ALZheimer's GARden

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il paese ritrovato

LA MERIDIANA

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EXECUTIVE SUMMARY

Throughout the last decades, the percentage of people aged 65 years or over has been rising steadily and is projected to reach 15% by 2050. Technological advancements and breakthroughs in the medical field, combined with rising awareness towards healthy life practices, have allowed a consistent decrease in mortality rates, thereby increasing demand for healthcare services leading to a possible shortage in availability. One of the leading causes of disability in the elderly is dementia, a chronic, degenerative disease compromising memory, visuospatial abilities, domain and functional cognition, and problem-solving capabilities affecting one in two people over 85 years of age. Alzheimer's disease (AD) is the most frequent form of dementia hindering independence and memory, causing a progressive withdrawal from family and society. Recent studies have found that loneliness and isolation accelerate the cognitive decline associated with AD. Therefore, engaging AD patients in social activities and encouraging them to build strong connections is crucial to preserve their independence and provide them with a better quality of life.

We collaborate with *Il Paese Ritrovato* (The Rediscovered Village), the first AD assisted care home in the form of a village ever built in Italy, managed by *La Meridiana* co-operative. The village features a series of apartments with common areas surrounding a large town-like ensemble of shops and other facilities, while green open areas are situated on the perimeter. Many technological devices are also present, among which a localization system that allows to track the position of the patients through the use of Bluetooth antennas and wristbands worn by the residents. The typical resident of Il Paese Ritrovato is a person diagnosed with mild to moderate AD with a fair level of self-reliance and independence, able to move around the village autonomously.

Our project, Alzheimer's Garden (ALZGAR), aims to understand the social behavior of AD patients living in *Il Paese Ritrovato* and to promote sociability among them to improve their quality of life and slow down the progression of the disease.

By analyzing the data collected through the existing localization system, we gain insight into the behavior of the residents to guide the design of novel space organizations and propose activity scheduling solutions, ultimately promoting socialization. We carry out our analysis on the relationships between residents and on the social places where all residents can meet and spend their time. To measure the sociability of the residents we resort to the Relational Index (RI), an indicator that aims to estimate the degree of relation between two individuals taking into account the amount of time they spend together.

By analyzing the trend of the RI and extending its definition to individual residents and to the whole community, it is possible to discriminate between more and less sociable patients, outlining a social profile for each of them and drawing the social network of the village. Social isolation can be easily identified by observing decays in the patient's Individual RI curve and changes in the visited places over time. We determine the correlation between the RI and possible influencing factors: we observe that the weather does not affect the sociability of the residents, being most facilities indoors, whereas other factors such as the season and the patient's bedroom floor do play an important role.

To assess the utilization and social utility of social places, we analyze the way these are visited by residents, identifying highly frequented areas and unpopular ones. We introduce the Popularity Index (PI) as an objective index to quantify how popular a certain place is. For each place, we obtain a curve describing the degree of popularity for each day. We leverage functional data analysis to group together places sharing a common pattern in terms of PI, detecting non-trivial and peculiar trends exhibiting time dependence representing four common behaviors of residents towards collective places. Furthermore, to enrich this analysis, we rely on functional principal component analysis identifying the places that are particularly popular, such as the cinema and the market, and those that are overlooked and in need of spatial enhancements to promote attendance, such as the garden and the vegetable garden.

Considering the statistical and architectural analyses we carried out and the thorough state-of-the-art knowledge on AD-sensitive architecture, we propose predictive tools and architectural interventions. We resort to neural networks and advanced machine learning techniques to accomplish the task of predicting the RI and the PI given relevant input variables describing the environment of *Il Paese Ritrovato*, including both external factors and the community's behavior. We propose the Community Behavior Prediction Table, a visual tool combining the aforementioned predictive models to support caregivers in organizing activities. We provide an extensive analysis and examples on how to leverage this tool with state-of-the-art, AD-designed activities. This tool can prove to be valuable for the caregivers of *Il Paese Ritrovato*, since the compatibility of an activity with the location it is held at and the social profiles of the participants engaged is crucial to guarantee therapeutic benefits to the dwellers.

As we wish to promote sociability among residents, we analyze the accessibility of the social places of *Il Paese Ritrovato*, and observe it does not present issues attributable to architectural barriers. Despite being easily accessible, the two main outdoor locations cover peripheral areas of the village, resulting in residents rarely spending time outside. As such, we focus the architectural design on the gardens to make them attractive to dwellers, considering also that these areas provide excellent sensory stimuli to the residents, ultimately improving their wellbeing.
We propose to act on the home environment to considerably improve the wellbeing of the patients, mitigating the risk of crisis and promoting mental stability. As such, we develop sensory maps to investigate intimate and subjective aspects of each patient through their sensory memories and routines, and we introduce "Sound Houses", "Gardens to Compose", a "Tactile Table" and a "Seasonal Window" as spatial enhancements. Space thus becomes part of a non-pharmacological therapy.

Unfortunately, the COVID-19 global pandemic disrupted our project by limiting our communication with the facility and made it infeasible to implement our ideas due to the new social distancing paradigm. Nevertheless, besides analyzing the localization data of residents during the lockdown phase and confirming the actuation of preventive measures, we propose an implementation plan for the near future taking into consideration the comfort of the residents. To evaluate the impact of the proposed solutions we compare the trends of the introduced indexes regarding the sociability of the community and the attendance of places before and after the interventions. Moreover, we plan to gather feedback from doctors, psychologists, caregivers, to augment the evaluation of the solutions and enhance them further.

We study the business model of *La Meridiana*, whose profits are mainly re-invested for the interests of the members of the community served, i.e. elderly people. The solution we present for *Il Paese Ritrovato* could have great potential if applied in other facilities specialized in dementia care, considering that the number of people with dementia is expected to reach 82 million by 2030. Moreover, the possibilities offered by the same technological bundle (Bluetooth wristbands and antennas) can serve many other purposes, such as monitoring social gatherings and tracing infections.

Finally, ALZGAR presents valuable innovative technological and architectural solutions to promote socialization and wellbeing in AD care facilities. The data awareness obtained from our analyses will be of great help to caregivers, doctors, and psychologists to enhance social activities in assisted care homes, adjust patient-specific treatments, and deepen the comprehension of the disease. The presented predictive tools will be of great support to caregivers during activity scheduling. The architectural enhancements, which leverage state-of-the-art sensory maps, will mitigate the risk of crises and promote mental stability. We believe there are several directions of work and research to undertake next, including the development of visualization tools and applications to support caregivers, doctors and psychologists, ultimately slowing down the progression of the disease, offering a better quality of life to the residents of *Il Paese Ritrovato* and AD patients of the whole world.

INTRODUCTION 1.

In the last decades, the rapid advancements and new breakthroughs in the medical field combined with the rising awareness towards healthy life practices have allowed people in developed and developing countries to live longer than ever before. On the other hand, declining fertility rates have been observed in many areas of the world, with highly developed countries reporting the lowest numbers. As a consequence, many societies are currently experiencing a steady increase in the age of their population. In 1990, only 6% of the world population was aged 65 years or over, 10% in 2019 and by 2050 the number is projected to rise to 15%, potentially surpassing that of adolescents, according to the United Nations forecast[1]. For these reasons, the importance and the interest towards studying and treating the diseases affecting elderly people, such as Alzheimer's, is already substantial and will keep growing.

1. World Population Ageing 2019. Tech. rep., Department of Economic and Social Affairs, United Nations (2019).

1.1 ALZHEIMER'S DISEASE

The ageing population phenomenon comes with a multitude of brand new problems that still need to be properly addressed, impacting areas from labour markets and economic growth to housing and migration[2]. In the healthcare sector, requests for assistance, which are already on the rise and having an impact on hospitals and other medical infrastructures worldwide, will further intensify, possibly leading to a shortage in service availability.

One of the leading causes of dependency and disability in the elderly is dementia, a chronic, degenerative disease that affects memory, visuospatial abilities, domain and functional cognition, attention, and problem solving capabilities. Although in the past dementia used to be a relatively rare disease, it has emerged over the last 50 years as one of the most critical issues faced by the developed world. Nowadays the number of affected people is rather large: 5-8% of people aged 60 and over suffer from dementia, rising to 50% when considering people over 85[3].

Alzheimer's disease (AD) is the most frequent form of dementia, accounting for about 50 to 80 percent of all dementia cases[4]. AD can be defined as a severe progressive neurological pathology in which the main cognitive functions of an individual are compromised. It usually starts slowly and gradually worsens over time, with the typical life expectancy following diagnosis being three to nine years[5]. As the condition progresses, the deterioration hinders independence, with subjects eventually unable to perform basic everyday activities without proper help and supervision[6]. At the same time, they are often subject to memory loss of significant life events, which causes a progressive withdrawal from family and society. The many negative effects of the disease significantly affect the quality of life of the subjects and the people close to them, posing a burden that is both economical and emotional. The causes of the disease are still uncertain, although factors such as ageing and genetics appear to be the main risk factors; moreover, the disease targets women more often than men.

So far, medical sciences have not been able to find an effective treatment to halt or reverse AD progression. However, recent studies have found that loneliness or living in isolation is likely to cause an acceleration in the cognitive decline associated with AD [7]. Engaging AD patients in social activities and strong connections could therefore be crucial for delaying their cognitive decline, preserving their independence, and providing a good quality of life for as long as possible.

2. J. Laurance, "Why an ageing population is the greatest threat to society," Independent, 10 April 2002.

3. Dementia, World Health Organization, https://www.who.int/news-room/fact-sheets/detail/dementia, last accessed 3 Aug 2020.

4. J. Evans, T. Coughlan, M. A. Brown and G. Lawson, "A Systematic Review of Dementia Focused Assistive Technology," in Lecture Notes in Computer Science, 2015.

5. Burns A, Iliffe S (February 2009). "Alzheimer's disease". Querfurth HW, LaFerla FM (January 2010). "Alzheimer's disease". The New England Journal of Medicine. 362 (4): 329–44.

6. Förstl H, Kurz A (1999). "Clinical features of Alzheimer's disease". European Archives of Psychiatry and Clinical Neuroscience. 249 (6): 288–90.

7. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5102822/.

1.2 PROJECT OBJECTIVE

Alzheimer's Garden (ALZGAR) is an Alta Scuola Politecnica project that aims to understand the social behavior of AD patients living in a healthcare facility and to promote sociability among them to improve their quality of life and slow down the progression of the disease. The project is in the context of Ambient Assisted Living (AAL) and Architectural Design and has been carried out in partnership with Cooperativa *La Meridiana*, an Italian social co-operative born in 1976 that focuses on helping elderlies suffering from age-related diseases.
The case study of ALZGAR is *Il Paese Ritrovato*, an assisted care home managed by La Meridiana since 2018. It is the first village dedicated to the treatment of AD ever built in Italy and one of the most innovative AAL projects in Europe. It was built privately in Monza by *La Meridiana*, taking the Dutch Hogeweyk village as a reference[8].

8. https://hogeweyk.dementiavillage.com/en/.

The complex hosts 64 patients, divided in apartments with 8 private rooms each. All the apartments are equipped with communal areas such as a kitchen, a living room, and a TV area, where social interactions can take place.
Outside of the apartments, the atmosphere of an actual town is recreated. The central building, which is the pulsing heart of the social life in the village, contains a theater, a gym, a church, a hairstylist, a cafeteria, a minimarket, a haberdashery, and a bricolage store, where all the professionals running the businesses are in reality nurses specialized in dealing with AD patients. The facility also provides a multitude of large, open, green areas, such as a park and a vegetable garden. Moreover, several brain stimulation activities and therapies are offered in specialized rooms enhancing memory recollection through the sense of smell and sight.

The village also features a plethora of interactive technological devices and appliances. The lighting system can be softened or intensified according to the patient's will or necessity. The television is equipped with a smart webcam able to identify facial expressions and thus identify the emotions of patients, thus reacting to the specific emotion and eventually changing the displayed content . Beds are equipped with pressure sensors located beneath the mattress, which are able to detect whether a patient is lying or sitting on it.
Most importantly, a localization system allows to track the position of the patients through the use of multiple bluetooth antennas scattered around the facility and bluetooth wristbands worn by the patients. The system assigns each few seconds a patient to the nearest antenna, providing us with real time knowledge on their position within the facility. This information is stored in a database for later inspection and analysis. One of the critical issues of the system is the tendency of the patients to reject the wristbands. This problem has been partially addressed by CLONE, an Alta Scuola Politecnica XIII project that focused on the design of comfortable bluetooth wristbands to avoid stress and rejection.

Finally, the objective of ALZGAR is to analyze the data collected through the localization system to provide *La Meridiana* with novel space-organization and activity-planning solutions in the context of dementia and AD care, so that they can

be implemented in *Il Paese Ritrovato*, with the ultimate aim of providing patients with a healthier and more social lifestyle. It is in our interest to recommend solutions that are not only beneficial for AD patients, but also economically, socially and emotionally sustainable for all the stakeholders involved. We hope that this project will contribute to setting a new trend in the care and services provided to AD patients in assisted care homes across the world, as well as addressing some of the new problems resulting from our ageing population.

1.3 OUR APPROACH

Taking into account our team composition and objective, we identify two main lines of work for the project:

- We study the state-of-the-art solutions in architecture that promote social interactions to identify the ones that are better suited for our scope. We propose some possible implementations to *La Meridiana* in the context of *Il Paese Ritrovato*. We also focus our attention on the design of buildings and spaces for people with AD, especially outdoors.

- We analyze the data collected through the localization system to extract patterns, gather insights, and model the social behavior of the residents of *Il Paese Ritrovato* leveraging statistical and machine learning techniques. The knowledge gained is then useful to identify the places in the village that are suitable for social interaction and the ones in need of enhancements. We also provide a way to predict the future social behavior of the community of patients and use it as a tool to support the organization of social activities.

Indeed, the first line of work mainly involves the architects in our team, while the second pertains to the data engineers. Nonetheless, a steady flow of information between the two is established to allow for the highly multidisciplinary and interdisciplinary nature of our project.

Unfortunately, throughout the development of our project, the COVID-19 global pandemic has taken place, disrupting our communication with *La Meridiana* and making it infeasible to implement our ideas because of the new social distancing paradigm. Nevertheless, we provide an analysis of the data collected during the lockdown to verify the quality of social distancing and as proof of the versatility of our work. We look forward to implementing our proposed solutions in the near future and hopefully receiving positive and useful feedback from all the parties involved.

UNDERSTANDING THE PROBLEM 2.

The goal of ALZGAR is to understand the social behavior of the residents of *Il Paese Ritrovato* to improve their quality of life. To reach our goal, we first identify the stakeholders involved in the project, including people and organizations that are actively interested or indirectly affected. Stakeholders have different needs, priorities, desires, and expectations that we take into consideration when defining the possible directions of work and choosing which ones to pursue. We measure the needs of the stakeholders through the definition of requirements.

Once the stakeholders analysis is carried out, we analyze the resources at our disposal, including existing technology and data, and brainstorm the possible solutions to tackle our problem. Finally, by outlining advantages, disadvantages, and constraints of the considered solutions, we discard the infeasible ones and focus our attention towards a specific direction of work.

2.1 STAKEHOLDERS ANALYSIS

Needs and Requirements

This Section will focus on the needs and the requirements of the stakeholders involved in the project. We first present the profile of the typical resident of *Il Paese Ritrovato*, then we present requirements analysis for the different stakeholders, explaining their role and their needs related to the considered problem.

The Typical Patient – Antonio

Antonio lives in Monza, where he has been a manager for 25 years and a faithful husband and father. He was diagnosed with AD at the age of 70, so, after talking with his family, he agreed to move to *Il Paese Ritrovato*. At the beginning, Antonio did not like to spend time with the other residents, preferring going for a walk just when his family came to visit him. Despite his initial condition, thanks to the activities organized inside the village, Antonio was able to start enjoying other residents' company. His level of socialization strongly increased and, consequently, his health improved. He really likes to spend time in the garden, however, he does not usually frequent it as there are not many other dwellers to socialize with.

ANTONIO

Stakeholders Description

Besides the main stakeholder represented by the village residents, we hereby present the other stakeholders involved, which were chosen for the great interest they have in the problem and especially for the impact it has on their lives and interests.

La Meridiana

It is the organization that has requested the project and that manages *Il Paese Ritrovato*, as well as other medical care facilities. *La Meridiana* will be the final owner of the solution and the one approving it. Being a particular type of organization, specifically a co-operative, it invests the majority of its revenues in improving the services it offers, with the aim of enhancing patients' wellbeing.

Caregivers

The nurses working inside *Il Paese Ritrovato* play a crucial role in the life of residents and consequently in our project. They are the ones that will fully exploit the potentialities of our solution in order to help patients. In terms of usability, the solution should, therefore, consider the expectations of this category of stakeholders.

Doctors

These stakeholders (including psychologists and physiotherapists) are different from caregivers since they are not directly involved in everyday patient care, but still monitor the physical and mental health of the patients. Insights on the sociability of patients can be quite helpful for them to better understand their behavior and dive deeper into the treatment.

Relatives

This class of stakeholders is quite important given the concern they have for the patients of the facility. For instance, they could decide to reject the solution or, worse, decide to move out of the facility of their beloved ones. Furthermore, they could be concerned about privacy relatively to the way data is handled.. In order to obtain their approval, we must be able to explain how the solution can improve social interactions at *Il Paese Ritrovato* making patients' lives better.

Needs and Requirements for Each Stakeholders

Economic

The solution should be profitable	⟶	*La Meridiana*	⟶ The solution should be able to guarantee a positive return within 3 years from its launch or, at least, not compromise the financial position of *La Meridiana*.

Regulatory - Policy

Patients data should be managed securely and in an anonymous way	⟶	*Patients - Relatives*	⟶ The way data are handled and analysed in order to conceive the solution should be compliant with EU - GDPR (2016/679) regulations with a particular focus of the subjects' right to data and the informed consent of the patients.
The architectural solution should be compatible with all safety standards which are currently implemented in the care home	⟶	*Patients*	⟶ All the interventions proposed must be approved by a state supervisor.

Human Based

The redesign of the spaces should be comprehensible by the patients and not confusing	⟶	*Patients*	⟶ The redesign of the areas of Il Paese Ritrovato should be easy to understand for the residents: at least 70% of them must express comfort when asked about the new areas.
The redesign of the spaces should be able to improve patients' social relationships	⟶	*Patients*	⟶ The level of sociability after the space redesign must be evaluated comparing it to the past.
The caregivers should be able to quickly understand the functioning of the solution	⟶	*Caregivers - Doctors*	⟶ The user interface of our solution should be as user-friendly as possible and accepted by all the caregivers.

Technical

The solution should allow to track patients' location in order to provide caregivers with information on patients' socialization level	⟶	*Caregivers - Doctors*	⟶ The solution should be based on a simple and reliable tracking system (Bluetooth and antennas), leveraging the existing one if possible.
The solution should be easy to adapt and to expand according to further needs of caregivers and doctors	⟶	*Caregivers - Doctors*	⟶ The solution should be modular, expandable both in terms of software (new functionalities, same data) and in terms of hardware (number of bracelets, different hardware).
The data cleansing procedures should be able to produce reliable and meaningful data to be analysed by the system to gather more meaningful insights on patients	⟶	*La Meridiana - Caregivers - Doctors*	⟶ The software should be able to identify and remove at least 75% of the outliers. Possible new hardware should be considerably reliable: uptime of at least 95%, sensitivity of at most 2 dB.

The measures and the statistical methods chosen for data analysis should be able to provide a picture of the socialization level with a fairly good precision	→ *Caregivers - Doctors* →	The analyses must be validated by the caregivers working in the facility for at least 6 months.
The solution should be able to provide an efficient prediction for activity scheduling	→ *Caregivers - Doctors* →	The system should be able to output suggestions for activity scheduling for a certain week at least 7 days in advance, with prediction errors lower than 5%.
The solution should be able to identify with a fairly good level of precision the areas that require an architectural intervention	→ *La Meridiana* →	Need of intervention must be supported by precise architectural and data analyses.

2.2 EXPLORING THE OPPORTUNITIES

Il Paese Ritrovato is an assisted care home featuring architectural designs and technological devices that support the wellbeing of its AD residents.
The data at our disposal consists of the localization of the residents collected through Bluetooth wristbands every 10 seconds. We may leverage this data to understand which places are frequented by residents throughout the day. Moreover, we may gather insights into the social behavior of residents, spotting interactions with and isolation from the rest of the community. Predicting the behavior of residents can be useful to plan activities in the village accordingly and to prevent social isolation by intervening on specific patients.
Sociability at *Il Paese Ritrovato* is promoted through activities held throughout the village public areas. To assess the impact of a certain activity we may resort to synthetic control techniques [cite], estimating the community sociability level in the case the engagement did not happen and comparing it with the actual sociability measured.

Furthermore, we may analyze external factors, such as the weather, to understand how these may be influencing the sociability of the residents.
While the innovative designs and technologies of *Il Paese Ritrovato* are indeed helpful for our analysis, they may not be enough to fully understand and effectively promote sociability in the village. From a technological standpoint, we believe the introduction of security cameras is crucial to identify social gatherings more precisely, allowing us to distinguish casual encounters from actual interactions leveraging powerful computer vision techniques. Furthermore, social interaction usually comprises a conversation between parties; as such, the installation of microphones would allow for speakers identification for a better analysis of sociability at *Il Paese Ritrovato*.
Sociability is not only measurable through the sensor data, but also through the opinions and feelings of the people in the community, namely the residents and caregivers.

Thanks to the information collected from periodical surveys and interviews we would be able to understand how dwellers feel about themselves and the other community members, who they interact the most with and which places are the ones they prefer and why. Moreover, we may validate the gathered sensor data and the information provided by dwellers by taking into consideration the reliable opinion of caregivers, as they spend most of their time in close contact with the dwellers. Consequently, we may gather insight on the social network of *Il Paese Ritrovato*, including identifying leaders and followers, specific social patterns, and socially isolated residents.
From an architectural perspective, we may identify the most and the least frequented places by analyzing accessibility and attendance. We may propose architectural interventions in the form of spatial redesign and AD-specific installations for the places that are in need of intervention.

Finally, together with *La Meridiana*, we analyze the downsides of the presented opportunities of work and identify the ones we will focus on. The introduction of new technological devices is potentially invasive, possibly violating privacy regulations, besides constituting a considerable economical investment. Conducting surveys and interviews would pose an additional burden on caregivers and residents, with the latter not being able to always provide reliable answers because of their mental condition. Despite synthetic control being a powerful technique to measure the impact of an engagement, this technique would require much more data to conduct a reliable analysis. From an architectural standpoint, invasive spatial interventions may confuse residents, hindering their comfort and familiarity. Furthermore, technical installations simulating reality might disorient the residents, promoting undesired behaviors.
Therefore, the direction of work we choose to take is that of leveraging the existing technological solutions and proposing non-invasive spatial redesigns at *Il Paese Ritrovato*. Specifically, we aim to analyze the sociability and places attendance of the village through data analysis, predict the social behavior of the residents, and introduce installations to stimulate their senses, with the ultimate aim of slowing down the disease progression and improving the quality of life of the residents of *Il Paese Ritrovato*.

STATE OF THE ART

3.

This chapter provides an overview of the main therapeutic approaches to slow down the progression of Alzheimer's disease. We first report the main types of dedicated facilities and outline the main traditional pharmacological therapies. We then shift the attention to innovative approaches designed to mitigate the symptoms of the disease. Finally, we provide an architectural collection of Alzheimer's villages case studies and analyze them from a spatial point of view. The Alzheimer's villages are compared to *Il Paese Ritrovato* through schemes showing spaces dedicated to the households, the families, and the interior and exterior wandering paths.

3.1 TRADITIONAL PHARMACOLOGICAL THERAPIES

Alzheimer's disease's complexity is significant, and it is unlikely that any drug or other intervention will successfully treat it. Current approaches focus on helping people maintain mental functions, manage behavioral symptoms, and slow down the symptoms of the disease[1]. Typically, AD patients are treated in dedicated facilities in one of the following ways[2]:

- Retirement housing, appropriate for individuals in early stage Alzheimer's.
- Assisted living, which offers a combination of housing, meals, supportive services and health care.
- Nursing homes, which provide around-the-clock care and long-term medical treatment.
- Alzheimer's special care units (SCUs), most often cluster settings in which persons
living with dementia are grouped on a floor or a unit within a larger residential care
building.
- Continuing care retirement communities (CCRC), which provide different levels of care (independent, assisted living and nursing home) based on individual needs.

In all of the aforementioned approaches, AD is treated through medical drugs and the patient lives as if it were hospitalized. The treatment deprives the patient from social interactions, evoking a sense of loneliness and undermining their sociability.

3.2 INNOVATIVE APPROACHES

Il Paese Ritrovato uses a different, innovative approach, promoting physical activity and socialization other than only medicines to improve the quality of life of the residents and to slow down the progression of the disease.

According to Myuri Ruthirakuhan et al.[3], health benefits attributed to physical activity are numerous and well known. Exercise has been associated with a lower incidence in many chronic diseases, such as coronary heart disease, type 2 diabetes, obesity, cancer, bone loss, and high blood pressure.

1. https://www.nia.nih.gov/health/how-alzheimers-disease-.

2. https://www.alz.org/help-support/caregiving/care-options/residential-care.

3. Ruthirakuhan, Myuri, Angela C. Luedke, Angela Tam, Ankita Goel, Ayaz Kurji, and Angeles Garcia. "Use of Physical and Intellectual Activities and Socialization in the Management of Cognitive Decline of Aging and in Dementia: A Review." Journal of Aging Research 2012 (2012): 1–14.

Higher cardiorespiratory fitness has been related to higher scores on tests of cognitive function. A meta-analysis of randomized controlled trials examining the relationship between exercise and cognition showed modest improvements in attention, processing speed, executive function, and memory among older adults in the treatment arms. This is highly relevant for the elderly population, as it suggests that physical activity can serve as a preventative measure against age-related cognitive decline.

To encourage the patients to perform physical activities and, more in general, to have a healthy and social lifestyle, it is possible to leverage music and many other activities, such as pet[4] and art[5] therapy.
These activities play a crucial role in enabling people with AD to live a life as satisfying as possible, allowing them to pursue their own hobbies and interests, creating immediate pleasure, restoring dignity and enabling friendships[6]. It has been shown that high social engagement reduces the rate of cognitive decline by 91%[7]. On the contrary, both actual social isolation, including having a small social network and participating in few activities with others, and perceived social isolation, that is, feeling lonely, are robustly associated with AD progression and cognitive decline[8].

To further enhance socialization among patients, it is possible to exploit many different spatial solutions, especially the ones focused on accessibility. Van Hecke et al.[9] state that when AD patients are not allowed to leave a dementia special care unit, it is important to provide sufficient freedom of movement and social interaction within the unit itself, including access to private outdoor space. This freedom of movement is crucial for patients walking through the unit without a specific destination, experiencing the phenomenon of wandering [10]. This statement is reinforced by the research of Ferdous et al.[11] proving architectural configuration affects the type of conversations likely to occur in certain locations within assisted care homes and, consequently, social relations.

The research team *Lab.I.R.Int* of the Design Department of Politecnico di Milano with Lapo Lani and Ivo Cilesi describes the concept of therapeutic habitat to define good design for Alzheimer's patients[12]. It recognizes the value of intangible environmental features that act as activators of opportunities for social relationships, conversations and daily rituals, improving the wellbeing of patients. Several outdoor environments do not adequately address accessibility issues concerning people with AD, as they often are disorientating, difficult to interpret and navigate, and threatening or distressing for them[13].

3.3 ALZHEIMER VILLAGES: CASE STUDIES

The topic of the Alzheimer's Village is a rather recent design theme in which relatively few case studies can be identified. The young age of this social problem means that, even from the regulatory point of view, there are no specific references. In fact, regulations are merely referred to the design of RSAs (assisted care residences) and Alzheimer's centers, but there is nothing specific about the villages exclusively intended for dementia. However, we could wonder which role the regulations have in the design of care spaces, how they can affect the project.

4. Cevizci, Sibel, Halil Murat, Fahri Gunes, and Elif Karaahmet. "Animal Assisted Therapy and Activities in Alzheimer's Disease." In Understanding Alzheimer's Disease. InTech, 2013.

5. Chancellor, Bree, Angel Duncan, and Anjan Chatterjee. "Art Therapy for Alzheimer's Disease and Other Dementias." Journal of Alzheimer's Disease 39, no. 1 (January 7, 2014): 1–11.

6. Mace, Nancy L. "Principles of Activities for Persons with Dementia." Physical & Occupational Therapy In Geriatrics 5, no. 3 (January 1987): 13–28.

7. Barnes, L. L., C. F. Mendes de Leon, R. S. Wilson, J. L. Bienias, and D. A. Evans. "Social Resources and Cognitive Decline in a Population of Older African Americans and Whites." Neurology 63, no. 12 (December 28, 2004): 2322–26.

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We believe that the architectural design in this area should be guided mainly by "other" factors, which transcend mere technical issues, although they should be taken into account. The complexity of the individual suffering from dementia is made up of impalpable aspects, which escape the logic of reason. Sounds, smells, temperatures, are all perceptive elements that give complexity to the individual's habitat and that, despite their importance, hardly are taken into account by legislation.

We take into consideration several case studies to focus and guide our study, very often referring to Alessandro Biamonti's work in the field of dedicated design and to the thoughts of medical experts such as Ivo Cilesi, a specialist in dementia studies, and Santiago Quesada, an authority in therapeutic architecture.

3.3.1 Corinne Dolan Alzheimer Center, Ohio, 1980s

The very first examples of villages dedicated to dementia can be found in America, where the Corinne Dolan Alzheimer Center opened in Cleveland, Ohio, during the second half of the 1980s. Since the beginning, one of the main objectives of the structure was to achieve a high quality relationship between staff, residents, and their families. To pursue this objective, there is currently one staff member per six residents in the village.

Patients were assigned to one of four different groups according to their social and cognitive skills.

- Community Circle: composed by the most socially capable residents. The activities performed in this circle are discussions, reminiscence, and nature walk.
- Family Circle: composed by residents with attention issues and fewer cognitive skills. The patients perform activities that were common in their past routine, such as looking at old photos or taking tea.
- Men's Club: Since there is a significant male presence the proposed activities are more comfortable for men and include gardening, woodworking, and yard work.
- Open Circle: conceived for residents with very limited communication and social skills. Individual needs of each patient are met through one-on-one tailored activities such as music, reading, sensory stimulation, and walks.

To perform these activities and to enhance or (at least) to maintain the patients' cognitive and social skills, many operations were applied in shared living spaces increasing social interaction and decreasing the hospital character. Taking into consideration the innovative approach of the Weiss Pavilion at Philadelphia Geriatric Center, large open spaces were created outside of the residents bedrooms, principles common areas find their place in a shared home atmosphere.

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3.3.2 Woodside Place-Osman, Pennsylvania, 1991

Following Cleveland's experience, the Woodside Place-Osman was inaugurated in Pennsylvania in 1991. Since most Alzheimer's sufferers need little medical care until the disease's late stages, nursing homes serve mainly for security, therefore, Woodside was meant to feel more like a home than a hospital.
Woodside structure was developed giving a big role to outdoor common spaces to give residents the sensation of a more familiar environment, based on the idea of a village settlement. Woodside residents maintain high levels of independence, particularly in their ability to move, eat, bathe, and dress.
A joint study by Pittsburgh and Carnegie Mellon University over an 18 month period showed that two-third of Woodside residents declined more slowly than Alzheimer's patients in a traditional nursing home, maintaining a higher independence level with respect to the others.

3.3.3 Hogeweyk, Netherlands, 1992

Hogeweyk is the first example of Alzheimer's Village in Europe. The idea of a village dedicated to dementia was born in a town close to Amsterdam in 1992. The first nucleus of the structure was inserted inside an existing assisted living residence with the aim of reducing the possible causes of BPSD (Behavioral and Psychological Symptoms of Dementia), improving the daily lives of the patients. To avoid the depersonalization of the individual life, a "neighborhood" configuration is adopted. The Dutch model has been quite successful and in 2009 the structure was expanded by reproducing a typical Dutch village featuring low buildings, gardens, tree-lined boulevards, and spaces where street artists could perform activities. Nevertheless, it was made sure to utterly guarantee the residents' freedom and safety in a controlled environment.

The pioneer model was taken as an example and replicated in other countries. We report some of them in chronological order: Alzheimer Center Fundacion Reina Sofia (Madrid 2007), Villafal Project (Trebago 2008), Boswijk Nursing Home (Vught 2010), Alzheimer Respite Center (Dublin 2010), up to the first Italian village: Il Paese Ritrovato di Monza, that opened in 2018.

For each of these case studies we tried to analyze and compare from a social point of view, through some diagrams, the relationships between: spaces for the exclusive use of individual residents, shared common spaces and outdoor spaces.

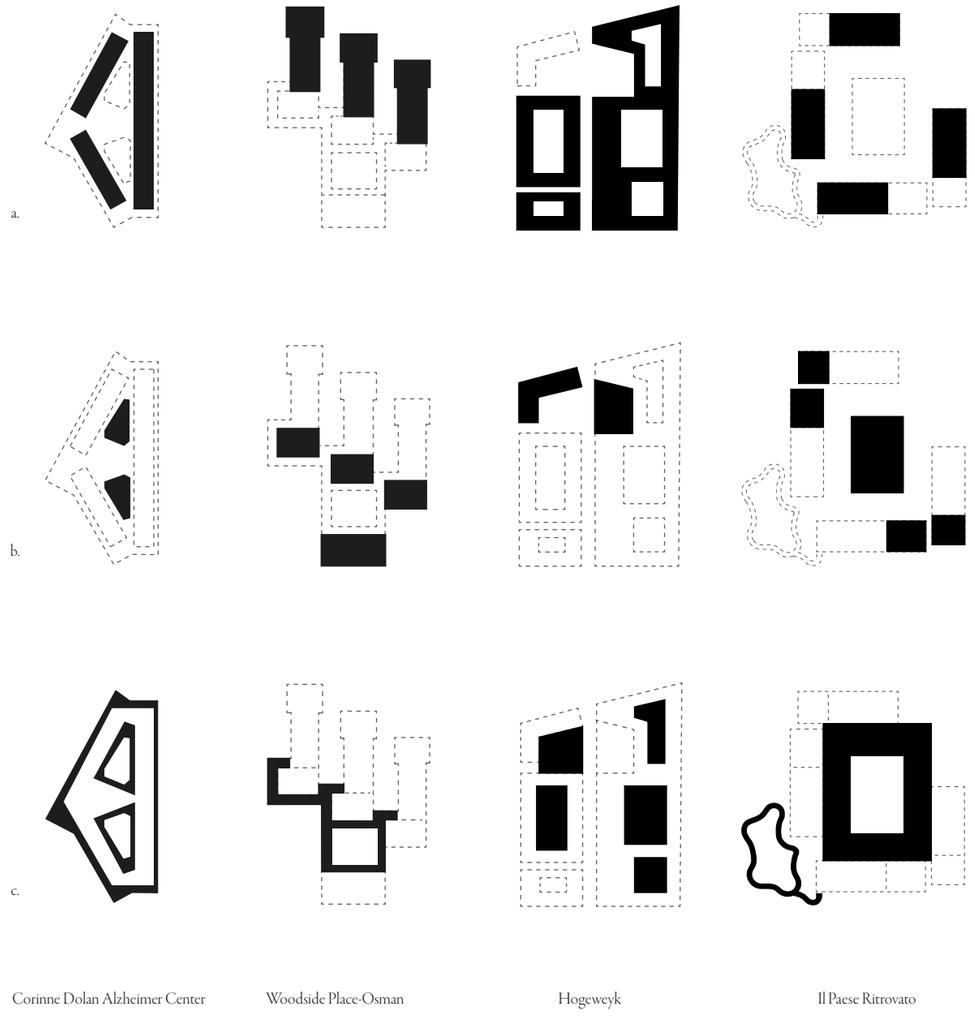


Figure 2.3, Alzheimer villages comparative schemes: a, households; b, family common spaces; c, interior and exterior wandering paths.

DATA ANALYSIS 4.

In order to have a deep understanding of the data at our disposal, we perform an initial extensive data analysis. We leverage a secure cloud database to access the data at any time and place and develop tools to easily interact with it. We perform a thorough preprocessing of the data to correct errors caused by sensor malfunctions and inaccuracies. We leverage the notion of Relational Index and define the Popularity Index to extract from the localization data information on the relationships between dwellers and the popularity of places respectively. Finally, we perform an additional analysis on the data collected during the Covid-19 pandemic to verify the occurrence of social distancing and isolation.

4.1 HANDLING THE DATA

The localization data collected at Il Paese Ritrovato are in the form of a MySQL data file. To avoid unnecessary conversion costs, we also opt for a MySQL database. To facilitate access to the data, we decide to create a database in Microsoft Azure, a cloud service that allows us to perform queries through the internet. Since we are handling private data, we revise Microsoft Azure privacy policy, verify its compatibility with the non-disclosure agreement we have signed, and protect our database with a strong password and whitelisted IP addresses.

Despite being a very popular query language among computer scientists, the members in our team have a varying degree of familiarity with SQL. We therefore decide to implement a database library acting as a wrapper of the MySQL database to render it easily interactable through high level Python objects and methods. This allows us to be far more productive when writing our data analysis scripts and avoid overhead costs related to familiarizing with the SQL language. Using Python to develop the wrapper also provides us with a much more powerful and expressive language. As an example, many functionalities provided by the library are implemented to account for many different time granularities such as day, hour, and minute. This allows us to later exclusively focus on the statistical and machine learning part of the problem and easily test new configurations without having to deal with cumbersome implementation details.

The database library is developed following the object-oriented programming paradigm, where entities are treated as objects that contain data in the form of fields and procedures. Examples of entities are patients and places in the village. The retrieval of the information related to a certain entity generally requires a query of the online database. To avoid performance degradation due to excessive number of transactions, whenever specific information about a certain entity is not needed, we refrain from retrieving data we will not use and refer to such entity using a simple identifier. Additionally, leveraging the static nature of historical data, we store the results of our queries in the local memory to maximize data reuse and avoid unnecessary remote data retrieval.
Nevertheless, we achieve a tradeoff between simplicity and performance of the library according to our needs. During the course of the data preprocessing and analysis phase the library is maintained and updated to offer new required functionalities and improve the performance of the ones that are excessively slow.

Finally, we try to provide a framework that is as general as possible, that is, compatible with a generic nursing home that has access to a database containing localization data about their patients. As an example, our library can be used in locations having space configuration and number of inhabitants that are different from the ones in our case study. We therefore hope that our library will prove useful to data scientists and researchers dealing with similar problems both in Il Paese Ritrovato and other assisted care homes in the world.

4.2 DATA CLEANING and PREPROCESSING

Preprocessing data is a fundamental step when it comes to data analysis. We identified a few problems with the localization system and hereby present the procedures and heuristics we used to solve them.
First, we observed that the granularity of the places is too fine, leading to several signal jumps, especially between two adjacent rooms. Then, we observed some impossible behaviors, such as repeatedly changing floors without taking any steps. These scenarios happen seldom, however ignoring them would result in inaccurate data, potentially hurting the statistical analyses, the performances of the predictive tools we intend to design and the architectural proposals' effectiveness.
Therefore, we decided to cluster some antennas together to increase the granularity (see *Fig. 4.2.2*) and obtain more reliable data. We identified rooms at the boundary as those rooms that are close to a cluster that is either a kitchen or a TV room. We observed that when dwellers are in the common apartment areas, sometimes their signal jumps in one of these rooms.

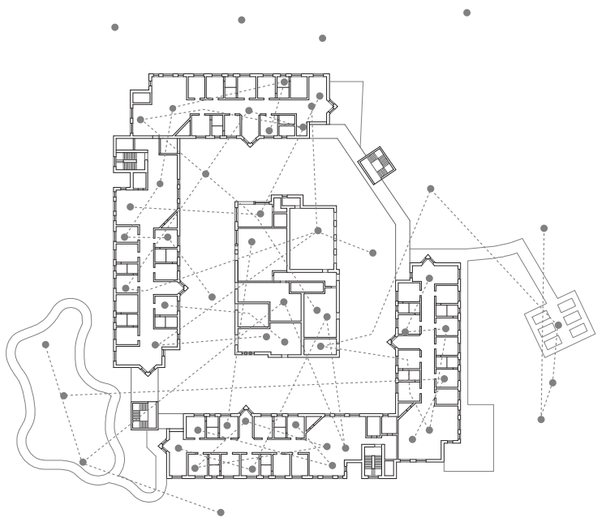


Figure 4.2.1, The data are collected by several antennas spread in the structure.

Figure 4.2.2, The criteria used to clean the data are hereby presented.

First, we considered some specific antennas: 136, 140 (inside or near the church) and 137, 139 (inside or near the bar) have signal issues. In general, people in the street may be erroneously registered as being inside the adjacent residential building due to the presence of residence antennas 76, 78, 80, 110. We want to avoid errors of this type, especially for the case of the antenna near the bar, as it represents a crucial spot for social interactions. For this reason, we corrected presumable errors with a simple heuristic that forbids abrupt movements from the street to the internal parts of the residential building: when a dweller is localized by the antenna inside or near the church/bar and by residence antennas immediately after, we assume that the dweller is standing near the church/bar instead of inside the residential building. The new positions can be interpreted as the most likely positions given the set of observations provided by the antennas up to that point in time, which is why in this case we consider the user to be in the street. Moreover, dwellers inside the residential building near antenna 154 (outside, in the park) are sometimes erroneously reported as outside the facility due to the presence of this antenna. In particular, the most affected antennas seem to be 28, 30 (near and inside the kitchen). We therefore applied the same heuristic as before.

After this preliminary cleaning, we substituted the current position identifier of the dweller with the respective cluster identifier. Then, assuming that dwellers can only be outside of their apartments between 6 AM and midnight, we checked the time and reset the position of those dwellers that happened to be not in their apartment to the cluster of their room. We believe this is a reasonable assumption to make. Moreover, we made sure that dwellers whose room is at the boundary are positioned in the rooms cluster when they are localized in their room, as they are much more likely to be in their room compared to others, who are instead probably in the kitchen or TV room even if localized in another dweller's room.
Finally, thanks to this cleaning and clustering step, we were able to obtain data much more consistent with reality, transforming outliers into useful data identifying and correcting errors. This step was only possible and significantly correct thanks to the domain knowledge of the caregivers.

4.3 MEASURING THE STRENGTH of RELATIONSHIPS: THE RELATIONAL INDEX

Building social well-being is crucial for "Il Paese Ritrovato". Being socially active, in the sense of spending time with others, allows people to feel less angry, lonely, and disconnected. Gaining insights on the social dimension can therefore contribute to the overall assessment of patients' well-being.
Social activities can be distinguished in: being with others, interacting with others, and participating in common activities .
While interaction detection requires dedicated devices and sophisticated techniques related to the field of Artificial Intelligence leveraging Computer Vision and Natural Language Processing techniques, the mere involvement in social activities can be inferred through the use of localization data. With the data at our disposal, we have information regarding which user is in a certain place at a certain time.
We hereby present a measure of sociability, namely the Relational Index, introduced by Masciadri et al.[1], and extend its definition to study the behavior of single individuals and of the entire community.

4.3.1 RELATIONAL INDEX

The Relational Index aims to estimate the relation between two individuals measuring the amount of time they spend together in a day. The Relational Index is defined for a couple of individuals *i*, *j* and it is calculated by counting the number of times the two individuals are located under the same space over a day. We adapted the calculation of the Relational Index to the newly defined spaces. We assume that users spend time together in the same bedroom quite seldom, so we neglect this case. The following is the definition of the Relational Index for individuals *i* and *j* on day *d*.

$$RI_{i,j}^{d} = \frac{\sum_{t=1}^{T} V_{i,j}^{d}(t)}{T}$$

where $V_{i,j}^{d}(t) = \begin{cases} 1 \text{ if } i \text{ and } j \text{ are in the same place (rooms excluded) on day } d \text{ at time } t \\ 0 \text{ otherwise} \end{cases}$

$T = 8640$, number of times data is sampled every day

T is the time horizon over which the calculation is made. In our case its value is 8640, since data is sampled every 10 seconds and we consider a whole day. The Relational Index assumes values in the interval [0,1], 0 being the two very socially distant and 1 being completely socially close. It must be noted that it is impossible for a pair of individuals to have a relational index equal to 1, since they are required to be in their room for the night and we assume that people cannot be in the same room, especially at night.

Individual Relational Index

We extend the definition of the Relational Index to capture the sociability of an individual dweller.

$$RI_{i}^{d} = \frac{\sum_{j \in A^d \setminus \{i\}} {RI_{i,j}^{d}}^2}{|A^d| - 1}$$

where A^d is the set of active users on day d

Since the Relational Index for an individual over the entire day is the mean of squares, spending a certain amount of time with one person is valued more than spending the same amount of time - cumulatively - with more people. For instance, an individual spending 1 hour in their kitchen with another person is considered more sociable than one spending only 5 minutes at the bar with 12 people. Yet, if the daily Relational Index were to be a linear mean, then the second individual would be considered as sociable as the first one. We prefer the first situation as we believe meaningful and strong bonds are more valuable than occasional presence in crowded areas.

Period Relational Index

We also define the Period Relational Index for a user as the average daily Relational Index over a period of time T:

$$RI_{i} = \frac{\sum_{d \in D} RI_{i}^{d}}{|D|}$$

where D is the set of days in the considered year

Community Relational Index

Finally, we define the Community Relational Index as:

$$RI^{d} = \frac{\sum_{i \in A^d} RI_{i}^{d}}{|A^d|}$$

where A^d is the set of active users on day d

An indicator of the combined sociability of all dwellers could reveal some important insights if used in the right way. For instance, caregivers could look at the long-term trend of this indicator in order to understand if there is an overall process of isolation going on. Indeed, in this sense, the usefulness of the indicator is similar to the Individual Relational Index, with the whole structure treated as if it were a unique patient.

4.3.2 HIGH LEVEL ANALYSIS

Individual Relational Index

The first type of analysis we carry out is the study of the graph of the Individual Relational Index, which shows the sociability trend over the year for a specific user...

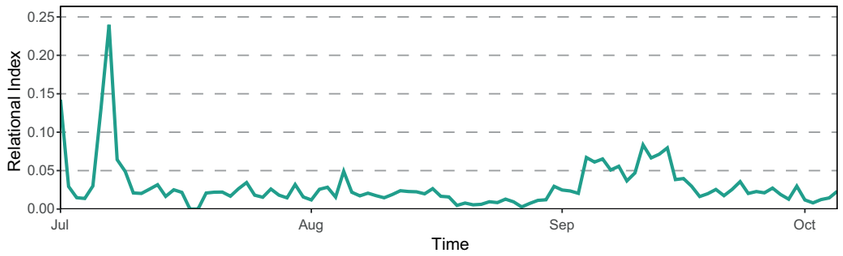
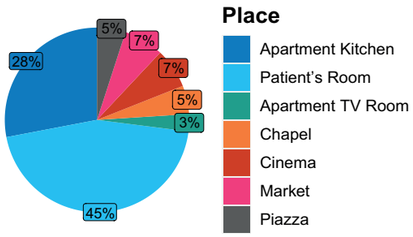


Figure 4.3.2, Individual Relational Index plot.

The graph of the Individual Relational Index could be quite useful for caregivers to monitor the progression of the disease. For instance, registering a decreasing trend in a certain period of time could mean that the patient is isolating themselves for some reason. In *Fig. 4.3.2*, the change in late September could be investigated further by doctors and caregivers.

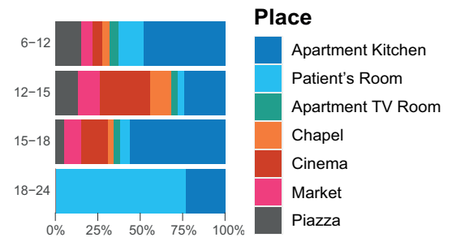
User Profiling

Localization data can show how the typical day of a resident looks like by observing which are the visited places and comparing them with the Relational Index. This might be a useful tool to understand factors influencing and promoting sociability.
For instance, user 22, who lives in room 11 at the ground floor, typically has a high Relational Index. From an analysis of the whole year, it is evident that the places they visit the most daily are their room, the TV area and the kitchen of their apartment. However they also enjoy hanging out at the cinema, spending time at the bar, at the chapel, at the gym and around the city center.



Visited Places Pie Chart.

Usually, user 22 prefers going to the cinema in the early afternoon to attend the organized activities, while they attend the gym, the chapel and the kitchen in the morning. Between an activity and another they like to talk with their friends in the city center and at the hairdresser. This daily routine results in an average walking distance per hour of 230 meters.



Visited Places by time of the day.

User 22 is an outgoing and sociable person. Indeed, they have many friends, like dweller 104, 94, 23, 26 and 27, as they spend quite a lot of time together. For instance, they usually enjoy staying in the kitchen with dwellers 27 and 28, with whom they share the apartment, and also watching a movie at the cinema or praying at the chapel with dwellers 26 and 94.

Close Friends

We study the behaviour of two dwellers that are particularly close to each other, in order to understand which are the places that they visit the most and what could have made them be so close.
For instance, a really close couple of friends is composed by user 22 and user 26 who have an average relational index of 0.20 in the whole year, which shows that generally they spend a lot of time together. Considering the localization data at our disposal, we imagine what a typical day may look like for the couple of friends.

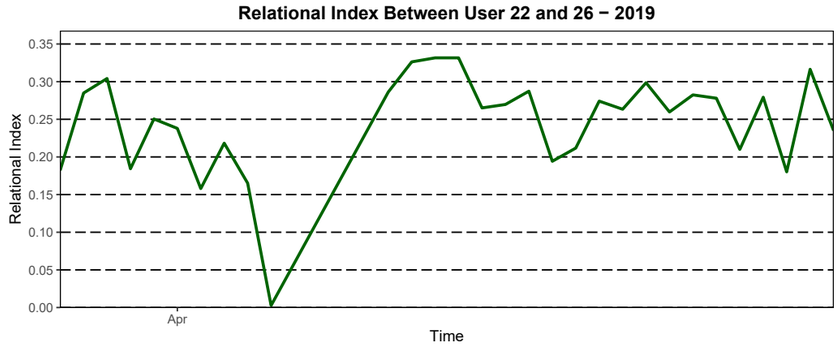
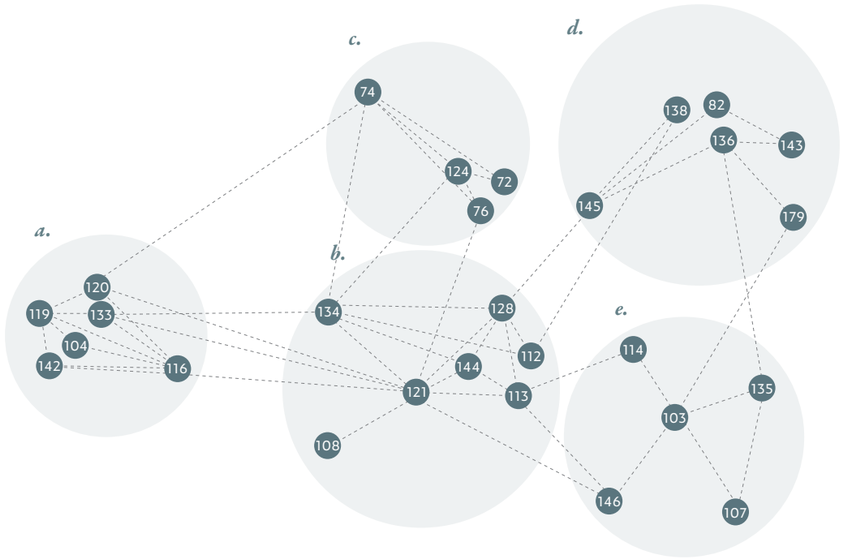


Figure 4.3.3, Relational Index Between User 22 and 26.

The two considered users live in the same apartment and their rooms are really close. Usually they like to spend a lot of time together, talking, eating and also going for a walk in the city center.
We observe their favorite activity is going to the cinema to watch movies together, especially in the afternoon. Afterwards, they go for walks in the city centers, sometimes together with other dwellers. Moreover, they seem to enjoy going to the laboratory, the chapel, and the gym, depending on the organized activities. Generally, they like going out together, as when they are alone they are usually in their own rooms, and if one partakes in any activity, the other generally follows along.
We suppose that both of them are sociable, outgoing and likeable, and thanks to this they have many friends and like to spend time with other dwellers too.

Finally, we present the social network of a day in *Il Paese Ritrovato*, where closeness between two dwellers indicates they are more socially related.



Residents ID

Residents belonging to the same apartment

a. *Betulla Rooms*

b. *Faggio Rooms*

c. *Lanterna Rooms*

d. *Pendolo Rooms ground floor*

e. *Pendolo Rooms first floor*

Figure 4.3.4, Social network of a day in Il Paese Ritrovato.

This graphical tool allows the identification of clusters of residents, close friendships, and social isolation for a better understanding of the social behavior of the community.

4.3.3 CORRELATION ANALYSIS

We carry out a statistical analysis to understand which factors influence the social behavior of residents the most, and consequently leverage the insight obtained to promote sociability to ultimately slow down the progress of the disease. We study the correlation of the Relational Index with the following factors: the season, the temperature, the dweller's bedroom floor, the predisposition to walk on a certain day, the patient's average hourly walked distance and the weather.
The analysis has been carried out using two methods: linear regression and chi-squared independence test through contingency matrices. We decide to consider these two models for their reliability and compare their results for validation.

Linear Regression

In statistics, linear regression is a linear approach to model the relationship between a scalar response, the dependent variable, and one or more explanatory variables, the independent variables, using linear predictor functions whose unknown parameters are estimated from the data. Linear regression analysis can be applied to quantify the strength of the relationship between the response and the explanatory variables, and in particular to determine whether some explanatory variables have no relationship with the response at all.
Given a data-set $\{y_i, x_{i1}, ..., x_{ip}\}$ of n statistical units, the relationship is modeled through a disturbance term or error variable ε — an unobserved random variable that adds "noise" to the linear relationship between the dependent variable and regressors.

Thus the model takes the form:

$$y_i = \beta_0 + \beta_1 x_{i1} + ... + \beta_p x_{ip} + \epsilon_i, \qquad i = 1, ..., n$$

Since the goal of our analysis is to study the existence of any kind of relationship between the dependent variable (i.e. the Relational Index) and the independent variables, we neglect the goodness of the estimation, focusing our attention on the values of the regression coefficients β, which capture the significativity of the independent variables. Indeed, it's simple to understand that if β is really close to *0*, then the *i-th* independent variable is likely not to influence the dependent variable. In other word, this is the test is carried out for each independent variable:

$$H0 : \beta_i = 0$$
$$H1 : \beta_i \neq 0$$

The *p*-value can be seen as a statistical descriptor of the level of significance for which the null hypothesis *H0* would be rejected. Herein, we decide to consider a threshold α*=0.05*, such that if the *p*-value is less than α, then we reject *H0*.
We consider the relational index as the dependent variable, and the temperature, the weather, the walking index, the movement per hour, the bedroom floor and the season as the independent variables.
Applying ordinary least squares, our analysis shows that temperature, movement per hour, floor, spring and summer are correlated to the relational index (since their p-value is strictly less than the threshold 0.05). On the other hand we obtain that winter, walking index and weather are not. For what concerns the former, this is due to the lack of data (only 8% of all the data were taken in winter time), while for the other two this is probably due to the fact that they are multicollinear with the other independent variables temperature and season.
The R^1 index is only 15,7%. This result could seem quite poor, however,in social sciences it is quite common to witness R^2 indexes lower than 30-40%; this is because in this field of study, it is much more difficult to determine the real relationship between predictors and response.

Contingency Matrix

In statistics, a contingency table, also known as a cross tabulation or crosstab, is a type of table in the form of a matrix that displays the multivariate frequency distribution of the variables. It provides a basic picture of the interrelation between two variables and can help in finding interactions between them.
Given two data sets $\{x_1, ..., x_N\}$ and $\{y_1, ..., y_N\}$ of N statistical samples of two variables X and Y, we first discretize the domain of the two variables identifying the set of values $(X_1, ...X_k)$ and $(Y_1, ...Y_h)$ that each variable may assume. Then, we build the contingency matrix in the following way: the (*i,j*)-th element is the number of times that the couple (x_n, y_m) is equal to the couple (X_i, Y_j) . In this way, we define the frequency of (X_i, Y_j) .

Once the matrix is built, we can construct the χ^2 independence test:

$$H0 : X \perp\!\!\!\perp Y$$
$$H1 : X \not\perp\!\!\!\perp Y$$

Defining the statistical variable:

$$\chi_0^2 = \sum_{i=1}^{N}\sum_{j=1}^{N}\frac{(n_{ij} - E_{ij})^2}{E_{ij}}$$

where $n_{ij} = \#\text{observations where } \{x = x_j, y = y_i\}$; $E_{ij} = \frac{\sum_{i=1}^{N} n_{ij} \sum_{j=1}^{N} n_{ij}}{\sum_{i=1}^{N}\sum_{j=1}^{N} n_{ij}}$

we reject *H0* if $\chi_0^2 > \chi^2_{1-\alpha}((N-1)(N-1))$, where α=*0.05* and $\chi_0^2 \sim \chi^2((N-1)(N-1))$.
Even though this method is less intuitive than linear regression, we decide to adopt it mainly for two reasons. First of all, because it has a strong statistical basis that makes it reliable, and yet at the same time really simple to use and apply to our dataset. Second, because we want to be sure that the results we get in the first analysis are consistent. However, we also resort to linear regression as the former can only be used to study the dependence of exactly two variables, and hence it does not provide an overview of the relationship between all the independent variables with the dependent one.
Again, we study the correlation between the Relational Index and the aforementioned variables.

Using the contingency matrix method, only the weather seems to be uncorrelated. Since linear regression also suggests this, we conclude that the dwellers' behavior is not influenced by the weather, probably due to the fact that the places they visit the most (kitchens, TV areas and the central areas) are indoor.

Conclusions

We have conducted statistical analysis on the Relational Index to understand which factors influence the social behavior of patients of Il Paese Ritrovato. Through linear regression and chi-squared independence test, we observed that many of the considered variables (the season, the temperature, the dweller's bedroom floor, the predisposition to walk on a certain day, and the patient's average hourly walked distance) influence sociability. Therefore, these factors are to be taken into consideration when planning activities and designing spaces.

4.4 ASSESSING THE ATTENDANCE OF PLACES: THE POPULARITY INDEX

Popularity Index Analysis

Along with the relational index analysis, we believe that it could be useful for the caregivers to know the popularity of the places in *Il Paese Ritrovato*. According to the data at our disposal and the context in which we are operating, our definition of

"popular place" is given in light of this statement: the more a place is frequented, the more it can be considered popular. Even if it is a rather simple consideration, this is everything we can use to obtain information, since we only have data about the visited places of the dwellers and nothing about their social or psychological aspects. Knowing, for instance, some key content of their character, one may also consider not only how many people are in a place but also which kind of people are there. It is clearly different if we have shy or talkative people. We also need to remember that all patients are diagnosed with Alzheimer, so their way of interacting with one another is way different from our usual way of thinking. Thus, while for ordinary, healthy people this consideration is not enough to infer about the sociability of a specific place, for people with Alzheimer this can be enough.
Based on the popularity of each place, managers can easily understand which places are more likely to attract a large crowd and which ones are less visited. Depending on the circumstances, higher or lower levels of popularity may be desired for a given place, which can be achieved by implementing architectural changes and redesigning the space around it. Furthermore, a manager may also want to know a prediction of how much a place is expected to be popular, as in crowded, in a given moment in the future, so that they can dynamically vary their schedule to exploit this information.

Hourly Popularity Index

To achieve these objectives, we first need to formally define a measure of popularity of a place. In particular, we want the popularity measure of a place *p* to be positively correlated with the number of people that visit *p*. As a consequence, we firstly introduce the Hourly Popularity Index. Namely, let $n_p^d(h)$ be the number of detected individuals in place *p* over an hour starting from hour *h* on day *d*. Then, the Hourly Popularity Index of place *p* on day *d* and hour *h* is defined as:

$$HPI_p^d(h) = \frac{n_p^d(h)}{|A^d(h)|},$$

where $A^d(h)$ is the number of active users on day d and hour h.

Having defined this index, we describe each place *p* with 4 vectors, one for each season, since we expect the dwellers to behave differently according to the season. The first half of each vector depends on the average Hourly Popularity Index of *p* in *s*, while the second half depends on the relational indexes of people seen inside *p* in *s*.

For each of the seasons, we train an autoencoder[2] to study the distribution of the places in the latent space provided by the central layer of the network through clustering, to find groups of places sharing similar features, such as their average crowdedness or the average sociability of the people visiting. Unfortunately, we have not managed to obtain autoencoders capable of accurately reconstructing the input, causing our obtained latent space to not be very meaningful.

2. https://towardsdatascience.com/generating-images-with-autoencoders-77fd3a8dd368.

Given this inconcludent result, we have decided to completely change our approach to the problem. We start again by observing the data we have at our disposal, i.e. the hourly accesses into a generic place of *Il Paese Ritrovato*.

Daily Popularity Index and Functional Embedding

The main issue while dealing with these data is the fact that we have attendance observations which depend on time, since they are recorded every hour of every day. Consequently, looking at the data in their roughest shape, the affluence of people in each site may change a lot even during a single day. On the other hand, we want to find results which are independent of time, in the sense that we would spot those places which are, in general, more attended and, on the other hand, the never-used ones. To do so, we decided to decrease the granularity of the data we analyze, considering a "day" as a unit of time, instead of an hour. Nonetheless, we need a way to take into account the time and, at the same time, provide results that are not strictly bonded to it. After some discussions, we ended up with the following idea: once a specific place is selected, all the attendance data are interpreted as a time series. Going a little further, if we manage to produce a proper index that summarizes how much a certain space is frequented, we can interpret the whole time series as a function of time *f(t)*. Hence, the resulting data are functional data, on which we can apply various techniques that are inherited from a branch of Statistics called Functional Data Analysis[2].
As a summary index, we introduce the Popularity Index: a measure of the attendance of a place. Namely, let $n_p^d(h)$ be the number of detected individuals in place p over an hour starting from hour h on day d, as previously defined. Then, the Popularity Index of place p on day d is defined as:

$$PI_p^d = \frac{1}{|A^d||D|} \sum_{h \in D} n_p^d(h)$$

where A^d is the set of active users on day d
D is the set of hours in which users are generally awake.

Basically, this index is the **18-hour averaged accesses in a certain place, normalized by the number of active users**: in this way we obtain a little smoothing through the averaging procedure, we focus on the part of day in which social interactions are relevant and, finally, the normalization makes the index fully objective, avoiding potential biases simply due to an higher number of tracked individuals.

Once the Popularity Index is defined, the curves need to be smoothed, i.e. interpreted as a discretized sample of a continuous function, in a suitable functional space. In this frameworks, a statistic unit, i.e. a generic curve Y_i, is seen as a linear combination of functions:

$$Y_i(x) = \sum_{j=1}^{N} \alpha_{ij} \varphi_j(x) + \varepsilon_i$$

where $\{\varphi_j(x)\}_{j=1:N}$ are a set of suitable basis functions
the coefficients vector $\boldsymbol{\alpha}_i$ is to be determined.

At this stage, the crucial aspect is to select the proper basis function. Due to the fact that the time series do not exhibit any kind of evident periodicity, the fact that data are non-negative and the fact that we require a certain degree of tuning in order to clean some noise residue, we ended up choosing penalized B-spline basis functions of 3rd order[3].

3. Paul H. C. Eilers, and Brian D. Marx. Flexible Smoothing with B-splines and Penalties. Statistical Science 11, no. 2 (1996): 89-102.

These type of smoothing allows us to:

- Gain some regularity of the function, since at third order, functions are of class C^3;
- Preserve the non-negativeness of the functions, since we choose to penalize, through a parameter λ, the 1st derivative of the smoothed curves, thus letting us free to smooth strong peaks of noise;
- Avoid to fix the dimension of the basis space, since with this type of splines the dimension is automatically selected in order to generate curves that blindly follow the original data.

In *Figure 4.4.1* there is a comparison between the curves before and after the smoothing procedure. The result, which clearly preserves the main characteristics of the original curves and visibly reduces the residual noise, is quite satisfactory.

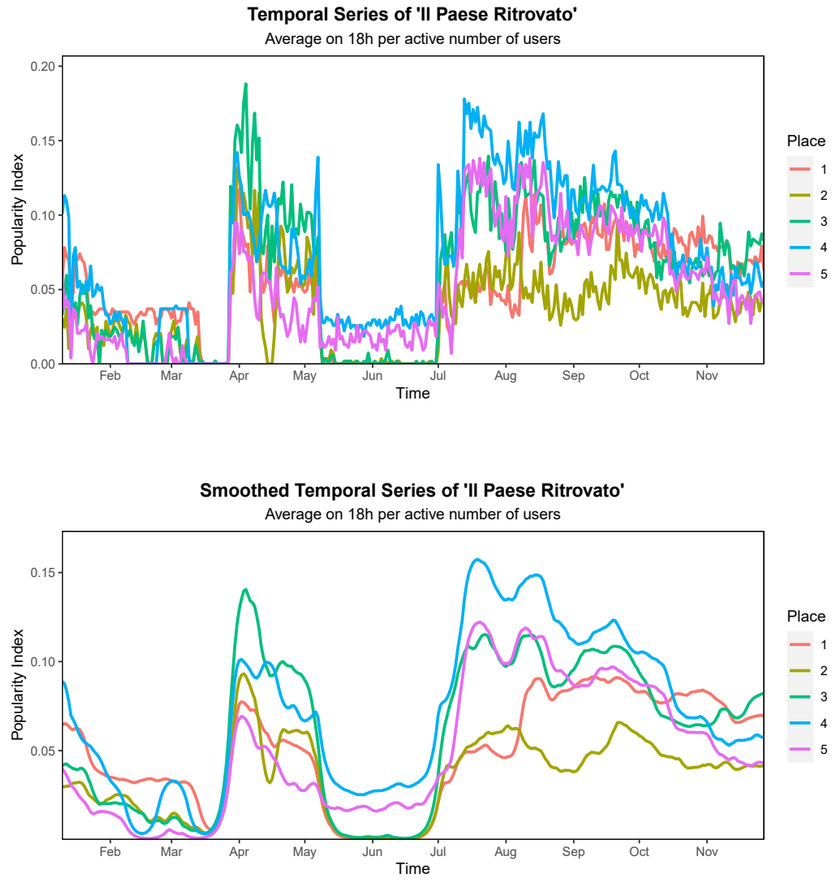


Figure 4.4.1, Temporal series of Popularity Index at some locations before and after smoothing.

Functional K-Means Clustering

We are now ready to apply typical methodologies proper of Functional Data Analysis (FDA) in order to detect common features and patterns among the places of the facility. Since we aim to elicit some hidden pattern in how different spaces are attended during our observation period, the most intuitive thing to do is to perform a clustering, in order to highlight some common behavior among groups of spaces. While dealing with functional data that describe a phenomenon which depends on time, the collected curves may not be aligned. If not taken properly into account, the misalignment acts as a confounding factor and may blur subsequent analyses. We have at our disposal a functional extension of the well known K-means algorithm[4], named *kma* which also perform, automatically, the alignment of our data through a continuous registration procedure (for further reference about how it works[5], while for its implementation and an example of application[6]). The last choice that needs to be taken regards the distance with which two curves are compared. While in usual cases, where data are points in R^n, all distances are equivalent, in this case the output of the clustering algorithm truly depends on the choice of the similarity function.

As metric we choose the D0 - Pearson distance, which is defined as:

$$d_{P_0}(f_1, f_2) := \frac{\langle f_1, f_2 \rangle_{L^2}}{\|f_1\|_{L^2} \|f_2\|_{L^2}}$$

where $\langle \cdot , \cdot \rangle_{L^2}$ is the usual L^2 inner product and $\| \cdot \|_{L^2}$ is the induced norm.

This kind of metric is the functional equivalent of the correlation coefficient among two sets of data in traditional statistics. This similarity metric tends to group together functions that manifest a similar shape without keeping into account their amplitude. Consequently, with this choice, we group together spaces that share a similar occupation trend throughout the observation period, regardless from the fact that those spaces are attended less or more than the mean.

This choice entails, on one hand, that we hope to depict some sort of seasonality among different clusters and, on the other hand, that another type of analysis must be introduced to highlight whether a space is highly attended or not. We perform functional k-means clustering with the aforementioned settings, detecting non-trivial and peculiar trends exhibiting some sort of time dependence (see *Figure 4.4.2*), thus obtaining four clusters of places.

4. see MacQueen, James. "Some methods for classification and analysis of multivariate observations." In Proceedings of the fifth Berkeley symposium on mathematical statistics and probability, vol. 1, no. 14, pp. 281-297. 1967.

5. Sangalli, Laura M., Piercesare Secchi, Simone Vantini, and Valeria Vitelli. 2010. k-Mean Alignment for Curve Clustering. Computational Statistics & Data Analysis 54 (5): 1219–33.

6. Patriarca, Mirco, and Simone Vantini. 2013. Review of Development of the Fdakma R Package for the Joint Alignment and Clustering of Functional Data : Application to Neuronal Spike Trains Data. Master Thesis, Politecnico di Milano.

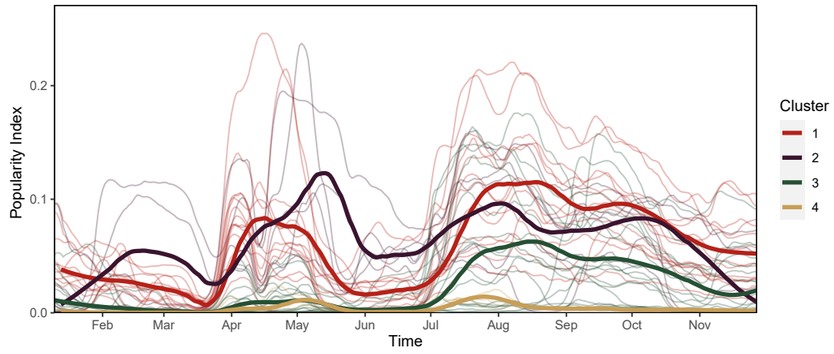


Figure 4.4.2, Popularity Index plot and identified clusters of places.

The thicker curves in the foreground, representing the identified clusters, are the main Popularity Index trends distinguished inside *Il Paese Ritrovato*: we observe which places are more frequented (clusters 1 and 2) and which are less popular (clusters 3 and 4). Places belonging to the different clusters are depicted in Figure 4. Note that cluster 2 is generally more popular than cluster 1 during the first half of the year, while we may observe an opposite behavior in the second half; cluster 3 shows an increasing popularity in the second half of the observance period; cluster 4 is stable and represents those areas that are barely visited by the residents. This procedure groups together places exhibiting a similar trend during the observation period. As a consequence, the metric introduced for clustering is blind towards constant shifts. More specifically, clusters 1 and 2 show higher curves, but only represent an average trend. Hence, places belonging to these clusters may not be so popular.

Functional Principal Component Analysis

To enrich the aforementioned results, we perform a functional principal component analysis (FPCA) detecting those features clustering may leave unseen. This methodology is just a functional extension of the usual principal component analysis[7], that is often used in multivariate statistics. PCA, in its original form, is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The various components are selected in order to maximize the variance at each step and a result is simply achievable through a spectral decomposition. In a functional setting, as a matter of fact, we do exactly the same thing, i.e. given a set of N zero-mean functional observations X in I$\mathcal{H}$ Hilbert space, $\forall k = 1, \ldots, N$ we look for a function ξ_k .

$$\xi_k = \underset{\xi \in H}{\operatorname{argmax}} \frac{1}{N} \sum_{i=1}^{N} \langle \xi, \mathbf{X} \rangle_H$$

s.t. $\|\xi_k\|_H = 1$ and $\langle \xi_k, \xi_j \rangle_H = 0$ if $j < k$. If we consider our case, we embedded our curves in L^2, so this procedure is perfectly viable. As happens in the traditional case, the problem is solved through the spectral decomposition of our functional dataset into eigenfunctions, which are usually named harmonics, and their associated eigenvalues, called loadings. Through the first two principal components, interpreted in terms of their contribution as perturbations with respect to the average curve, we are able to explain more than 80% of the total variance. The considered principal components are summarized through FPCA scores, preserving the respective component interpretation and resulting in a clearer graphical representation. The score of the first principal component captures the variance in the popularity of a place with respect to the average value for the whole observation period.

Considering the two halves of the observation period, the score of the second principal component rewards a place for its popularity in the first half and penalizes it for its popularity in the second half.

7. see Pearson, Karl. 1901. On Lines and Planes of Closest Fit to Systems of Points in Space. The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science 2 (11): 559–72.

Hotelling, H. 1933. "Analysis of a Complex of Statistical Variables into Principal Components." Journal of Educational Psychology 24 (6): 417–41.

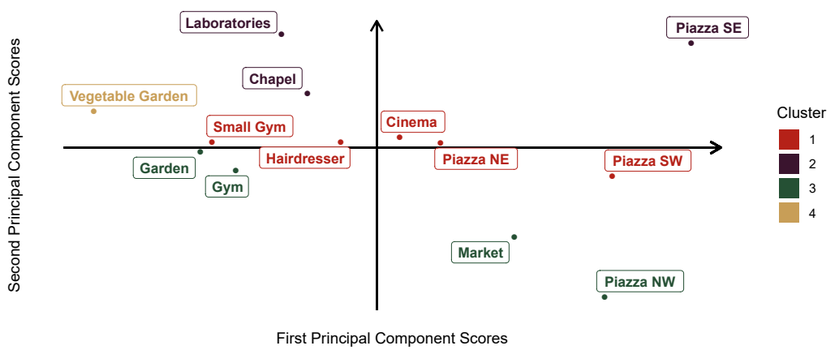


Figure 4.4.3, Functional components scores scatter plot for public social places. Places on the right (left) are quite popular (unpopular) among residents; those at the top (bottom) are more popular during winter and spring (summer and autumn). Places on the left definitely need enhancements.

This analysis truly extends the results obtained through clustering, since we can observe strong coherence in the outcomes, constituting highly reliable and valid hypotheses for future interventions. Combining the results of the presented analyses, we can clearly identify neglected places in need of enhancements. For instance, the outdoor areas, namely the vegetable garden and the garden, are rarely frequented.

Conclusions

We have performed an in-depth analysis on the Popularity Index of places inside *Il Paese Ritrovato* in order to highlight which are the highly frequented areas and those in need of enhancement. Through a proper functional embedding and typical methodologies of functional data analysis, we have managed to group together places that shares a common pattern in terms of daily popularity index and rank them according to their popularity throughout the whole period and also according to cold and warm seasons. The results obtained with these two methods are widely related thus witnessing the goodness of the overall analysis.

4.5 COVID-19 ANALYSIS

COVID-19 is the infectious disease caused by the most recently discovered coronavirus. This new virus and disease were unknown before the outbreak began in Wuhan, China, in December 2019. COVID-19 is now a pandemic affecting many countries globally[8]. The first reported case of COVID-19 in Italy dates to January 30th 2020, a couple weeks later, on February 17th, the first cluster was identified in Lombardy, and on March 8th Lombardy was locked down: people could only go out of their houses to buy food or for proven working needs and commercial closed down[9]. Prevention measures include wearing a mask to cover one's mouth and nose, washing and sanitizing hands regularly, and, most importantly, keeping a considerable social distance of at least 1 meter. The disease symptoms comprise those of a regular fever, in addition, however, COVID-19 causes shortness of breath, leading to respiratory failure in the worst cases.

The mortality rate is around 4%, however, it is important to note that it rises up to 11% for people between 60 and 70 years, to over 26% for those between 70 and 80, and finally to over 33% for those over 80 year old. Therefore, hospitals and care homes (should) have respected rigorously the preventive measures to avoid the spread of the disease among those who would suffer the most and are more likely to die from it.
Also Il Paese Ritrovato had to put into place these measures, including limiting the accessible places to the apartments, thus enforcing social distancing among dwellers and caregivers.
We hereby briefly present the impact of COVID-19 on the community of *Il Paese Ritrovato* in terms of sociality and frequented places just prior to the lockdown, during and after it.
We observe the Community Relational Index during the period from January 2020 to June 2020 (*Figure. 4.5.1*)

8. https://www.who.int/emergencies/diseases/novel-coronavirus-2019.

9. https://en.wikipedia.org/wiki/COVID-19_pandemic_in_Italy#Under_national_lockdown.

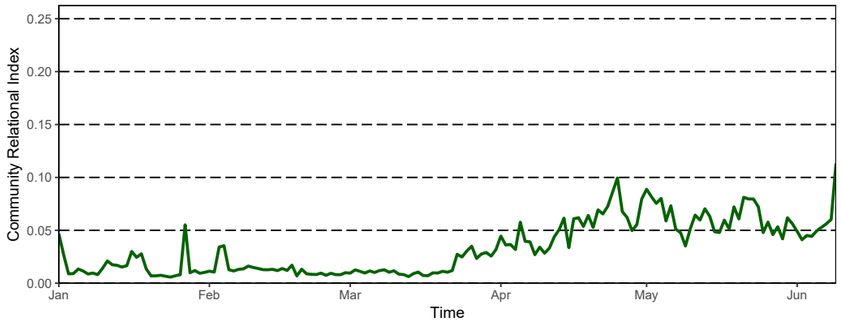


Figure 4.5.1, Community Relational Index January-June.

The first period until the beginning of February is characterized by a steady low/medium Community Relational Index, probably due to the weather not being pleasant, with some peaks in correspondence of weekends, during which relatives usually visit their loved ones, so that even less sociable dwellers are encouraged by their relative to spend more time in public areas rather than alone in their room. Starting from early February the sociality in *Il Paese Ritrovato* is very low, almost *0*, showing that patients were constrained to their rooms and apartments. It is only at the end of March that the sociality index starts to rise, probably thanks to the preventive measures that were solidly in place throughout the village, to the awareness of the absence of infected dwellers and staff and to the new organization allowing dwellers to spend time with one another.

Along with the observation of the Community Relational Index, we also observe, for the same time period, the Popularity Index of places in *Il Paese Ritrovato*. *La Meridiana* let us know that all public areas have been closed during the lockdown phase as a measure for preventing the disease spreading, letting the dwellers stay all day inside their own apartment. Hence, we decided to observe the pattern of the Popularity Index for apartments and public areas separately. The results are shown in *Figure 4.5.2 and 4.5.3.*

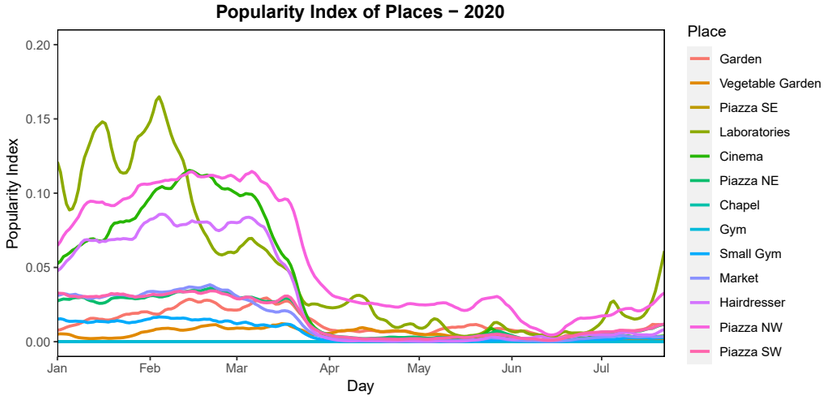


Figure 4.5.2, Popularity Index of Places 2020.

For all public areas of the structure, starting from the middle of March, we observe a sharp drop in the Popularity Index of these places. These results are clearly in line with the COVID-preventing measures adopted and declared by *Il Paese Ritrovato*. We can also observe a timid increase in the Laboratories at the end of the observation period, thus anticipating a relaxation of the measures also inside the structure.

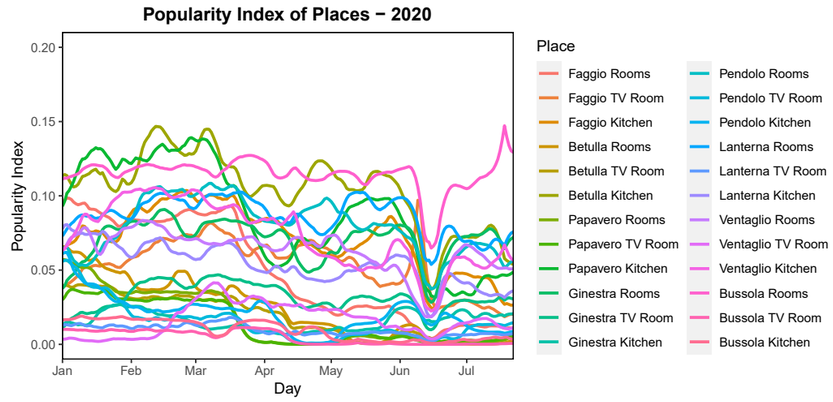


Figure 4.5.3, Popularity Index of Places 2020 January - June.

As far as apartments are concerned, we notice that the Popularity index of these places is essentially constant during the whole observation period. This fact can also justify the unexpected increase in the Community Relational Index from mid March to June observed in *Figure 4.5.3*: since dwellers are forced into their own apartments, sharing common areas such as corridors, TV rooms and Kitchens may encourage them to socialize with their flatmates as they are the only ones they can interact with, thus increasing both the Popularity Index of these places and their own Relational Index, with a consequent increase in the Community Relational index as well.

In this Section we have inquired about the impact of COVID-19 on *Il Paese Ritrovato*. We observe that social distancing is respected, especially during the critical months of February and March, and that starting from the end of March sociality starts to go back to normal, with a substantial increase at the end of April, probably due to the internal lockdown of patients in their own apartment but also thanks to warmer temperatures and to the more enjoyable season. Finally, the measures implemented during the lockdown phase are perfectly mirrored in the Popularity Index of Places, where we observe a significant drop for all public areas inside the structure.

5. DATA-DRIVEN PREDICTIONS

In this section we propose and describe our core solutions for *Il Paese Ritrovato*, which leverage statistical analysis of the localization data and thorough state-of-the-art knowledge on AD-sensitive architecture.

Our statistical analysis is centered around the definition of Relational Index provided by Masciadri et al. [1], which is then further extended and manipulated for our objectives. The resulting indexes can be of great utility for managers, caregivers, doctors, and the staff of *Il Paese Ritrovato*, as they summarize complex information on social dynamics into a small set of parameters easy to comprehend and monitor, as well as enable the development of predictive tools, which can be of great help when planning activities. To demonstrate this, we also provide examples of ways in which, starting from high-level visualizations of the data and the resulting predictions, it is possible to evaluate the social well-being of patients or to support activities planning for the week.

Indeed, the knowledge obtained from the data is used to suggest possible architectural interventions in *Il Paese Ritrovato*. We propose to act on the home environment to considerably improve the well-being of the patients, mitigating the risk of crisis and promoting mental stability. To accomplish this, we leverage sensory maps to investigate intimate and subjective aspects of each patient through their sensory memories and routines. Space thus becomes part of a non-pharmacological therapy.

In the following sections we describe the process through which we obtain our predictive models. When training our models to predict, we want to adapt to possible evolutions in the behavior of the patients. To accomplish this, we discard or give less importance to old data records in the dataset by employing a sliding window approach. Still, this decision must be carefully evaluated, as too few training data samples can lead to overfitting when leveraging machine learning techniques.

1. Masciadri, Andrea, Sara Comai, and Fabio Salice. "Wellness Assessment of Alzheimer's Patients in an Instrumented Health-Care Facility." Sensors 19, no. 17 (2019): 3658.

5.1 PREDICTING THE SOCIABILITY of THE COMMUNITY

In Section 4.3, through an in-depth analysis of the correlation between the social behavior of individuals measured through the Individual Relational Index and other variables, we observed patients' social behavior is dependent on almost all of the considered ones. We now wish to exploit the observed dependence and predict the social behavior of the whole community given some of these variables. Our ultimate aim consists in better organizing social activities at *"Il Paese Ritrovato"* by considering this prediction, as well as that of the Popularity Index.

Community Time-Specific Relational Index

Shifting the attention from the individual patient to the whole community, we define the Community Time-Specific Relational Index, for a specific time of the day.
We first introduce three time-specific measures.

$$RI^d_{i,j,\hat{T}} = \frac{\sum_{t\in\hat{T}} V^d_{i,j}(t)}{|\hat{T}|}$$

where $V^d_{i,j}(t) = \begin{cases} 1 & \text{if } i \text{ and } j \text{ are in the same place (rooms excluded) on day } d \text{ at time } t \\ 0 & \text{otherwise} \end{cases}$

$\hat{T}$ is the considered time of the day

We define the Time-Specific Relational Index for two individuals as their Relational Index limited to a specific time of the day.
Then, we define the Time-Specific Adjusted Relational Index for individual *i* in relation to individual *j* as:

$$\widehat{RI}^d_{i,j,\hat{T}} = \begin{cases} RI^d_{i,j,\hat{T}} + (1 - RI^d_{i,j,\hat{T}})(RI^d_{i,j,\hat{T}} - RI^d_i) & \text{if } RI^d_{i,j,\hat{T}} - RI^d_i \geq 0 \\ RI^d_{i,j,\hat{T}} + RI^d_{i,j,\hat{T}}(RI^d_{i,j,\hat{T}} - RI^d_i) & \text{otherwise} \end{cases}$$

where $\hat{T}$ is the considered time of the day

This index measures the social interactions between individuals *i* and *j* taking into consideration the Individual Relational Index of individual *i*. This latter index serves as a way to reward (penalize) the relationship between *i* and *j* if it contributed positively (negatively) to the Individual Relational Index of *i*.
Furthermore, we introduce the Individual Time-Specific Adjusted Relational Index for individual *i*, as the average of his/her Time-Specific Adjusted Relational Index with the rest of the community, during a specific time of the day.

$$RI^d_{i,\hat{T}} = \frac{\sum_{j \in A^d \setminus \{i\}} \widehat{RI}^d_{i,j,\hat{T}}}{|A^d| - 1}$$

where $\hat{T}$ is the considered time of the day
A^d is the set of active users on day d

Finally, we define the Community Time-Specific Relational Index as the average of the Individual Time-Specific Adjusted Relational Index of every member of the community.

$$RI^d_{\hat{T}} = \frac{\sum_{i \in A^d} RI^d_{i,\hat{T}}}{|A^d|}$$

where A^d is the set of active users on day d

Variables Choice

In Section 4.3 we observed the correlation between the social behavior of a patient and the following variables: season, temperature, weather, patient's bedroom floor (ground or first floor), predisposition to walk on a specific day, and patient's average hourly walked distance. All the considered variables, except for the weather, are strongly correlated with the social behavior of patients. As we want to predict the social behavior of the community, among these variables we choose to exclude the weather, the bedroom floor, and the average hourly walked distance. Besides the first variable, which has no correlation with sociability, the choice of excluding these variables is due to the fact that they are patient-specific.

We assess the correlation between social behavior and the following two variables: the specific time of the day (morning, noon, afternoon) and the attribute of a day being a workday. After confirming they are correlated, we include them in the variables set for prediction.

Methodology

The variables we consider for the prediction of the Community Time-Specific Relational Index are the following: attribute of a day being a workday, season, temperature, predisposition to walk on a specific day and specific time of the day. Having considered three different times of the day, for each day we have a piece of data, accounting for a total of about 1000 data.

Considering that the relationship between the considered variables and the one to be predicted is unknown and most likely quite complex, we choose to implement a neural network to model it and accomplish the task of prediction[2].
The task can be modeled as a regression problem and the network structure is here briefly described. The input and output consist of a neuron for each aforementioned variable, except for the season, which requires 3 neurons being categorical. The hidden part of the network consists of 4 layers of 128 neurons each, activated by a traditional Rectified Linear Unit function. The chosen loss function is given by the Mean Squared Error and the Adam optimization algorithm is used to perform gradient descent.

2. Russel Stuart, and Peter Norvig, Artificial Intelligence:a modern approach, (2002).

Results

Through the presented network we are able to predict the Community Time-Specific Relational Index for a certain day and specific time of the day - considering if that day is a workday, the season, the temperature, the predisposition to walk on that day - with a Mean Absolute Error of 0.025.
Note that the index is not a definitive and complete measure of the sociability of the community, as this is not only given by the time they spend together in the same place, but also by the quantity and the quality of interactions they have, which is not measurable with the currently implemented technology. Namely, patients could all be in the same place without socializing with one another and their indexes of sociability would still be quite high.
However, this result is significant for our case for two reasons. First, considering the index domain in [0,1] and the scope, a confidence of ± 0.025 is enough. Then, most importantly, not all the variables impacting on the sociability of an individual, measured by the Relational Index, are considered, since it is practically impossible to know all of them and some are impossible to measure with the current technology, as it is the case for most social and irrational factors.

5.2 PREDICTING THE POPULARITY of PLACES

The data on the movements inside Il Paese Ritrovato can be used not only to inspect the social behavior of the dwellers, but also to examine the attractiveness of the various public places in the facility. In particular, the Popularity Index defined in Section 4.4 is a robust measure of the popularity of a place and can be helpful to determine the areas that are more likely to engage dwellers in social activities. Given the dataset, it would be desirable to find correlations between the Popularity Index of a place and other variables to ultimately predict its value, so that activity planners can use this information to schedule activities that are more likely to be engaging.
We thus need to find a set of input variables in the dataset that are both strongly correlated with the Popularity Index and easy to predict. Examples of potentially relevant input variables are the weather, which can be assumed to be correctly predicted by online forecasters, and the period of the year, which is deterministic.
Upon a visual examination of the data in our dataset we find the following variables to be especially meaningful when predicting the Popularity Index of a given place at a certain time:

- Place identifier;
- Period of the year;
- Hour of the day;
- Weather;
- Temperature.

Methodology

Due to the nature of the problem, we are mainly interested in public places that are external to the residential buildings such as the gym, the garden, and the cafe.
As we are trying to evaluate the popularity of a certain place when activities are held in that place, we remove from the dataset the records with Popularity Index lower than 0.01, which is enough to reasonably assume no event is ongoing in that place at that time. An improvement to this heuristic would be to integrate information on the actual activities held at Il Paese Ritrovato and extract the relevant data records accordingly, however, we unfortunately do not have access to their activity schedule at the moment.

We model the prediction task as a regression problem where the value of the popularity index of a given place at a certain time across the year is estimated based on the inputs mentioned above. Because the correlation between input and output is potentially far from trivial, we opt to train a neural network to automatically extract interesting patterns from data. To do this, we use PyTorch[3], a popular python machine learning library. Still, we would like to embed into the model as much domain knowledge as we possibly can to improve its performance and introduce regularization. One way to do this is to introduce semantics in the input.

3. https://pytorch.org/

- **Place identifier**: using a single scalar value in this case may lead to unwanted behavior in the machine, such as recognizing two places as similar solely based on their identifiers. We thus encode the public places using one-hot encoding. The one-hot vector is preprocessed by the neural network and mapped onto a 3-dimensional latent space capturing relevant features of each place.

- **Period of the year**: we decide to encode the information as a triangular fuzzy set on the seasons of the year, as shown in *Figure 5.2.* For example, when considering the winter solstice, the information will be encoded as [0 0 0 1], while the middle of spring, which is equidistant from the spring equinox and the summer solstice, will be encoded as [½ ½ 0 0]. The model can thus easily interpolate and generalize on unseen periods of the year. In this way, we also avoid discontinuities that may occur between December 31 and January 1 when using other trivial encodings (e.g. linear mapping).

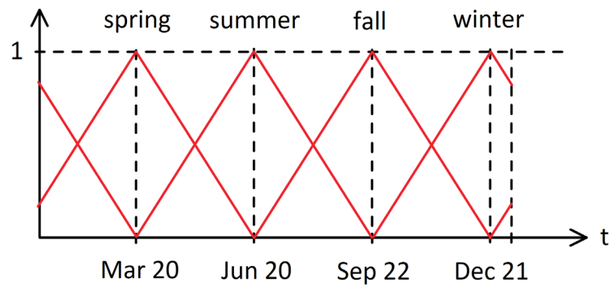


Figure 5.2, Triangular fuzzy set on the seasons of the year .

- **Hour of the day**: we are interested in the time of the day where dwellers will be awake and active, therefore from 6 AM to midnight. We choose to encode this interval of time using a linear mapping onto [0, 1]. In this way it is possible for the network to predict unseen time instants through simple interpolation. Note that, though it is true that time is circular, it wouldn't be appropriate to consider late night as similar to early morning from a social and physiological perspective.

- **Weather**: we encode the weather using one-hot encoding, taking into account three different types of weather: sunny, cloudy, and rainy.

- **Temperature**: we also encode the seen values from the database, that is, from 0°C to 40°C, onto [0, 1] through a linear mapping.

These encodings are then fed to a modular feed-forward neural network[4] with a variable number of layers. The number of layers, along with the dimension of each of them, will be individuated through a grid search.

However, we set some properties of the neural network such as:

- The first layer has 14 inputs and 3 outputs. It receives the place id one-hot vector as input and encodes it in a 3-dimensional latent space. The idea behind this choice is to reduce the place id vector dimensionality, so that the network does not operate on a very high dimensional space.

- The second layer has 12 inputs: the remaining 9 values from the input variables and the 3 outputs of the first layer. The output dimension depends on the dimension of the first hidden layer. Our grid search will consider 16, 64 and 256 as possible output dimensions.

- The final layer consists of a single output neuron, having a Leaky ReLU activation function at training time and ReLU activation function at prediction time. This allows to avoid zero-gradient problems when training and at the same time correct negative outputs when inferring (the Popularity Index is always non-negative).

We also introduce some regularization in the form of weight decay and apply an early stopping technique to avoid overfitting[5] and train the model in a supervised manner using MSE[6] as loss function and adam optimizer for gradient descent.
The output of the described neural network is the Popularity Index: a floating point value between 0 and 1, representing the percentage of dwellers expected to be located at a certain place, for a specified hour of the day (e.g., from 10AM to 11AM), and in a certain period of the year, also according to the expected weather and temperature.

The final structure of the network is chosen among 27 different possible configurations through a grid search that considers:
- Hidden layers dimension, with 3 possible values [16, 64, 256];
- Scaling factor (i.e. the factor for which the layer dimension was multiplied by when moving from layer x to layer x+1), with 2 possible values [0.5, 1];
- Number of layers, from 1 to 5.

These grid search parameters aim to obtain a reasonable tradeoff between coverage of the space of possible models, which is desirable to find the true optimal configuration, and the computational power we need to train all the possible models.

After performing the grid search, the resulting best performing architecture is composed of:
- A first layer with 3 neurons, receiving the place id one-hot vector as input and converting it in a 3-dimensional latent space;
- A second layer with 64 neurons receiving as input the output of the first layer concatenated to all the other aforementioned variables;
- Two hidden layers with 32 and 16 neurons respectively;
- One last layer with just one neuron that produces the final popularity index.

4. https://deepai.org/machine-learning-glossary-and-terms/feed-forward-neural-network.

5. Caruana, Rich, Steve Lawrence, and Lee Giles. Review of Overfitting in Neural Nets: Backpropagation, Conjugate Gradient, and Early Stopping. In Advances in Neural Information Processing Systems, 13:402–8, 2000.

6. https://pytorch.org/docs/stable/generated/torch.nn.MSELoss.html.

Indeed, we observe that both the simplest and most complex model in our selection perform worse than the best configuration we find, suggesting that our range of considered values is suitable for the problem at hand.

Results

Using this architecture, we are able to predict the Popularity Index of a given place for a certain day and specific hour of the day - considering also the weather, the temperature and the period of the year - with a Mean Absolute Error of 0.012.
Note that the considerations done for the Relational Index in the previous Section still hold for the Popularity Index. Also in this case the model's predictive performance is limited by the quality of the data available, since the dwellers tend to lose their bracelets and, even if the dataset has been substantially cleaned beforehand, it is not possible to detect and remove all the outliers.

5.3 THE COMMUNITY BEHAVIOR PREDICTION TABLE

Many avoidable mistakes might be made if the activities held at Il Paese Ritrovato are scheduled in advance without taking into consideration how the community will behave. For instance, scheduling an activity which aims to make the dwellers interact more is not suitable for a day in which they are not really sociable. Instead, their sociability should be exploited when they seem more interactive with one another avoiding activities thought for a single person.
Another possible solution could be thinking about scheduling the activities of a certain day each morning after having taken a look at how the dwellers are behaving. However, this is impractical, since it could generate confusion among the dwellers and the caregivers. Furthermore, this approach could not be applied for activities that need time to be organized, such as pet therapy.

Surely, having the upcoming week scheduled in advance might help the dwellers to somehow mentally organize and distinguish a day from another. Their sociability though is not random: there are many factors that influence the relationship between dwellers, their mood and, hence, their sociality.

At the same time, even scheduling activities in an arbitrary place might not be the best choice. Indeed, it would be better to exploit the already popular places and to understand how to increase the interest towards places that are not really frequented. On the other hand, one must consider that changing the usual place where the activities are held, to exploit place popularity or to enhance underused places, might have a negative effect on the dwellers making them feel nervous and anxious, especially at the beginning.

In order to support caregivers in the organization of more suitable and functional activity schedules, we built the afore-presented prediction tools for the Community Relational Index and the Popularity Index of each place for an upcoming week. These tools require only basic data for a certain day such as the temperature, the season, the predisposition to walk on that specific day and the attribute of that day being a weekday.

Having insights into the social behavior of the dwellers and on the popularity of places might be of great help to organize a better activities schedule. However, resorting only to these two pieces of information may not be enough. Indeed, it should be completed by considering also the knowledge of the caregivers, who work daily in the assisted care home and know quite well the activities' potential and drawbacks, besides having a personal direct relationship with the dwellers.

Unfortunately, our lack of medical, psychological and domain-specific knowledge does not allow us to design a proper and complete dynamic activity scheduler. Therefore, we can only provide caregivers with the prediction of the Community Time-Specific Relational Index and the Popularity Index for each place of the village for each day of an upcoming week, thus allowing them to combine it with their knowledge to build a more functional schedule in advance.

We propose the Community Behavior Prediction Table, a visual tool combining the predictive models to support caregivers in organizing activities at Il Paese Ritrovato.

	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		SATURDAY		SUNDAY	
time	RI^d	PI_p^d	RI^d	PI_p^d	RI^d	PI_p^d	RI^d	PI_p^d	RI^d	PI_p^d	RI^d	PI_p^d	RI^d	PI_p^d
8 - 12	**low**	café, 0,35 garden 0,13	**med**	ortus, 0,45 theatre 0,61	**low**	café, 0,35 lab 0,13	**high**	kitchen, 0,75 tv room 0,73	**low**	lab, 0,22 kitchen 0,17	**high**	café, 0,95 garden 0,73	**high**	church, 0,95 ortus 0,83
12 - 15	**high**	kitchen, 0,88	**med**	cafè, 0,54	**low**	cafè, 0,09	**low**	kitchen, 0,16	**high**	ortus, 0,91	**high**	kitchen, 0,78	**med**	cafè, 0,48
15 - 20	**med**	lab, 0,64 ortus 0,55	**low**	church, 0,10 cafè 0,22	**high**	lab, 0,84 garden 0,75	**med**	theatre, 0,54 ortus 0,45	**low**	lab, 0,14 garden 0,25	**med**	garden, 0,54 cafè 0,42	**low**	garden, 0,24 kitchen 0,15

Figure 5.3, Community Behavior Prediction Table .

This table provides the predicted value of the Community Time-Specific Relational Index and the Popularity Index for each place for three times of the day: morning (8-12), noon (12-15) and afternoon (15-20). In order to make this tool more readable, the indexes can be discretized and take a value between high, medium and low. Furthermore, places may be ordered by popularity.

In Section 5.4 we propose a list of popular activities for patients with dementia, in which each activity has a proposed value for the Community Relational Index and hints for the place where to organize it. This will allow caregivers to exploit even more the proposed tool. For instance, if an activity is thought for a low Community Relational Index, then it should be organized when the community is not really sociable, otherwise it may not be exploited in the best way.

We propose three ways to use the Community Behavior Prediction Table:

- **Community Relational Index to place**: through this method, we gather insight into the activities that can be scheduled by first looking at the Community Relational Index prediction. Then, we can filter out the activities not associated with that value, and, finally, the place in which to hold the activity can be decided, by looking at the list of popularity spaces.

Example: *consider the case in which in the morning we expect to have a high relational index. Two activities might be scheduled: playing Bingo and cooking. If the bar and the kitchens are popular while the gardens are not, an idea might be to organize the first activity in the gardens and the second in the kitchens. In this way, the bar that should work well by itself, will not be affected. Furthermore, the free space in the gardens will be efficiently used, instead of leaving it empty.*

- **Place to Community Relational Index**: through this method, we first gather insight on the places which are most popular, in order to exploit them, and the ones that are less used, in order to enhance them. Once the places have been defined, we can filter out the activities that can be done in those places and decide which ones to actually schedule by taking a look at the required Community Relational Index and the one we expect in that time slot.

Example: *consider the case in which in the afternoon we expect the cinema to be popular, while the laboratory to be way less crowded. We take into consideration four activities: for the theater the dwellers might watch a movie (low Community Relational Index CRI) or act in a play (high CRI), for the laboratory they might do handcraft work (low CRI) or play a table game (high CRI). If we expect a low relational index, a good idea might be to schedule a movie at the theater and handcraft work in the laboratory.*

- **Activity to Place and Community Relational Index**: through this method, we first define a set of activities which are in our opinion the most suitable ones for that day (for instance, the ones that have been enjoyed by many in the last days, the ones that haven't been scheduled for a while or the ones that have a sort of recurrency). Then, we filter out the ones whose required Community Relational Index is not fulfilled in that time slot. Finally, the places in which the activities will take place are decided taking into consideration the Popularity Index prediction.

Example: *consider the case in which on Monday mornings the organized activities are either playing cards, or listening to music or doll therapy, which are in general enjoyed by the majority of dwellers. However, if looking at the Community Relational Index prediction it is evident that on a specific Monday the community will have a low sociality, playing cards might not be the best activity to schedule. On the other hand, consider that the most popular place will be the cinema while one of the least frequented will be the gym. Hence, organizing an activity involving music at the gym and doll therapy at the cinema might be a good option.*

5.4 SOCIAL ACTIVITIES

In order to improve the life quality of the dwellers and to enhance the capabilities of the Community Behavior Prediction Table, we analyze some activities that could be carried out in Il Paese Ritrovato, according to the predicted popularity and relational indexes.
For each activity we provide a brief description, the benefits for the participants, the places in which the activity can be conducted, the community relational index for which it is more suitable and a list of pros and cons.

Doll and Pet Therapy

With doll therapy[7] AD patients receive a doll with peculiar features (in terms of weight, dimensions, appearance, legs and arms positions) with which they can establish a sort of stable affect, since they are in charge of taking care of it as if it was real. Nowadays, it is not only considered an activity, but also a non-pharmacological, additive treatment for behavioral disorder, which is often a side effect of such diseases.

With pet therapy or, more in general, with animal-assisted therapy (AAT)[8], we refer to an alternative or complementary type of therapy that involves animals as a form of treatment. While in doll therapy what is involved is merely fictional, in this case animals are real and selected for their social attitude. The most commonly used types of AAT are canine-assisted therapy and equine-assisted therapy.

Benefits:
The goal both of doll and pet therapy is to improve a patient's social, emotional, or cognitive functioning. There are various studies documenting the positive effects of these activities reported through subjective self-rating scales and objective physiological measures, for instance blood pressure and hormone levels.

Places:
Doll and Pet therapy are pretty versatile in terms of where they should take place, both indoors and outdoors.

7. Ng, Qin Xiang, Collin Yih Xian Ho, Shawn Shao Hong Koh, Wei Chuan Tan, and Hwei Wuen Chan. "Doll Therapy for Dementia Sufferers: A Systematic Review." Complementary Therapies in Clinical Practice 26 (February 2017): 42–46.

8. Cevizci, Sibel, Halil Murat, Fahri Gunes, and Elif Karaahmet. "Animal Assisted Therapy and Activities in Alzheimer's Disease." In Understanding Alzheimer's Disease. InTech, 2013.

While for doll therapy almost any kind of place is suitable (both indoor and outdoor, both common and private areas), for pet therapy outdoor or big indoor places should be fostered, since real animals are involved.

Target Community Relational Index: low/medium
Any level of community relational index is appropriate for these kinds of activities, but this therapy can provide more evident benefits to patients with low/medium relational index : in fact, one of the benefits of these activities is to improve the physiological conditions of patients, in order for them to be more relaxed and involved with others. The aforementioned activities can be carried out both individually (especially for doll therapy) and in small groups (as often happens with pet therapy), thus making these activities extremely versatile.

Pros and Cons:

+ Enhance cognition and memory
+ Can be performed both outdoors and indoors
+ These activities require a minimum intervention from caregivers, also in case of pet therapy, since specialists are often present during these meetings
+ Can establish long term relationships
- Require some materials (for doll therapy) and external collaborations (in many cases for pet therapy), so a (low) initial expense.

Table Games

The right board games, chosen wisely, can actually help Alzheimer's patients. For example, one study[9] into the use of Bingo with dementia patients concluded that "a simple cognitive activity such as Bingo can be of great value to the daily management of Alzheimer's patients".
To choose proper table games, it must be taken into account that games' board and tabletop should be visibly colourful or striking, and the players should be actively able to handle the pieces. This means that choosing larger scaled versions, such as large playing cards, can be beneficial as well as using items such as playing card holders. The game should be kept as stress-free as possible to encourage individuals to remain engaged.

9. Sobel, Benjamin P. "Bingo vs. Physical Intervention in Stimulating Short-Term Cognition in Alzheimer's Disease Patients." American Journal of Alzheimer's Disease & Other Dementiasr 16, no. 2 (March 2001): 115–20.

There are many different games that can be played by individuals with AD:

- Bingo (5+ players with 1 or more supervisors, depending on the number of players): The aforementioned study found that care workers reported increases in patients' alertness and the benefits lasted for several hours. Moreover, it is possible to move away from numbers and use anything from animals to food or body parts to work on specific recalls.
- Call to mind[10] (3-6 players + 1 supervisor): Call to Mind is a "specially designed board game that helps get to know and understand the thinking, like and dislikes of someone with dementia." Call To Mind is tested and approved by the Alzheimer's Society[11].
- Card games (2+ players, according to the chosen game)

Games which involve misdirection or lying should be avoided, such as Poker, but simple games like Uno can be very appreciated by AD patients and improve the overall sociality of the village.

10. https://www.call-to-mind.com/.

11. https://www.alzheimers.org.uk/.

Benefits:
All the presented table games stimulate memory and cognition. Moreover they enhance the interaction among participants. Special mention to Call to Mind, which is focused on enhancing social interactions and establishing long lasting bonds.

Places:
Table games are pretty versatile, suitable for outdoors when the weather is good , especially in green areas, to enhance the interaction with nature. They can also be played indoor, in large or small buildings according to the desired number of participants and the chosen game.

Target Community Relational Index: any

- Bingo: medium-high, because it requires the participation of a good number of people to have actual benefits and to be entertaining

Call to Mind: low-medium, it does not require much effort from the participants and it could be used to encourage the formation of small groups of long-term friends.

- Card games: low-medium, more focused on small groups, but less effective in establishing long term relationships. However, they may be useful to enhance places that already work well (like the bar) or to increase the interaction with nature, since they can be played on small tables positioned in green areas.

Pros and Cons:

+ Enhance cognition and memory
+ Cover all the targets both for group dimension and for target relational index
+ Can be played both outdoor and indoor
+ Can be used to enhance the interaction with nature
+ Can foster the establishment of long term relationships (especially call to mind)
- Call to Mind and bingo require at least a caregiver
- Require some materials and a (low) initial expense.

Green Care

Green care combines agricultural activities with care services to enhance the overall quality of life of patients from a physical, mental, and social perspective. While green care is related to a natural environment, it is not necessary for activities to happen within it. Typical farming activities of green care include caring for animals, sweeping the farm yard, and gardening, while other related recreational activities are going for a walk outdoors and preparing a meal. When the above activities are performed within a group of people, all three wellness dimensions we are interested in (physical, mental, and social) are positively affected by green care. In any case, it is strongly suggested to avoid a number of people that can lead to overcrowdedness of the designated area, which can lead to stress.

Benefits:
The benefits of green care come manifold. Physical activity helps patients avoid a sedentary lifestyle and keep themselves in shape, which in turn also results in improved mental health. Other benefits come from a sensorial exposition of the patients to nature, which can be therapeutic and further improve mental wellbeing. Finally, the resulting cooperation when activities are held in groups can promote socialization among patients.

Places:
The obvious choice for green care activities is outside, as direct exposure of the patients to nature is highly therapeutic. However, some activities such as cooking the harvested ingredients are more suitable indoors. Greenhouses can also provide a safe space to practice agricultural activities even in case of rain, provided that they can be reached without exposing the dwellers to hostile weather.

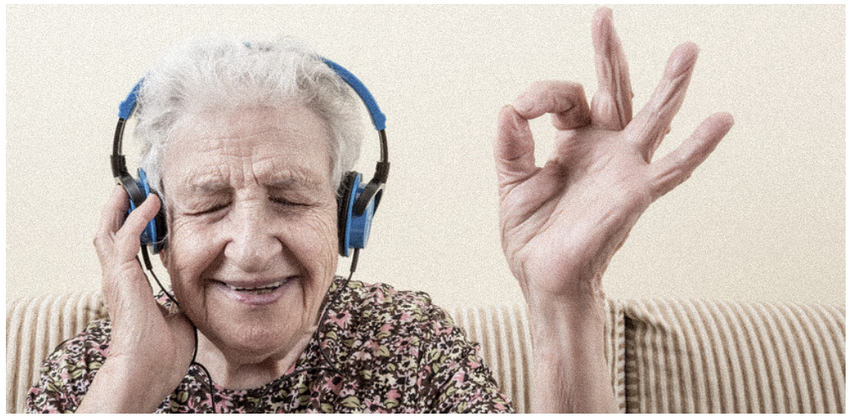
Target Community Relational Index: low (any)
Though green care activities are arguably suitable for any type of person, it is possible that they are most effective for people with a low relational index.

Most of them generally do not require any particular social skill to be performed. They also provide a way to bond with others through non-verbal communication by cooperating on the same or similar physical tasks.

Pros and Cons:

+ Activities promote physical exercise
+ Exposure to nature has a positive impact on mental health
+ Cooperation leads to socialization
+ Environment friendly
+ Suitable for people with low relational index
- Patients unable to perform simple motor tasks (e.g., walking) cannot partake in most agricultural activities
- Relatives may express concerns on the physical strain the patients are subjected to
- Some activities cannot be performed with unfavourable weather conditions
- Some activities require special equipment (e.g., gardening could require small shovels).

Music



Many of those with AD, despite aphasia and memory loss, continue to remember and sing old songs, and dance to old tunes[12]. Music can be leveraged both as a main activity and as a support to other activities. The former mainly involves singing, dancing, and listening to live music. Specifically, live exhibitions, dance classes, music classes and parties may be organized in places such as a gym, a theatre and a bar.
Organizing activities with music allows for great versatility, with no particular constraints, being adaptable to almost any situation. Consequently, any group size, place, technology will have many suitable activities.
It is interesting to note that participants can be either very active or quite passive: some may engage in dancing, singing along and playing instruments, others may benefit, relax and enjoy just from sitting and listening.
Specifically, having a 5-15 patients group singing along to some old popular songs would be a great way to stimulate the group, besides being quite easy to organize[13].

12. Sixsmith, Andrew, and Grant Gibson. "Music and the wellbeing of people with dementia." Ageing and Society 27 (2007): 127.

13. Olderog Millard, Kristine A., and Jeffrey M. Smith. "The influence of group singing therapy on the behavior of Alzheimer's disease patients." Journal of Music Therapy 26, no. 2 (1989): 58-70.

Benefits:
Music, besides being one of the most ancient forms of art and social interaction, is shown to have several benefits on people with dementia's well-being.
Generally, it contributes towards positive self-esteem, enhances feelings of competence and independence, and lessens the experience of social isolation. Music therapies have been shown to have many beneficial outcomes, including providing frameworks for meaningful activity and stimulation, management of problematic behavior such as agitation, improved activity participation, social interaction, and social, emotional and cognitive skills. It is also shown that it lessens the feeling of being isolated.

Places:
Although larger places offer more space to big groups, smaller places happen to be more engaging for music-related activities. Any public space with no particular physical constraint is suitable for activities involving music.

Target Community Relational Index: low (any)
As music stimulates participation in other activities, music, both as a main activity and as a support for others, could be a great way to stimulate the community to be more sociable when the relational index is low. Anyway, music can always be used as a support, played in the background while the dwellers perform other activities.

Pros and Cons:

+ Stimulates participation in other activities previously ignored
+ Stimulates reminiscence
+ Can be easily implemented
+ Not expensive
+ Safe
- Some participants might experience physical or cognitive difficulties in using instruments or dancing, resulting in frustration.

Hand Craft - Art Therapy

Art - defined as drawing or sculpting - is a powerful weapon to help people with moderate to mild dementia to express themselves[14]. The main idea behind art therapy is to let patients be free to draw, paint and, in general, create anything they want with the materials they are given.
This activity is more likely to be done in groups. The prerequisites are all the necessary materials and some staff that should help patients work. In any case, a specialist is not needed.

14. Chancellor, Bree, Angel Duncan, and Anjan Chatterjee. "Art Therapy for Alzheimer's Disease and Other Dementias." Journal of Alzheimer's Disease 39, no. 1 (January 7, 2014): 1–11.

Benefits:
Art therapy has been effective in serving AD patients by:

- Assisting with diagnosis and evaluation of cognitive status
- Providing a vehicle for nonverbal communication
- Offering a vehicle for reminiscing
- Enabling sensory exploration and stimulation
- Providing a self-reflective activity that results in a tangible end product
- Engaging attention
- Providing pleasure
- Improves neuropsychiatric symptoms, social behavior and self-esteem.

Places:
This activity can be done almost in any indoor place (most likely in the already designed hand craft room in Il Paese Ritrovato) and can be done by groups of people.

Target Community Relational index: low
When drawing, handcrafting and sculpting, patients tend to collaborate and interact with one another. Artwork comparisons are encouraged, stimulating socialization even among the less sociable patients.

Pros and Cons:

+ Easy and chill activity
+ Does not need very much attention of caregivers
- Might be difficult to give an interpretation to their artwork in order to understand what they're trying to communicate.

Food Oriented Activities

Under the name of food-oriented activities[15] we consider all kinds of activities related to food preparation. Some examples of this kind of activities are the following:

- Help to prepare fruit salads: This is a great way of stimulating the senses and can involve a number of stages: choosing , washing and peeling the fruit. In all these phases, the caregivers should encourage patients to smell and touch the fruit and to talk about its smell and flavour.
- Make sandwiches: This is a good thing to try and can involve several stages: buttering the bread, adding sandwich fillings and placing the sandwiches on a platter or plates.
- Wash and peel vegetables: To accomplish this task, Use a simple vegetable peeler to peel carrots and potatoes, for example.
- Ice and decorate cupcakes, biscuits or Easter eggs: Pre-made icing is available to buy in easy-to-use squeezy tubes in a variety of colours. It is also possible to link the activity to a theme or an event such as Easter or Christmas to stimulate memory.

15. https://www.scie.org.uk/dementia/living-with-dementia/eating-well/activities-around-food.asp.

Benefits:
Many people will have spent a lot of time over the years either preparing or working with food. Offering opportunities to continue this can help give patients a sense of purpose and usefulness, boosting confidence and self-esteem, as well as promoting an interest in food and mealtimes.

Places:
While dealing with food preparation, common kitchens are the perfect places. It is also possible to organize picnics with the food prepared during this kind of activities and eat it outside during spring or summer, enhancing the interaction with nature.

Target Community Relational Index: medium/high
For this kind of activities it is recommended a medium/high community relational index since they are all experiences to be carried out in groups with active participation of patients.

Pros and Cons:

+ Enhance cognition and memories
+ Involves all senses, thus fostering memory
+ Patients are quite involved
- Some injuries may occur, so caregivers need to be extremely involved to check patients' security.
- It is important to ensure the activity is manageable and suitable for the skill of the person involved.

SPATIAL APPROACH 6.

When treating AD, in addition to the role played by medical care, it is essential to adopt the most appropriate methodological approach. Medical experts have long believed that it is crucial to combine a traditional treatment with one that does not include the use of medicines. Today, non-pharmacological therapies represent a field of great experimentation and evolution in the treatment of AD. Non-pharmacological treatment includes any type of treatment able to relieve or make crises bearable without using chemicals of any kind. This type of approach, despite not curing the disease, is able to slow down its course.

In this Chapter we analyze the traditional medical method to AD, comparing it with a less traditional approach that puts architecture as a central element of care. This innovative approach considers space as a prosthetic element that could be more successful for patients than traditional therapy.

Finally, through our work, we reconstruct a specific method of intervention that includes objective factors such as the data analysis previously carried out on the movements of residents and other sensory parameters to deal with the complexity of the issue.

6.1 THE CLINICAL METHOD

Evaluation procedures are the main tool by which multiple problems of the elderly and the respective interactions among them are investigated, described and, if possible, explained by medicine. These procedures are referred to as "assessment", which, as far as somatic pathologies are concerned, must include the following stages[1]:

1) Initial approach
2) Collection of medical history of the patient
3) Study of functional status
4) Detection of prevalent symptoms
5) Objective examination
6) Laboratory tests.

1. R. Rozzini et al., Somatic Diseases and Dementia, in: M. Trabucchi, "Le Demenze", Utet 2000, (2" edition).

Independently of the phases listed above, it is possible to circumscribe three phases in which the progress of the pathology is articulated. These three phases are recognized by the National Health System as the initial phase, intermediate phase and final phase, for each one the corresponding clinical objectives are indicated.

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The stages imposed by the National Health System in the treatment of Alzheimer's disease can be summarized as follows

- **<u>Initial Phase</u>:**
(a) Diagnosis
(b) Design of therapeutic and rehabilitation programmes

- **<u>Intermediate Phase</u>:**
(a) Prevention and addressing complications
(b) Treatment of behavioural symptoms

- **<u>Terminal Phase</u>:**
(a) Accompaniment to the patient's death in the most dignified possible manner.

However, as reported in the document “Progetto Alzheimer”, published by Azienda Sanitaria Locale di Milano 3, in collaboration with the association Alzheimer Italia, a correct approach to the patient with dementia must be based on a global evaluation, including a close relationship between Psyche-Soma-Environment.
It is necessary, therefore, to think about interacting indirectly on the patient through the space surrounding him. In this scenario it becomes fundamental to take into consideration “the home environment” as the Habitat of the person. Interacting on it we can obtain, as a consequence, important successes on the patient’s well-being, mitigating the crisis and leading him towards a new stability.

6.2 TREATING THROUGH THE ENVIROMNENT: SPACE THAT CURES

It has now been demonstrated that space is one of the most influential elements, representing one of the few real tools through which one can obtain concrete results on dementia (*Bianchetti, 1993*). In the last thirty years architecture has undergone a methodological revolution that has been accompanied by the development of the latest technologies in the representation and modelling phase, first of all of the product, in the field of Design, then regarding the architectural space. It has therefore come to conceive architectural space as a third environment, an artificial space that constitutes a link between the inner and outer environment to improve comfort and facilitate the performance of activities.

The space is therefore conceived as a prosthetic element, as a completion that takes into account several disciplines:

- **Ergonomics**: a discipline that tends to achieve an optimal balance in the man-machine-space system.

- **Anthropometry**: study of measurements and movements described by man in the performance of his activities.

- **Proxemics**: study of the meaning and spatial relations assumed by man or in the performance of activities.

This method translates synthetically into the establishment of a process model that guides the designer to the project outcome through the support of a meta-project tool, in short it is a project of the project. In this regard, a research group at Gothenburg University in Sweden, during an original study conducted on the interaction between the environment and the elderly, highlighted that the sensory aspects of the environment play a decisive role not only in enhancing the residual perceptive faculties of people with dementia, but also in stimulating them further. Through the use of colors, lights, sounds and essences it is possible to build a sensory environment able to guide the person with memory disorders towards a better autonomy. Today the design of a home for an aging person must necessarily take an intelligent approach that integrates the environment, new technologies and products.

In Alzheimer’s disease the design of the environment plays a key role as it represents a real therapeutic tool.

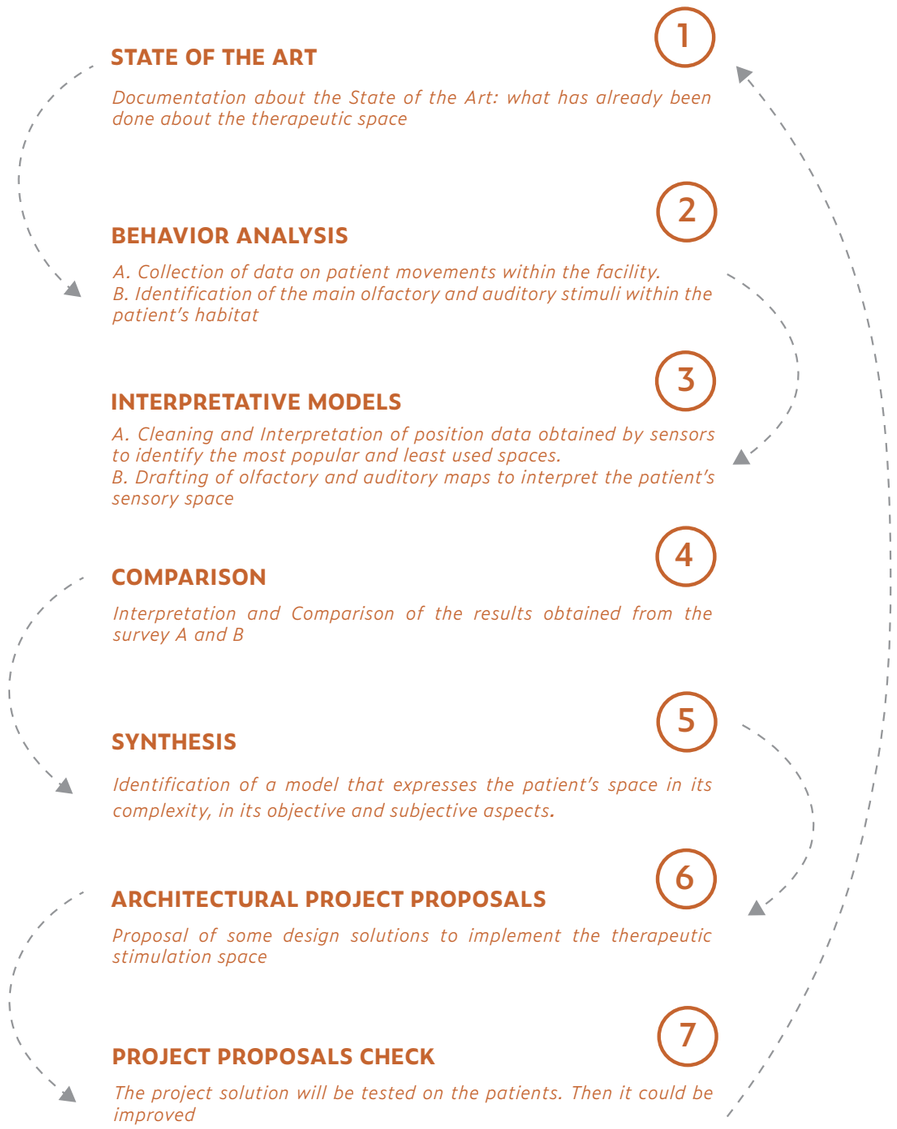
Taking into account the most recent studies on the subject it is possible to establish some lines that can guide a good design of the prosthetic space:

- **Multisensory design**
- **Sound absorbing panels**
- **Rooms with sound-insulating panels**
- **Avoid checkerboard colours or geometric patterns in flooring**
- **Prefer uniform colours and non-slip materials**
- **Use self-propelled modules for furniture**
- **Avoid the hospital image of the environment**
- **Use of appropriate colors**
- **Skilful use of room fragrances.**

6.3 OUR DATA-DRIVEN PROJECT METHODOLOGY

Since we have to approach the study of a therapeutic space with the aim of improving some aspects of the habitat of the residents of the Il paese Ritrovato, a research work is carried out that takes into account purely objective aspects and other more subjective ones in order to represent in the most complete way the complex reality of a residence for Alzheimer’s patients.
In the light of these considerations, an attempt is made to develop a strategic methodology that might consider objective aspects. For instance,”localization data” of patients within the structure, which monitor , through a wide network of sensors, the time spent in each space by the individual patient, can be used to understand which are the places that are the most loved by residents and which, instead, are the less appreciated and therefore less exploited.
This analysis is then accompanied by research aimed at recording the sensory stimuli offered by the surrounding space, then proceeds with the collection of sensory maps that report intangible aspects, such as sound and olfactory stimuli. These surveys of different nature are complementary to the data collected on the position.

Let's now try to develop a possible method that will guide, through experimental phases, the approach to the architectural design of prosthetic spaces for the treatment of dementia pathologies:



6.4 RISK ANALYSIS

Although there exist many good practices to follow for the design of care spaces, we must not forget that these spaces constitute the habitat in which the patients live. As confirmed by Alessandro Biamonti in his text Design & Alzheimer, we must not run into the problem of hospitalizing the environment. In the case of AD, the depersonalization of spaces can have negative aspects, such as causing them to get lost more easily and inducing panic. Experimenting in this field can be risky because any adjustment has to be tested on the patient, who may not always react positively. On the other hand, it is worth trying to improve the stability of the patients by proceeding in this way, as numerous studies on the subject claim that the space in which the patient lives has a key role in his stability, to the point that it is considered superior to any medicine[2].

However, it is to be taken into high consideration that, in order to achieve these purposes, it is imperative to build a profitable relationship between designers, therapists, artisans, and families. In residential health care realities, "living" is usually not contemplated, on the contrary, this is often replaced by the logic of "staying". The former does not assume any relationship of reciprocal exchange between the subject and the surrounding environment, while the latter implies the appropriation of the domestic environment that should be perceived as intimate.
Rehabilitation must take care of the domestic environment. To pursue this idea it is necessary to get out of the traditional schedule logic according to which all the residents of an assisted structure are led to do the same activities at the same time of day, this approach does not help the subject of dementia to feel the space in which they live as their own.
In any case, the outcome of every proposal is anything but taken for granted, just as it is true that major upheavals are not always necessary to help patients. Alessandro Biamonti refers to a project begun but not realized in practice for a hospital in the Bergamo area, in which he proposed only to paint over the bed of the dementia patient a panel depicting the starry sky. The proposal, inspired by Giotto's Cappella degli Scrovegni in Padua, is an attempt to give the individual a tool to travel with the imagination during the night hours, avoiding accumulation of anxiety that can lead to violent crises.

In a therapeutic process, the balance among spaces with different nature is vital: alternating between open and closed spaces is likely to improve the interpersonal relationships of the residents[3]. On the other hand, not actively promoting a healthy alternation between spaces devoted to actions, conversations and relaxation will never lead to a solid relationship with the patient. Alternating between resting moments and actions is the best way for caregivers to establish contact with the patient through a listening process. In physical space, this alternation inevitably results in balance.
Taking into account all the previous arguments we can underline that the therapeutic approach can be effortlessly detected in every step of the treatment: from the very first meeting to the therapy and environmental stimuli. Looking at it from the architectural point of view, it becomes clear that it is mandatory to shift from considering space as a container to perceiving it as an emotional element, that makes it possible for emotions to develop.

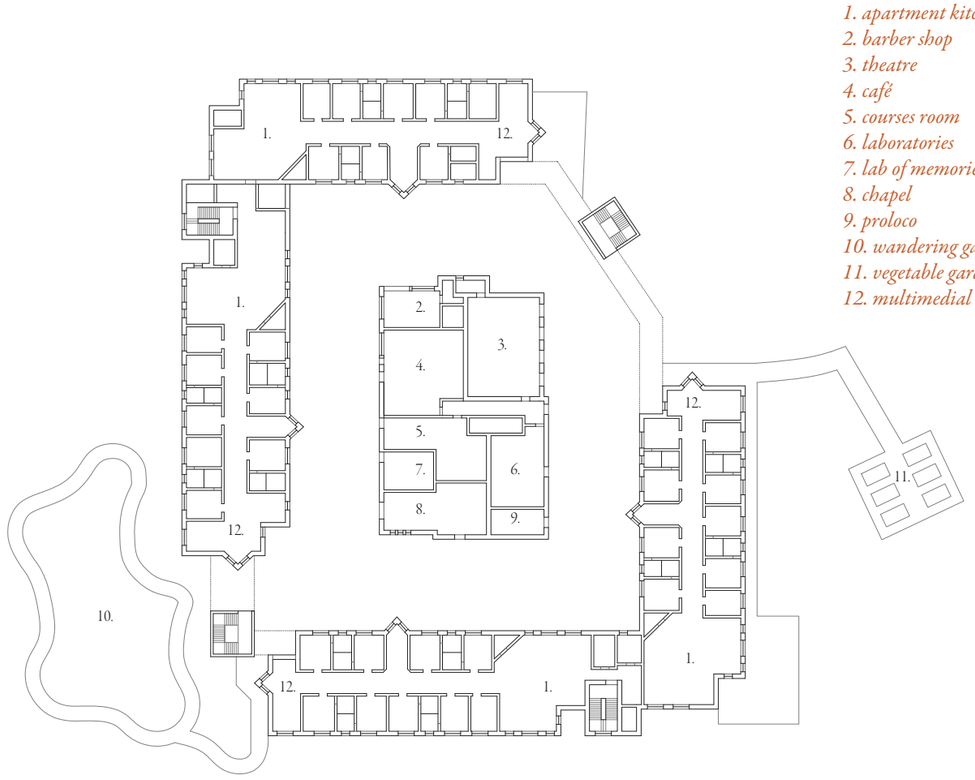
2. Cannara A., Brizioli C., Brizioli E.: Progettare l'ambiente per l'Alzheimer, Franco Angeli, Milano 2004.

3. Biamonti, A.: Design & Alzheimer: Dalle esperienze degli Habitat Terapeutici al modello GRACE. Serie di architettura e design, Franco Angeli Edizioni (2018).

6.5 SENSORIAL ANALYSIS

Il Paese Ritrovato is a modern ensemble of buildings that does not present accessibility issues attributable to architectural barriers. The main spaces meant for community life are located on the ground floor and are arranged at the center of the village to be easily identifiable and available to the residents. The two main outdoor locations of the village, the garden and the vegetable garden, are also easily accessible; however, they reside in the edges of the structure, causing the residents to rarely spend time in these outside areas. It is our objective to make these areas more attractive, as gardens provide excellent sensory stimuli to the residents. Moreover, olfactory and auditory stimuli are hardly affected by AD progression, so the dwellers could really benefit from interacting with nature. We therefore aim to work on intangible features of the external environment such as sounds, smells, lights, and climate to create therapeutic micro-habitats that provide tactile and sound stimuli, hence improving residents wellbeing.

6.5.1 Common Spaces



1. apartment kitchen
2. barber shop
3. theatre
4. café
5. courses room
6. laboratories
7. lab of memories
8. chapel
9. proloco
10. wandering garden
11. vegetable garden
12. multimedial room

Figure 6.5.1, Common spaces inside Il Paese Ritrovato.

6.5.2 Smells Mapping

Smells Typologies:

- *Traditional Dishes*
- *Coffee*
- *Wax and Incense*
- *Painted Wood*
- *Flowers*
- *Wet Soil*

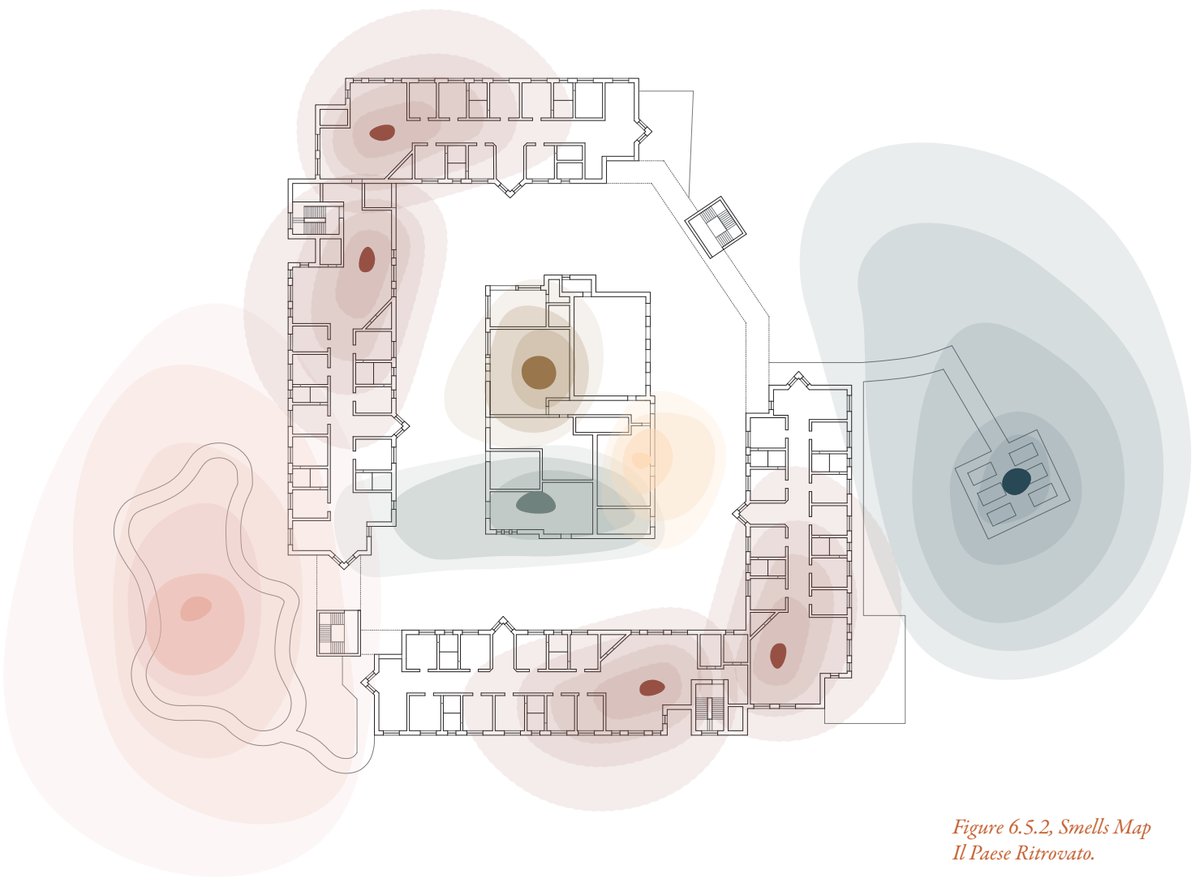


Figure 6.5.2, Smells Map Il Paese Ritrovato.

6.5.3 Sounds Mapping

Sounds Typologies:

- *Jangles of Kitchenware*
- *People Voices*
- *Applause*
- *Hammer Beat*
- *Hoe-Shovel Beat*
- *Children Voices*
- *Church Bell*
- *Train Rattling*

Sounds Repetition:

- *single repetition | from inside*
- *single repetition | from outside*
- *multiple repetition | from inside*
- *multiple repetition | from outside*

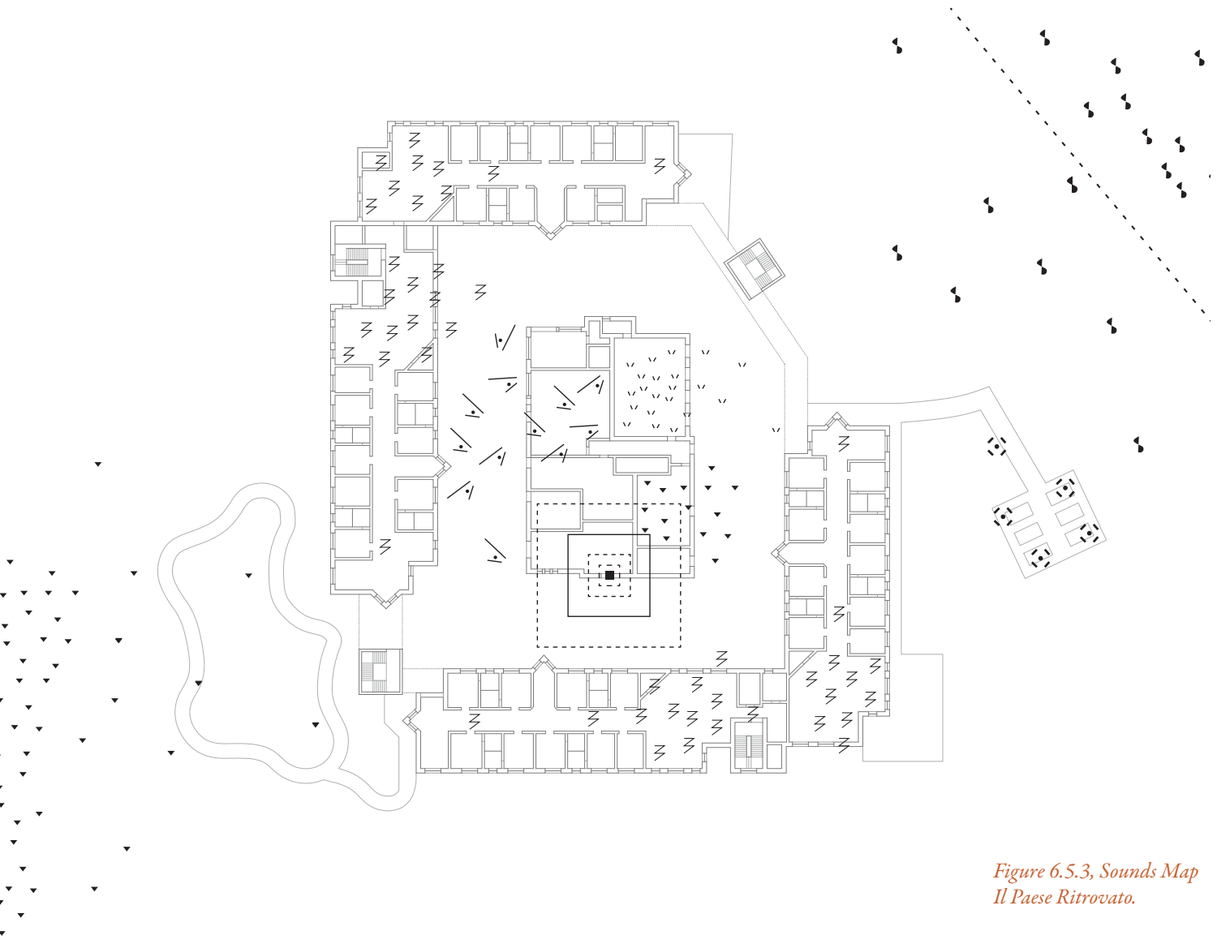


Figure 6.5.3, Sounds Map Il Paese Ritrovato.

Sounds frequency repetition scheme:

The most common sounds imput already collected have been clastered here in base at their own repetition in time. The Aim is to show which are the sounds that characterize the environment in which "Il Paese Ritrovato" is located.
We have considered sounds that are originated inside the Village and other that come from the neighborhood. The time variable considered is the time of an entire week, each day has also been subdivided into four time slot of six hours each.

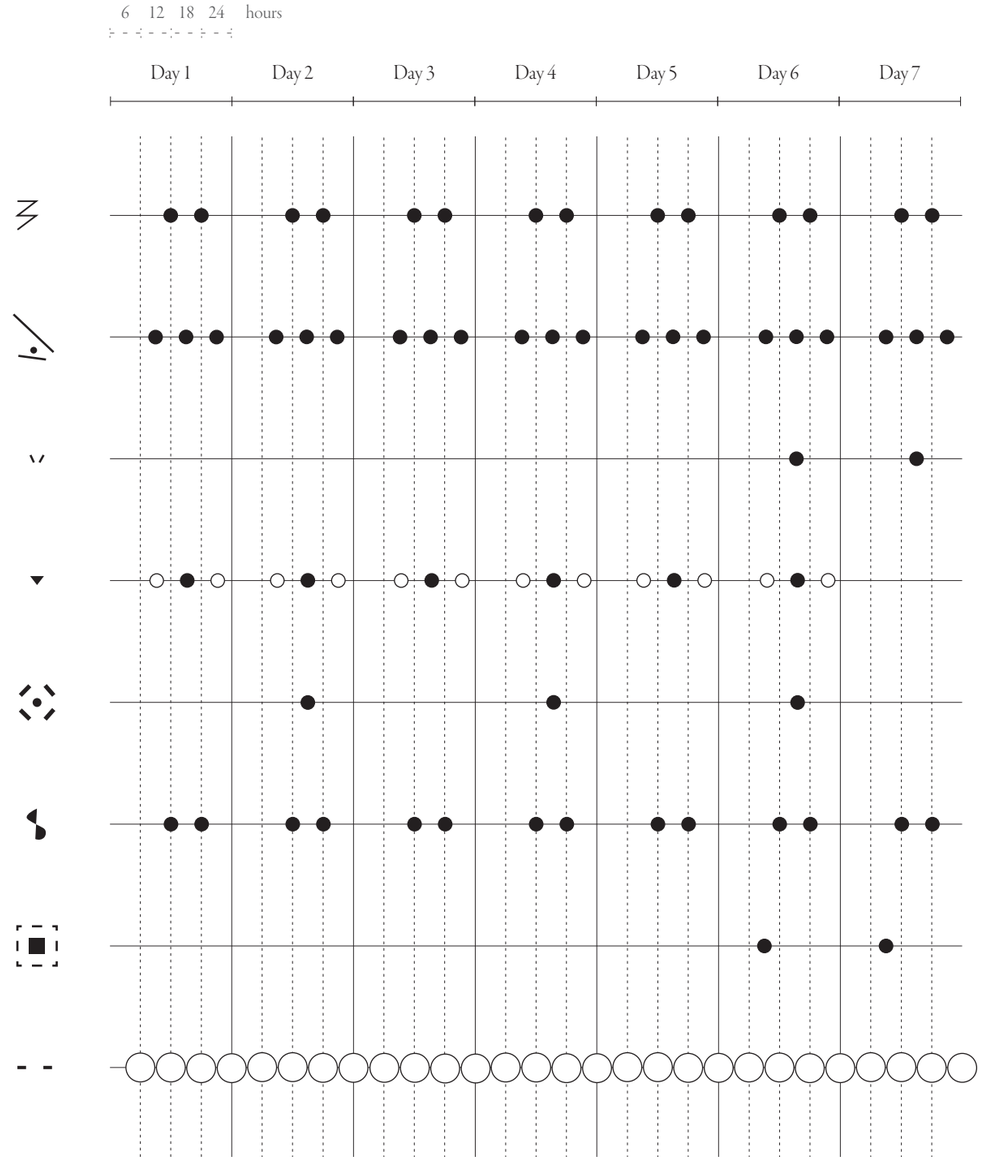


Figure 6.5.4, Sounds frequency repetition scheme Il Paese Ritrovato.

6.6 ARCHITECTURAL PROPOSALS

The prosthetic environment is a model of intervention that aims to improve the patient's stress conditions. It is a discipline with a long history of experimentation from the first research on the subject by Moyra Jones who formulated her own Gentle Care method to the most recent biopsychosocial intervention studies on dementia. What emerges is that in the majority of the cases designing the space around the patient we can obtain much more therapeutic results than a drug.

The environment is therefore configured as an intervention capable of filling the patient's cognitive deficits, attenuating nervous crises and stimulating memory. In order for everything to work, the care space must be equipped with certain characteristics, including simplicity, it should be able to improve its use, but this must not result in an excessive simplification or reduction of stimuli; flexibility, so as to adapt itself to the different phases of the patient's life, ready to accept his activities; security, there must be a good relationship between individual freedom and easy surveillance; the outdoor space, the presence of a garden is an excellent emotional stimulus for the patient.

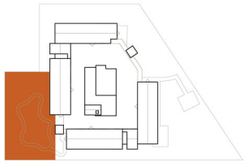
Taking all these aspects into consideration, it is decided to intervene on the spaces of "Il Paese Ritrovato" with a capillary intervention that goes to work in delimited and precise areas in order to express its full potential. Based on the results of the sensory and analytical analysis carried out and on the dialogue with the staff of the structure, we have identified some sensitive environments that lend themselves to improvement.

1. WANDERING GARDEN

2. LAB OF MEMORIES

3. MULTIMEDIAL ROOMS

Fig 6.6, Areas of intervention inside Il Paese Ritrovato.



6.6.1 WANDERING GARDEN

Fig 6.6.1, Detail of the Wandering Path inside the structure.

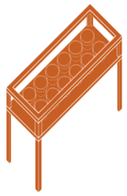
It is a beautiful and quite large garden, in which there is a twisting path that guides residents during the wandering crisis, a labyrinth of boxwood, different varieties of flowering shrubs and grassy areas. The presence of sounds and smells coming from the context makes this place one of the most stimulating spaces in the village. The flat pavement, the night lighting and the presence of some seats make it very interesting, but unfortunately it is not fully used by residents. "Sound Houses" and "Gardens to Compose" might be inserted to attract the attention of residents during their walks.

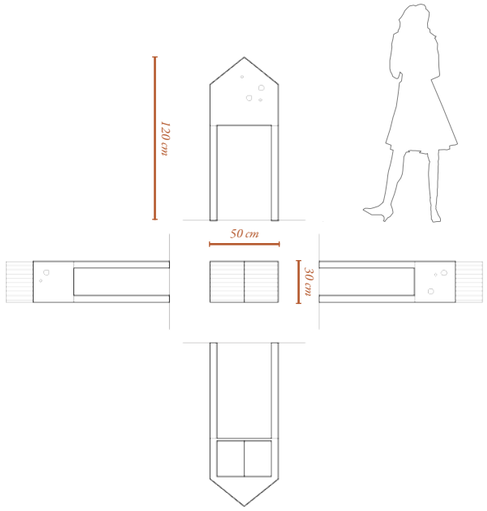
Sound House

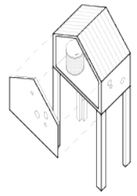
It is thought to stimulate the residents during their walks in the garden with sound sources incorporated in structures that reproduce the elementary geometry of the birdhouse. These elements can be freely organized along the wandering path in order to arouse emotional aspects in the residents by facilitating the memory through animal sounds or literary voices. It is not a matter of impositive action on the patients, but rather of light stimulations, which are not intended to be intrusive, but to leave it to the individual to stop and follow the stimulus or ignore it. To do this, it was decided to use simple Bluetooth technology.

Garden to Compose

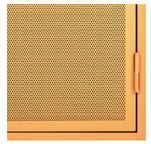
With these devices we want to approach the cultivated soil to the resident through special containers. The planting can be changed according to the seasonality, offering the elderly sensory and compositional activities. The pots become useful elements for the venting of repetitive movements. The resident can extract the individual vases and exchange them with each other, interacting on the conformation of the environment. For this purpose, the vases are designed in plastic material and small in size to facilitate their safe movement by residents.



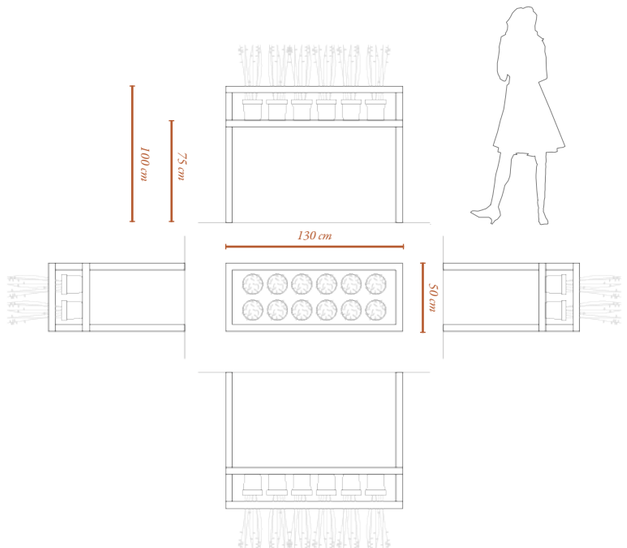


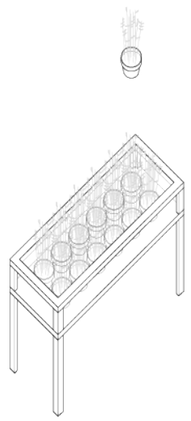


Materials



forated metal sheet





Materials

larch wood

Wandering garden after the intervention, with Sound Houses and Gardens to Compose inserted.

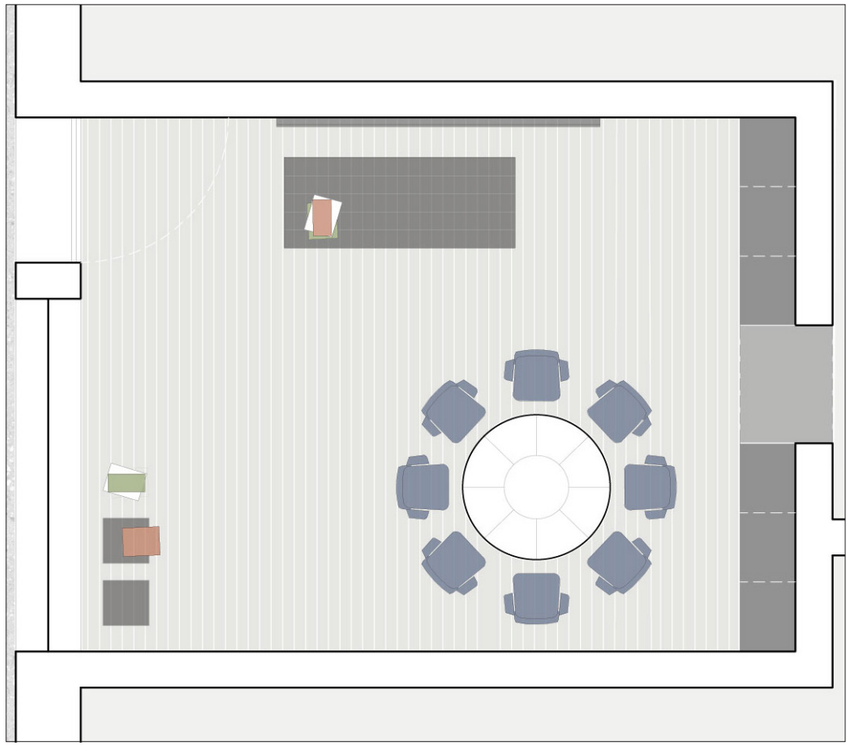
6.6.2 LAB OF MEMORIES

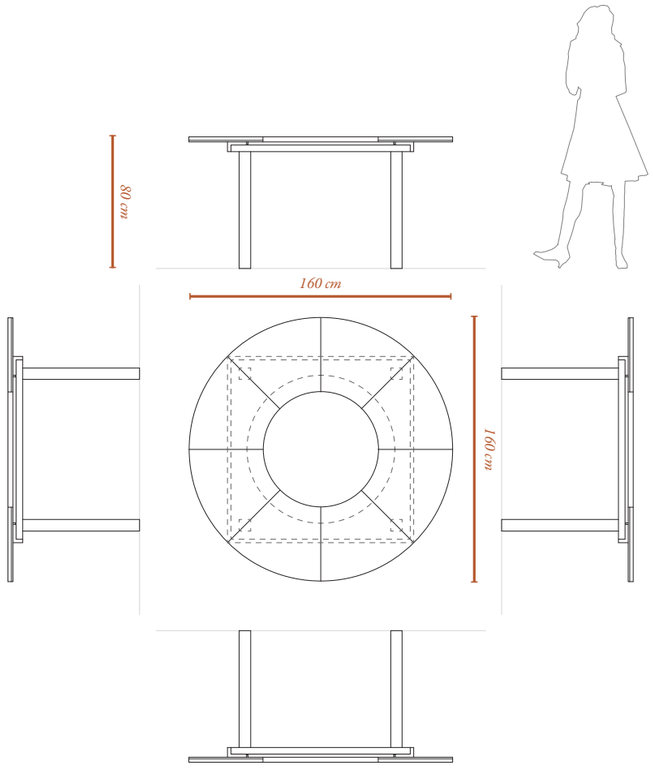
Fig 6.6.2, Inside the Laboratory of memories with the actual layout.

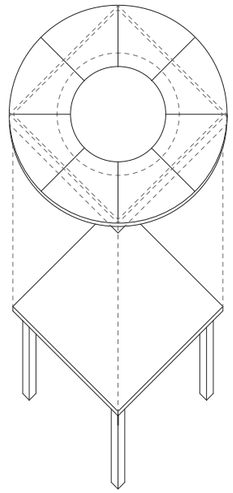
It is a rather intimate and cozy environment which is part of the village services block located in the center of the main square, next to the church and the cafeteria. This environment is characterized by a large wall equipped with drawers containing objects capable of awakening memories of daily life in the residents. Unfortunately, this activity is not one of the most popular among the residents, so it was decided to include a "Tactile Table" that can involve up to eight residents in sensory activities that can stimulate socializing among the elderly.

Tactile Table

This element consists of a circular top that can be placed on the tables already present in the country. The device consists of two levels: the lower one houses a rail that can rotate, while the upper one is divided into eight segments, each made of different materials with specific textures. According to the knowledge of many operators in the field of Alzheimer's, the tactile experience is very important for an elderly person, indeed caressing different materials the patient undergoes a relaxation that leads him to recover some cognitive skills. This activity can also have important implications on socialization among residents as each table can accommodate up to eight participants, in fact the circular shape favors direct communication.







Materials

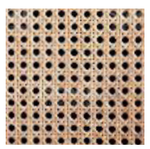

foam


wool


leather


felt

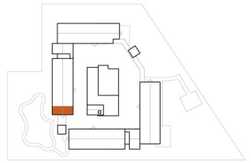

varnish


wien's straw


jeans


larch wood

Atmosphere of the Laboratory after the intervention, with the Tactile Table inserted.



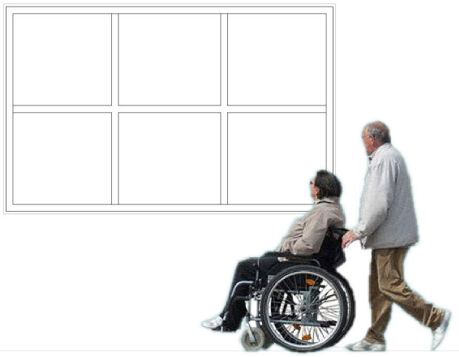
6.6.3 MULTIMEDIAL ROOM

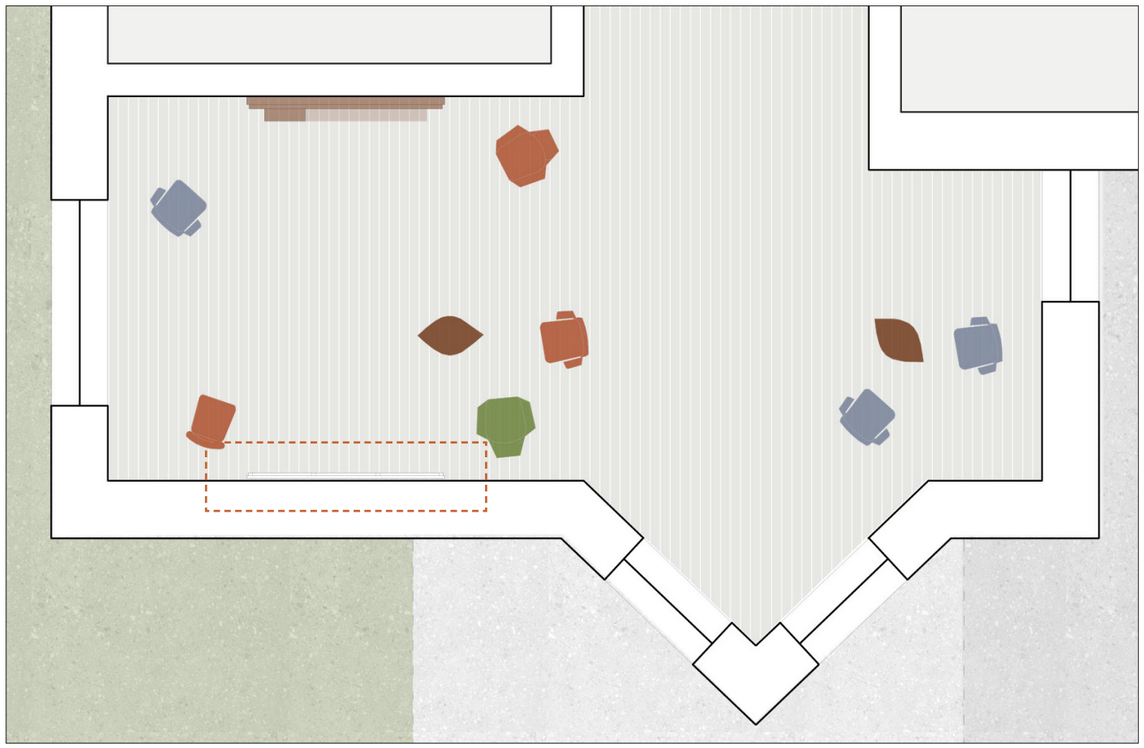
Fig 6.6.3, Inside the Multimedial Room with the actual layout.

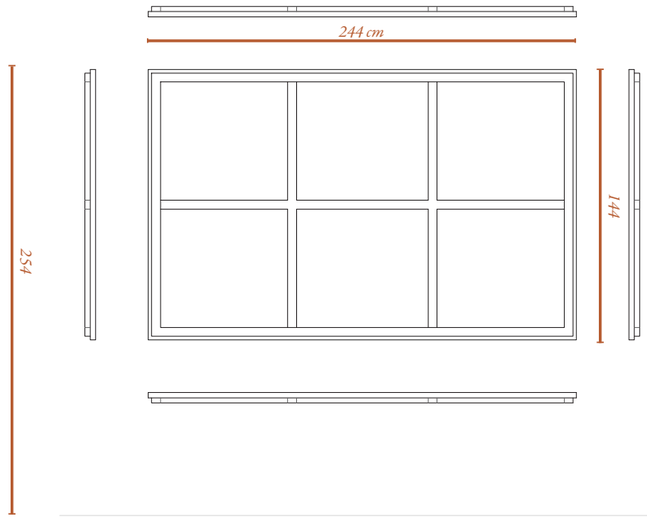
This space is included in each of the four residential units of which the village is composed. This space is equipped with a large screen on which images and memories of the patients, carefully selected by a camera that records the mood of the individual resident, different sittings complete the space. It was decided to insert in this room on the wall opposite the screen a “Seasonal Window” that helps residents to maintain a temporal contact with the current season.

Seasonal Window

One of the most common problems found among Alzheimer’s residents is to maintain contact with the seasonality during the year, in fact the disease inhibits the sense of time, especially in winter when, for climatic reasons, residents leave the structure less frequently. It was therefore thought to design a window that takes into account the changes in the landscape during the different seasons, the panels that make up the landscape are in fact interchangeable photographic panoramas that can help the staff in the critical interaction with the residents, encouraging socialization.



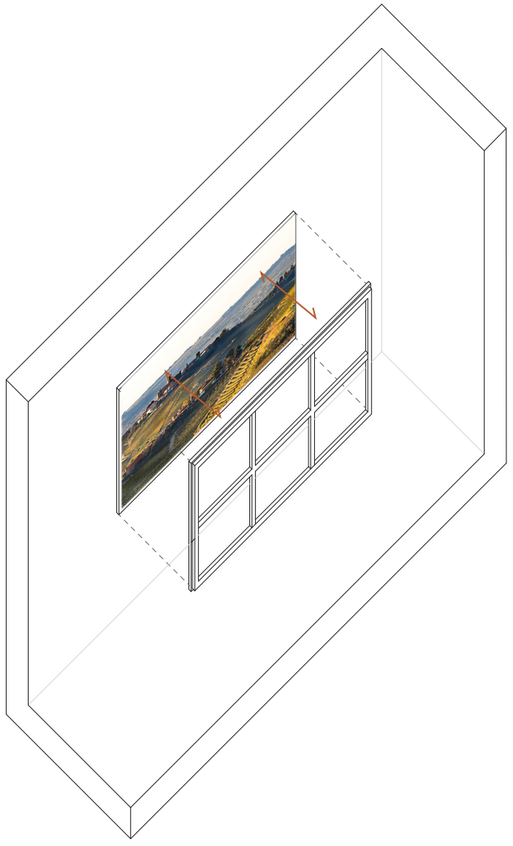




Materials

larch wood

printed FOREX panels

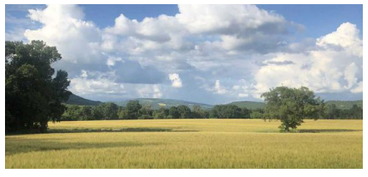


4 Seasonal Panels

Autumn

Winter

Spring



Summer

The Multimedial room with the Landscape Window .

IMPLEMENTATION PROPOSAL

Finally, once the preliminary thorough analysis has been carried out and the solution, in the form of a community behavior prediction tool and substantial architectural proposals, has been presented, we hereby present an implementation plan for the near future.

Our implementation proposal is based on the two main elements of our solution: the Community Behavior Prediction Table and the sensory architectural installations. In particular, we aim to finalize the predictive tool by setting up the sliding window data collection approach presented in Section 5 and by designing a graphic interface for the caregivers. We would then organize training sessions for the caregivers to teach them how to use the proposed tool. After a period of testing at *Il Paese Ritrovato*, we plan to collect the feedback of caregivers on the usability of the interface and on the effectiveness of the tool itself with respect to the sociability of the residents. To evaluate the impact of the Community Behavior Prediction Table we compare the trends of the Relational Index and the Popularity Index before (baseline) and after usage. Specifically, we will observe whether the identified overlooked places exhibit an increase in the Popularity Index with respect to the baseline in the same period, and if the more isolated residents show greater sociability, integrating the feedback provided by caregivers. Moreover, we will assess the predictive performance of our models by comparing the predicted values with actual data, and adjust them accordingly.

On the other hand, with respect to the architectural design proposals, we will discuss with *La Meridiana* to understand whether or not it is possible to implement our enhancements in the proposed places taking into account possible economical and normative constraints. In order not to disrupt the familiarity of the residents with the places of the facility, we propose a gradual introduction of the architectural installations. To minimize the initial impact of the solutions on dwellers, we propose to implement the outdoor ones first, i.e. "Sound Houses" and "Gardens to Compose". Once the residents will get used to these novelties, the "Tactile Tables" and the "Seasonal Window" will complete the proposed intervention.
To evaluate the effectiveness of the aforementioned architectural proposals, we will assess the attendance of the places where the architectural enhancements will be made through the Popularity Index. Moreover, as these interventions are designed to have a positive impact on the sociability of the residents, we will observe the change in the Relational Index of the community and by gathering feedback from doctors, psychologists, caregivers, and, from dwellers themselves, where possible.

BUSINESS ANALYSIS

7.

We analyze the economic viability and attractiveness of the solutions we provide, from the point of view of both *La Meridiana* and other assisted care homes in Europe. We carry out our economical analysis taking into consideration several factors, such as the financial stability of *La Meridiana* and the value-added through time, the market we could reach, and the cost of the solution.

7.1 LA MERIDIANA

Before considering the market sizing and the economical opportunities offered by the integration of the proposed solutions, we focus on understanding the main characteristics of the business model proposed by *La Meridiana* and its current financial and non-financial sustainability. This provides us with a clearer picture of the mission that *La Meridiana* would like to accomplish with its business model and allows us to evaluate how far the project should be pushed.

La Meridiana – Mission and Values

La Meridiana is a very peculiar company. Its business model is not based solely on pure profit as the one of traditional firms. Being a "Cooperativa Sociale", namely a co-operative, the great majority of the profits earned by the company are re-invested for the interests of the members of the community benefitting from the services offered. In the case of *La Meridiana*, its activities are directed primarily at the creation of value for elderly people. As pointed out on the website of *La Meridiana*, its vision is:

"The activity of La Meridiana, in all of its forms, is oriented to the wellbeing of the person welcomed, supporting them by creating the favorable conditions for them to autonomously fulfill their own life plan despite the limitations and sufferings, even existential ones, that they may have".

This particular business model is explained also by the financial data of the company presented in the next Section.

La Meridiana – Financial and Non-Financial Considerations

On 31/12/2018, the most recent date for which a financial statement is available, the peculiarity of *La Meridiana* can be summed up by indicators such as the ROE (Return On Equity) which in 2017 and 2018 has been respectively equal to 0.3% and -4.7%. Being calculated as the ratio between the profit generated and the shareholders' equity, it testifies that the interest of the firm is to generate value and re-invest it for the sake of its own members, in this case, people.

La Meridiana publishes a quite appealing sustainability report every year, with the last available one published at the beginning of 2019. From this report, some interesting non-financial key performance indicators can be extracted. Integrated with the financial ones, these indicators provide a better picture of the value created by the company that does not lie in its financial performance.

Throughout the years, *La Meridiana* has always expanded its workforce, in terms of the number of human resources. In particular, in 2018 the number of nurses and social assistants highly increased thanks to the opening of *Il Paese Ritrovato*. Moreover, it is interesting to point out that the percentage of the female workforce is 74% while the non-Italian ones are 27% out of all the professionals. In addition to that, almost 50% of the workforce is less than 50 years old (22% is less than 30 years old).

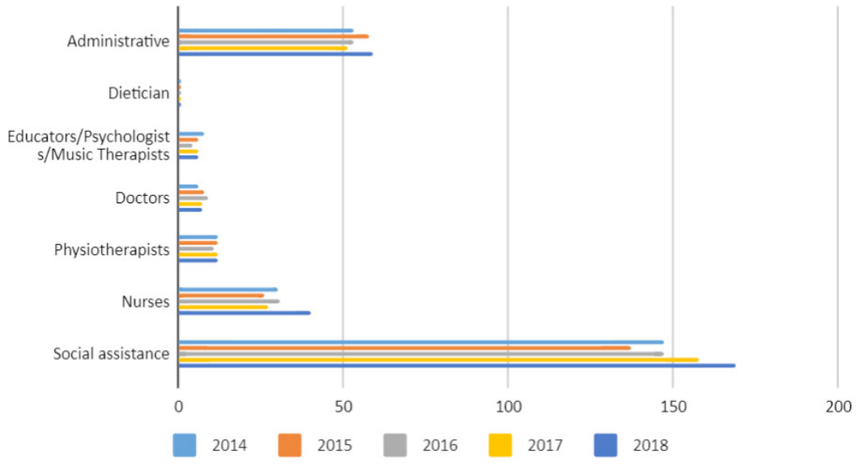


Fig 7.1.1, Workforce Graph.

Considering the value-added distributed by the company in 2018, 82% of it has been distributed to employees, almost 16% to non-employees, and 2.1% to other stakeholders. These percentages are in line with the ones of the previous years. Also, if we consider the percentage of distributed value over the generated one (101.2% in 2018) we have a clear image of the business model of *La Meridiana*, that is, everything is re-invested for the members of the community it serves.

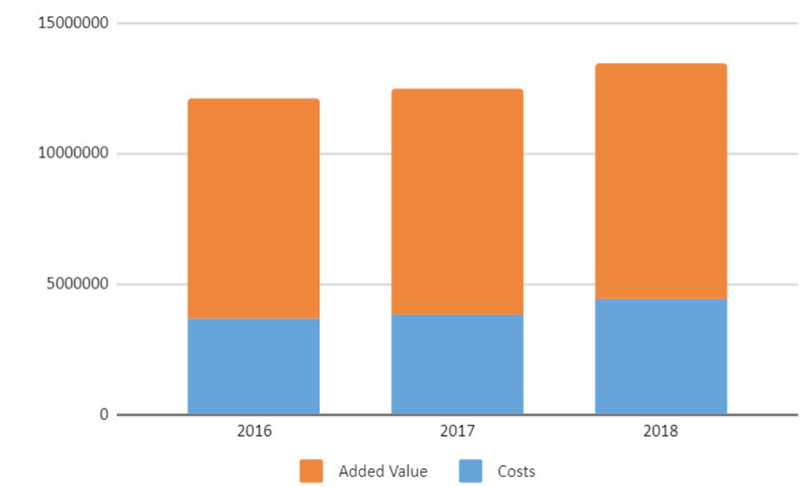


Fig 7.1.2, Value Added Graph.

This particular typology of business relies also on donations. In 2018, the total amount of money donated to *La Meridiana* was equal to 2,374,838€, mainly coming from non-profit donors.

7.2 ALZGAR

ALZGAR - Business Opportunity

The solution implemented at *Il Paese Ritrovato* could have great potential if applied in other facilities. In this report, we explain how the technology installed throughout the village is leveraged to study socialization and to propose architectural interventions; however, the possibilities offered by the same bundle (Bluetooth bracelet and network of antennas) can be suitable for several other purposes. Considering the health crisis the world is experiencing and the impact it has had especially on nursing homes, the same system could be used, for instance, to monitor gatherings and trace infections.

Since the solution is a quite peculiar combination of hardware and software developed specifically for *Il Paese Ritrovato* and for research purposes (not for real profit), it is not possible to predict a precise turnover. Furthermore, especially in markets such as the European one, the majority of the medical system still works under the public administration or under business models such as the one of *La Meridiana*: patients' wellbeing will always be the priority as opposed to earnings.

Market Sizing

In this Section, we present a possible market sizing for the technological model introduced at *Il Paese Ritrovato* and our project ALZGAR. For simplicity of calculation, we only consider the European (EU 28) market, together with the regulations that apply for nursing homes which are very different in non-European countries. According to the projections made in Dementia in Europe Yearbook 2019[1], the number of European people with dementia is expected to reach 10 283 905 by 2025 and 82 million by 2030.

In order to evaluate the expected market size, we are just considering nursing homes and not private ones, since the technology used by ALZGAR can be fully exploited only in spaces with numerous. The percentage of people with dementia residing in nursing homes in Europe (EU 28) is 50%, which means that solutions similar to ALZGAR could have the potential to tackle a market with 5 billion customers in 2025 and a projected value of almost 2€ billion only in Europe[2].

1. Europe, Alzheimer. "Dementia in Europe yearbook 2019: Estimating the prevalence of dementia in Europe." (2019).

2. AAL Market and Investment Report: Summary by Technopolis (2018).

Cost of the Solution

It is very difficult to estimate a projected cost for this kind of solution, since there are no data at European level on the number of facilities that could actually be prepared to fully implement such a technological solution and on the number of people they are currently hosting (*Il Paese Ritrovato* constitutes a very peculiar example inside the European context and there are just few facilities which can be considered as similar examples).

Also, the costs for the implementation strongly depend on the architectural structure of the facility: according to the different disposition of the rooms, the number of antennas could vary significantly, as well as the cost of installation and maintenance.

However, we should also consider that the Bluetooth technology on which the technical solution is based is becoming cheaper and cheaper. Just considering the hardware, the cost of a bluetooth antenna is usually up to 100€ (also considering the costs related to the implementation of a system based on Arduino), while the one for a simple Bluetooth wristband is usually lower than 30€. Of course, we should also consider the necessity of building an infrastructure for position tracking. This opens up the necessity for a server and implementation, which in this case was carried out by the DEIB department of Politecnico di Milano. Also, we should consider data storage and cleansing (usually a cloud service which offers this service requires a 100€ monthly fee).

Marketing Plan

In september 2020, we presented the development of our project to the 17th International Conference on Computers Helping People with Special Needs (ICCHP 2020). This has been a great opportunity to show the potentialities of our technical solution when applied to patients' socialization. This first presentation can be considered as the first real trial for expanding the model proposed by *Il Paese Ritrovato* and start looking for potential investors and philanthropists interested in applying the same technology for similar purposes.

In order to showcase the solution, *La Meridiana* should exploit similar occasions, attending conferences around Europe showing the potentialities of the technology applied in the context of AD care and the related purposes. In particular, we suggest focusing on those conferences gathering impact investors.

Conclusions

The framework of ALZGAR and the proposed solution could be extended also to other contexts, even if dementia care alone already represents a big and expanding market. Despite the majority of the initiatives being conceived without a real profit-making purpose , it is still possible to create a significant impact on people's lives and attract investors which are interested in this new field of solutions.

CONCLUSIONS, FUTURE WORK 8.

In this chapter we summarize our original contributions and identify new possible lines of work to further explore in the future.

8.1 ORIGINAL CONTRIBUTIONS

In this work, we analyzed the localization data of the residents of *Il Paese Ritrovato* to gather insights on their behavior and designed digital and architectural solutions for the improvement of their social life and wellbeing.

We conducted a thorough analysis on the state-of-the-art solutions for Alzheimer's disease (AD) care similar to those implemented at *Il Paese Ritrovato*, and outlined the stakeholders profile, needs and requirements. We analyzed the existing technological devices present at *Il Paese Ritrovato*, including the Bluetooth wristbands and the network of antennas scattered throughout the village providing the localization of the residents. Leveraging this data alone we defined objective measures of sociability for individuals and for the entire community, and for the popularity of places.

To understand the social behavior of the dwellers, we considered the Relational Index and extended its definition to capture the sociability of single individuals and of the entire community. We observed dwellers' sociability is correlated with the season, the temperature, the dweller's bedroom floor, the predisposition to walk on a specific day, and the dweller's average hourly walked distance. Furthermore, we identified clusters of residents, close friendships and social isolation, drawing the social network of *Il Paese Ritrovato* through a graph and outlining the social profile of residents.

To assess the attendance and social utility of places, we introduced the Popularity Index. Leveraging functional data analysis and functional principal component analysis, we identified highly frequented areas, such as the market and the cinema, and unpopular ones, namely the two gardens. Despite being easily accessible, the latter areas cover peripheral areas of the village resulting in the residents rarely spending time outside. Therefore, we focused our architectural design on these to promote accessibility and attendance, considering also that gardens provide excellent sensory stimuli to the residents, ultimately improving their wellbeing.

Considering the aforementioned analyses, we designed technological and architectural solutions to enhance social activities scheduling and to augment the accessibility of underutilized areas to promote attendance of places.
Furthermore, we built predictive models leveraging neural networks and powerful machine learning techniques to estimate the Relational Index and the Popularity Index for a specific state of the environment, described by several predictable variables such as the weather, the temperature and the season.

The behavior of dwellers, captured by these measures, plays a fundamental role when it comes to organizing social activities at *Il Paese Ritrovato*. As such, we introduced the Community Behavior Prediction Table, a visual tool combining the predictive models to support caregivers in organizing activities.

Furthermore, considering the thorough data and architectural analyses, we decided to intervene precisely on those areas in need of specific enhancements so as to leverage their full potential, such as the wandering garden and the lab of memories. We proposed to act on the home environment to considerably improve the well-being of the patients, mitigating the risk of crisis and promoting mental stability, leveraging sensory maps to investigate intimate and subjective aspects of patients through their sensory memories and routines, letting space become part of a non-pharmacological therapy. Sound houses, gardens to compose, tactile tables and a seasonal window are among the proposed architectural solutions to improve the wellbeing at *Il Paese Ritrovato.*

The solution we present for *Il Paese Ritrovato* could have a great potential if applied in other facilities specialized in dementia care, considering that the number of people with dementia is expected to reach 10 million by 2025 and 16 million by 2050. Despite focusing our project on the way the technology installed inside the village may be leveraged to study socialization and to propose architectural interventions, the possibilities offered by the same bundle (Bluetooth bracelet and network of antennas) can serve many other purposes, such as monitoring social gatherings and tracing infections.

Finally, we proposed a roadmap to implement and evaluate our solutions, taking into consideration the needs of the facility, the resources available and the impact of our proposals on the comfort and wellbeing of the residents.

The solutions presented by ALZGAR are quite innovative. The data awareness obtained from our analyses will be of great help to caregivers, doctors, and psychologists to enhance social activities in assisted care homes, adjust patient-specific treatments, and deepen the comprehension of the disease. The presented predictive tools will be of great support to caregivers during activity scheduling. The architectural enhancements, which leverage state-of-the-art sensory maps, will mitigate the risk of crises and promote mental stability.

8.2 FUTURE WORK

Once the implementation proposal is put in place, there are several directions of work to be undertaken next.

First, a data visualization tool, in the form of a web application, shall be implemented to allow caregivers, doctors and psychologists to access the collected data and gain further insights on residents' behavior. This online portal would become a powerful tool to support the daily work of the staff of AD care houses.

Besides data on the movements of patients inside the facility, several other information could be included on this platform, including patient-specific medical records, treatments, and activity attendance. Most importantly, this application would allow the visualization of all the measured indexes through graphs and the usage of the Community Behavior Prediction Table.

Furthermore, a mobile application can be developed for caregivers to manage and keep an eye on their patients in a smarter way. Besides being a mirror of the afore-presented portal, the main functionalities of this application would also include alerts for anomalies in the behavior of patients (e.g., when patients are in forbidden places such as next to the exit), an internal staff chat to avoid using third-party services for privacy reasons, an activity attendance monitoring system, and a survey-based check-up system for patients health and disease progression monitoring. This application would empower caregivers relieving them of part of the burden they experience daily.

To effectively monitor patients wellbeing and their health condition, other data may be collected such as the heart rate, the temperature and the sleeping activity. Smart bracelets, such as those of *Empatica*, can be used to extend data collection integrating the existing localization monitoring system. Being able to observe not only their position but also other variables could allow a full digitalization of the patient profile for enhanced data analysis.

Finally, our data analysis can be extended to caregivers so as to understand how their behavior influences the sociability and the wellbeing of patients in *Il Paese Ritrovato*.

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The tree of life becomes the logo of our project as the intention of the group is to contrast the common ideology according to which the elderly, suffering from dementia, are seen as a burden for the community.
Our tree, on the contrary, is an element of wealth anchored to the past through its roots and reaching out to the future with new fruits.

XV CYCLE