead of 0.25). This represents a scenario in which the physical and psychological status matching of individuals is more critical than the activity preferences and the friendship relationships. We must note that, in order to make clearer the results plotted in the figures, *RDM* and *OPT* strategies are not shown (these are always below and above the rest of the strategies, respectively).

As it can be observed, *FRI*, *ACT*, and *STA* strategies showed a similar behavior, in which the performance was high from the very early and it did not increase considerably. As in the previous experiments, both *FRI* and *ACT* strategies increased the performance as more information was learned. However, since the largest impact in the

value of the group structure was related to the status matching, this increase was limited.

In Figure 15 (top-right) it is shown the performance of the strategies when the ϕ_2 function was given more importance over the other functions (0.55 instead of 0.25). This represents a scenario in which the activity preferences of each individual are more critical than the status matching and the friendship relationships. As it can be appreciated in the figure, *FRI* and *ACT* strategies had a similar evolution, causing that their differences are not significant during the 30 days. This was caused because the difference between both strategies (the consideration of the friendship relationships) had not a significant impact in the value of the group structure.

In Figure 15 (bottom) it is shown the performance of the strategies when the ϕ_3 function was given more importance over the other functions (0.55 instead of 0.25). This represents a scenario in which the friendship relationships of each individual are more critical than the status matching and the activity preferences. In this case, the increase in the performance of the *FRI* strategy was really significant compared to the other two strategies. Since the friendship relationships was the parameter that had the highest impact into the value of the group structure and *FRI* was the strategy that learned this information, this strategy was able to considerably improve the performance. Through this experiment it can be observed that the fitness function can be easily adjusted depending on the requirements of a specific scenario.

6.7. Group Size

Finally, the last experiment was focused on testing the influence of the group size in the value of the group structure. Figure 16 shows the performance of the *OPT*, *FRI*, *ACT*, and *STA* strategies in the formation of groups of four and six members. In this case, the Fitness function follows Equation (2). In order to compare both group size configurations, we applied these strategies in a subset of 24

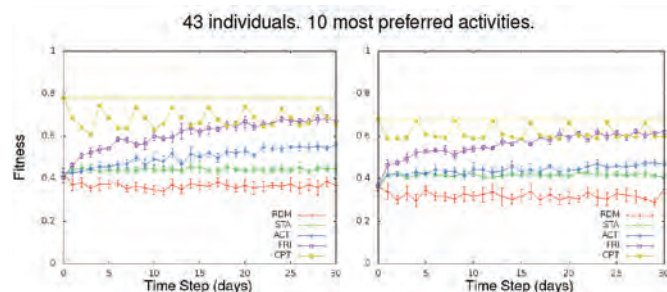


Figure 14 Ten most preferred activities (left), and 10 least preferred activities (right).

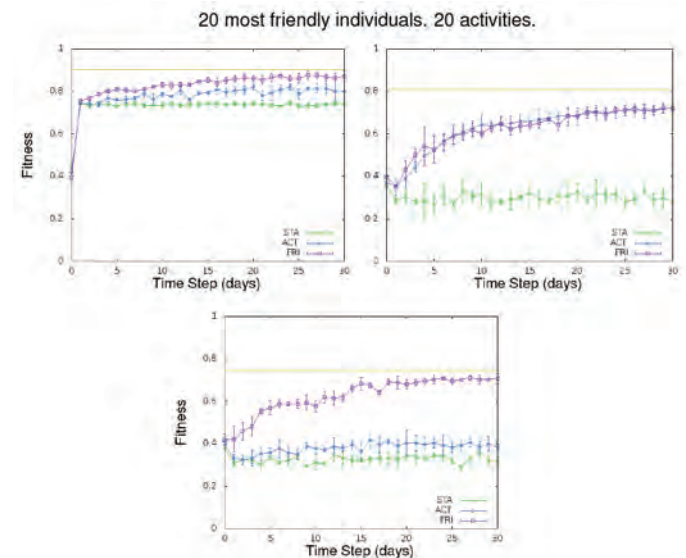


Figure 15 Physical and psychological status matching importance (top-left), activity preferences importance (top-right), and friendship relationships importance (bottom).

individuals from the whole population. The first thing that can be appreciated in the figures is that the values of the group structure were usually higher for the configuration of groups of four members. This can be explained because the value of the group structure is related to the physical and psychological status, the activity preferences, and the friendship relationships. Thus, when considering larger groups, it is more difficult to obtain good values of these parameters for all the members. This can be observed for the *OPT* and the *FRI* strategies (Figure 16 top-left and top-right). The differences between both group size configurations were significant for the *OPT* strategy during the 30 days and for the *FRI* strategy from day 11 on. However, differences were not significant for *ACT* and *STA* strategies as it can be observed in Figure 16 (bottom-left and bottom-right). Hence, it can be concluded that groups with a smaller number of members are more likely to satisfy the different conditions that are considered for calculating the value of the group structure.

6.8. Tool Questionnaire

After the tool was used by the questionees of the questionnaire presented on the Introduction, the following follow-up questions were made:

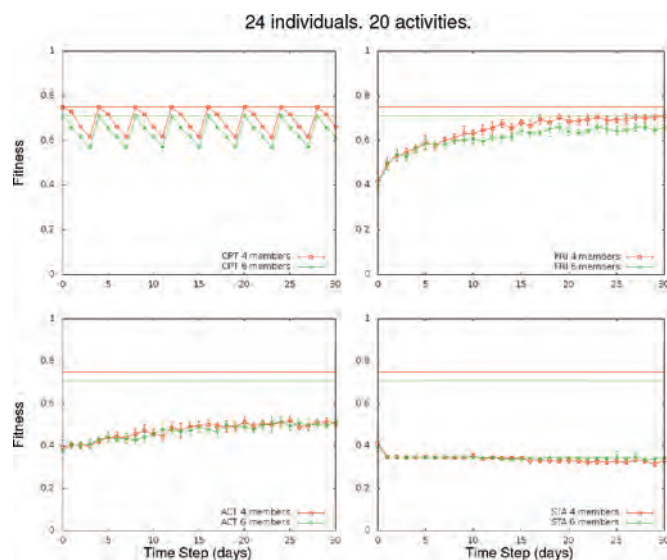


Figure 16 | *OPT* str. for groups of 4 and 6 members (top-left), *FRI* str. for groups of 4 and 6 members (top-right), *ACT* str. for groups of 4 and 6 members (bottom-left), and *STA* str. for groups of 4 and 6 members (bottom-right).

In Figure 17 it is clear that the caregivers believe that the tool is interesting and have validity of this environment. The objective is to aid the caregivers and shorten their time spent in planning activities and selecting the people which will be performing it. Furthermore, Figure 18 shows that most of the respondents would personally benefit from this tool, by alleviating their effort, thus improving their work process.

Finally, in Table 6 are presented the last questions performed. In terms of the questionees wanting to have this tool on their daily work, the response was very positive. They believe that this tool would help them and be useful. They also responded positively to the fact that this tool would help to maintain the information relative to the residents updated both in terms of participation and in terms of likes and social integration. Lastly, the questionees responded positively that the tool would help them in terms of having an historic about the activities performed and the groups generated to them.

We were expecting a positive response of the questionees after using the tool. This may be explained if they did not use it at its full capacity or believe that this tool could replace them, thus providing conservative responses.

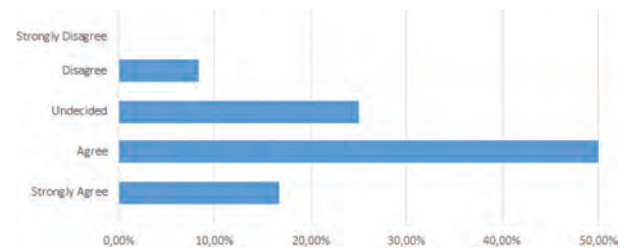


Figure 17 | Do you think that a tool that gives you an initial set up of group activities may save you time?

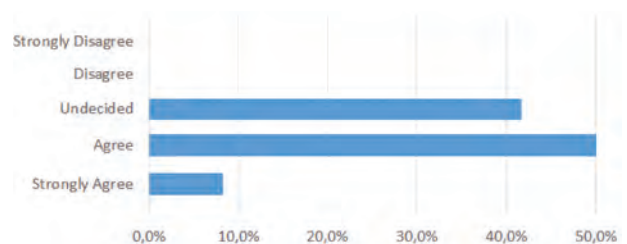


Figure 18 | Would a tool that offers planning of groups and activities per day reduce the mental effort involved in this action?

Table 6 | Tool evaluation.

	Strongly Agree (%)	Agree (%)	Undecided (%)	Disagree (%)	Strongly Disagree (%)
Would a tool that offers planning of groups and activities per day be useful and would it improve your work?	8.3	50	41.7	0	0
A tool that offers planning of groups of residents and activities per day would help maintain centralized and accessible information about the residents and activities?	8.3	58.3	33.4	0	0
Would a tool that offers planning of groups and activities per day give useful information about the residents and activities that are planned?	16.7	66.7	8.3	8.3	0

7. CONCLUSIONS

Many older people with active participation in social and leisure activities report positive well-being. In this sense, numerous studies in the elderly literature have examined associations between group activity participation and aspects of well-being. This paper focuses on one of the challenges for a recreational therapist that consists on determining how to match each care-receiver to the most appropriated activity. We can summarize the contributions of our work as follows: (1) We presented a computational model for group formation of elderly people. This model is defined according to the profiles of the participants and the activities that can be carried out by them. This computational model is wrapped by a web tool in order to facilitate the group management to the therapist. (2) The model is flexible to be adapted according to the information that is important for the caregivers. In our experiments, we considered information regarding physical and psychological status, social relationships, preference of activities, and historical information of activities since these were the criteria defined as most important according to our questionnaires, but other factors could be include. (3) Learning can be incorporated to maximize the personal satisfaction of individuals as much iterations are carried out. In a real execution this would be introduced by using the web tool.

In order to validate the proposal of group formation, we presented different tests simulating 30 days of planned activities. Although this was a simulation, we used a set of real data that gave much more realism to the simulation. Throughout the experiments that we carried out, we tested the performance of different group formation strategies under different scenarios, observing that depending on specific requirements, some considerations for group formation may lead with significant differences of performance. As a general conclusion, we demonstrated that the learning process of the information that is relevant to the value group structure allows to obtain a performance really close to the optimal with nonsignificant differences. In our case, we considered three different factors that affect this performance (physical matching, activity preferences, and friendship relationships), however, this could be easily adapted in order to include other factors.

We also presented a web tool as the interaction interface for the therapist and the elder people. Regarding the opinion of caregivers, they responded positively to the fact that this tool could help them to manage the activities carried out by individuals. We must point out that this tool is not intended to replace the caregivers but providing some help, but they are free to carry out any modification of the solutions provided by the tool.

As a future work, we plan to modify the underlying technology used for obtaining the groups in order to incorporate genetic algorithms. In addition, we would like to include a module for learning the adjustments made by the caregivers. This is, any change carried out by the caregiver after the solution is provided, should be considered in order to provide future solutions. Moreover, we plan to continue our collaboration with the daycare center *Centro Social Irmandade de S. Torcato* in order to validate our proposal with nurses and medical personnel of the daycare center.

CONFLICT OF INTEREST

We declare that this work and its authors do not have any conflict of interest, that is, there is no financial/personal interest or belief that could affect our objectivity or the objectivity of our work.

AUTHORS' CONTRIBUTIONS

- A computational model for group formation of elderly people is presented.
- A web tool integrates this model to facilitate the group management to the therapist.
- Apart from physical factors, we introduce personal preferences.
- Learning is incorporated in order to maximize satisfaction of individuals.
- Several simulations have been carried out with real data to validate de computational model proposed and the web tool.

Funding Statement

This work has been supported by COMPETE: POCI-01-0145-FEDER-007043 and FCT – Fundação para a Ciência e Tecnologia within the Project Scope: UID/CEC/00319/2013. A. Costa thanks the Fundação para a Ciência e a Tecnologia (FCT) the Post-Doc scholarship with the Ref. SFRH/BPD/102696/2014. This work is also partially supported by the MINECO/FEDER TIN2015-65515-C4-1-R.

ACKNOWLEDGMENTS

We would like to thank the collaboration of the residence *Centro Social Irmandade de S. Torcato* and *Fundao Manuel Francisco Clérigo*.

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