From Isolation to Connection: Community Service Robots for Social Cohesion and Sustainability

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***Abstract*—Social alienation challenges community cohesion, particularly in diverse societies like Australia. This study introduces the Neighbor Koala, a community-sharing robot designed to foster social connections and promote sustainability. By facilitating item exchanges and capturing shared memories, it aims to address isolation while reducing waste. Leveraging the sociological concept of the "gift", it strengthens emotional bonds and community belonging. This work provides a cornerstone for future studies on how robotics can enhance social well-being and environmental responsibility in urban contexts.**

***Index Terms*—Service Robot; Community; Social Cohesion; Sustainability**

I. Introduction

Social alienation has become a defining feature of urban life over a century [1]–[3]. The increased mobility nowadays has led to greater uncertainty and instability in modern communities, resulting in more fragmented, discrete and atomized interpersonal relationships. This is particularly evident among new immigrants, especially those whose first language is not the official language, who may experience a diminished sense of national belonging compared to native-born residents [4]. In diverse societies like Australia, where more than 260 languages are spoken [5], cultural and linguistic diversity is a strength, fostering creativity and broad perspectives, but also presents challenges, as differences in communication can sometimes hinder social cohesion, contributing to feelings of alienation [6], [7]. Promoting positive social connections is vital, as they strongly correlate with increased collective happiness [8]. Alienation disrupts these beneficial relationships, undermining both individual well-being and community harmony. Studies from the Australian context have shown that informal social participation and connections significantly enhance social cohesion and personal mental well-being [9]. This underscores the importance of reintegration and revitalization efforts to foster a sense of belonging and connection in local communities.

There is growing concern that emerging technologies may contribute to social alienation [10]. For instance, many service robots, such as food delivery robots and unmanned taxis, are designed primarily to reduce labor costs in daily life. Similarly, other technologies incentivize online behaviors, such as offering discounts for online shopping, further encouraging a lifestyle centered around digital interactions. These trends have contributed to a reduction in face-to-face human communication. As a result, the issue of social alienation has been further exacerbated.

This raises an intriguing question: could advancements in robotics technology, particularly with its rapid progress, be leveraged to address and mitigate social alienation? Pioneering research introduced the concept of the mutual shaping of technology and society, highlighting how societal needs can inform the design of robots, which in turn shape social behaviors and lifestyles [11]. This concept has opened the door to innovative approaches for developing service robots that foster social engagement, challenging widespread fears of technology as a driver of isolation. Building on this framework, it is worth exploring the potential of robots to facilitate communication and connection within communities, promoting interaction rather than isolation. In this new perspective, the robots are not intended to replace human "friends" and "family"; rather, they can serve as a social lubricant to enhance and foster relationships, thereby addressing issues of social isolation and alienation.

Although the issue of fostering social connections through human-robot interactions has gained increasing attention, research on designing and developing robots to enhance context-specific shared goals, interactions, and experiences within geographical communities remains limited. Several studies have demonstrated that robots in group settings can increase interactions not only between individuals and robots but also among people in the surrounding environment [12], [13]. For instance, a pilot study explored the use of shared social robots in a retirement village, focusing on their potential to support communal living [14]. The findings revealed that robots could assist with tasks such as remembering new acquaintances' names and facilitating community events, positively contributing to community connectedness. However, there is a notable gap in the literature regarding the use of robots to build collective community memory, foster public narratives, and promote sustainable lifestyles. Further investigation is needed into how service robots can be designed and utilized to create participatory and empowering community interactions,

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particularly in the areas of social cohesion, belonging, and the development of collective memories.

Thus, in this work, we introduce the concept of community-sharing service robots and a series of associated service systems to encourage residents to share items they no longer need with their neighbors, fostering participation and social interaction. This approach not only facilitates the exchange of goods but also helps establish stronger emotional connections, shared narratives, and collective memories within the community, ultimately building a sustainable system to enhance community cohesion. This project aligns with the United Nations Sustainable Development Goals (SDG), particularly sustainable cities and communities (SDG 11), good health and well-being (SDG 3), and reduced inequalities (SDG 10). It also calls on the community to actively participate in sustainable development research.

II. Design and Interaction

A reciprocal community can support the collective well-being of its residents and contribute to a sustainable, inclusive, and prosperous future. While language and cultural differences may pose barriers, kindness and sharing are universal traits that transcend these boundaries. This project employs the design concept of "sharing" as a bond to strengthen community connections, promote cohesion, and foster neighborhood care. It draws on the sociological concept of the "gift", introduced by Marcel Mauss, as a foundation to mobilize surplus assets in daily life [15]. As a fundamental concept for understanding the formation and maintenance of relationships in society, "gifts" play a role in alleviating individuals' insecurities at the level of social relationships [16]. Unlike commodity exchanges, which are transactional and do not inherently foster ongoing interactions, gift exchanges are not based on strict equivalence and include a strong moral dimension. The purpose of gift exchange extends beyond immediate transactions, aiming instead to build lasting, repeated, and deepening interpersonal relationships over time. Described as a "non-obligatory expression of ideal reciprocal social relations" [17], the concept of the "gift" is utilized in this study to encourage the production and reproduction of social relations and cultural values. As the final step in the robot's service system, unclaimed "gifts" are periodically sent to charity shops, contributing to social equity. By extending the life cycle of items and increasing their circulation, this system reduces pressure on municipal hard waste disposal and promotes broader societal well-being.

To facilitate the functionality of the item exchange, an autonomous robot is designed and prototyped based on the criteria. The robot, naming Neighbor Koala, is inspired by the koala, a marsupial native to Australia, well-known for its round ears and large nose. The body of the Neighbor Koala is a storage cabinet with a lockable door. And in front of its chest is a touch screen with Graphical User Interfaces (GUIs), showing a default welcome page. A physical interface is implemented in the Neighbor Koala's nose as the main switch to start and end the interaction. The Neighbor Koala is designed to navigate autonomously to predefined destinations

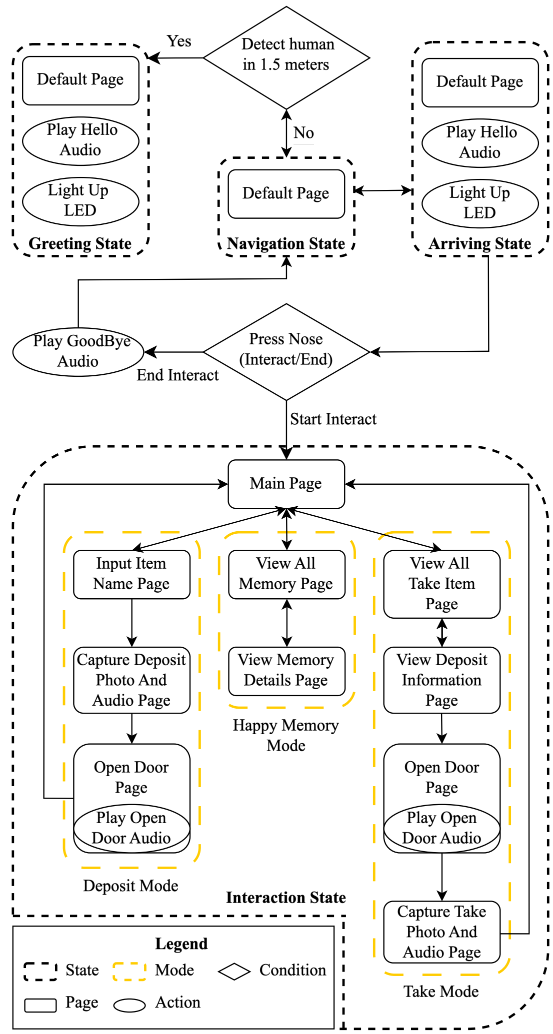

Fig. 1. The robot state and interaction flow of the Neighbor Koala.

within the community while actively avoiding obstacles in the 'Navigation State' (its default state). As shown in Figure 1, if a human comes within a short distance (currently set at $1.5m$), the robot transitions to the 'Greeting State' by pausing its motion and using voice and lights to greet the individual. Existing research suggests that such social expressions in interactive scenarios enhance the perceived friendliness of the robot's interactions based on human preferences [18]. Once the Neighbor Koala arrives at its destination, it switches to the 'Arriving State' and uses audio and visual aids (voice and LEDs) to notify residents. If there is no response within a set period, the robot will leave. However, if a user presses its nose, the robot transitions to the 'Interaction State.' In the 'Interaction State,' community residents can deposit unused items or take existing ones using the robot's user interface. They can follow the guided process to unlock the cabinet door and access its contents. Residents also have the option to capture a photo or record an audio message to introduce items, share memories, or send good wishes. On the main page, users can view 'Happy Memories' which include the history of items along with photos and messages from both

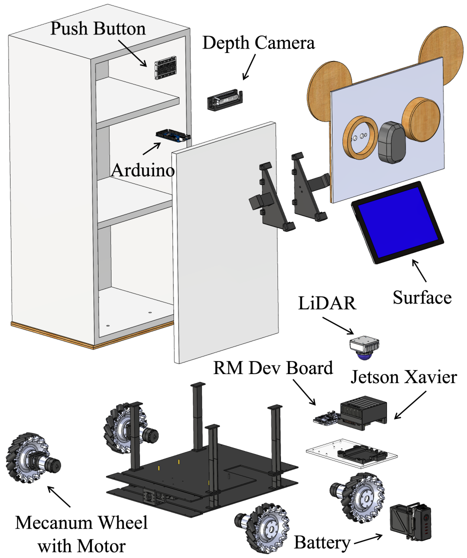

Fig. 2. Exploded view of the mechanical structure of the Neighbor Koala.

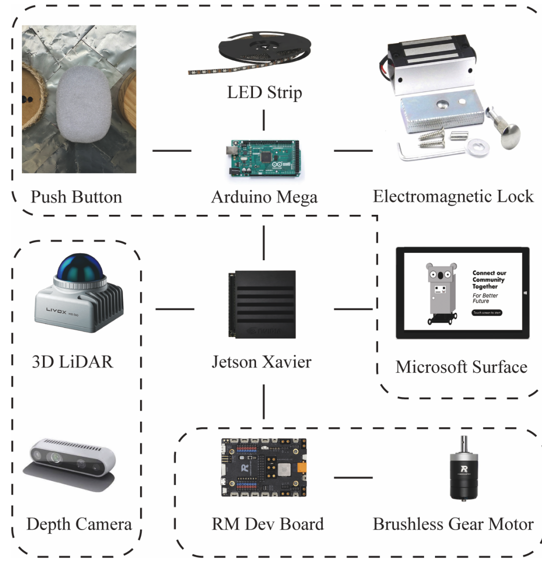

Fig. 3. Hardware schematic.

sharers and recipients. After the user presses the robot's nose again, the Neighbor Koala says goodbye and returns to the 'Navigation State,' resuming its journey to the next destination.

III. Implementation

Neighbor Koala is implemented based on the sustainable design concept by reusing and recycling the existing devices from the universities and household waste to the maximum extent.

As shown in the Figures 2 and 3, the mechanical structure can be generally categorized into the body and the chassis. The body, which is a shelf-like storage cabinet with lockable doors, is built using recycled construction waste. A Surface Pro (Microsoft Corporation, U.S.) is mounted on the outside of the cabinet door as the GUI. The top shelf of the cabinet serves as the device compartment, housing an Arduino Mega Development Board (Arduino, Italy), an Intel D435i depth camera (Intel, U.S.), and an interaction push button located behind its nose. The head is made of laser-cut Medium Density Fiberboard, covered with recycled cans. The koala's eyes are crafted from material from a broken cat tree, while the nose is hand-crafted using Expandable Polyethylene (EPE foam), recycled from packaging material. A Livox Mid-360 3D LiDAR (Livox, China) is suspended under the cabinet, above the chassis. The chassis, driven by four RM3508 DC brushless gear motors (DJI, China) and Mecanum wheels, was reused and modified from a previous student challenge in a robotics conference. The main robot controllers include a Jetson Xavier AGX (Nvidia, U.S.) and a RoboMaster Development Board Type A (DJI, China), which features an STM32F427IIH6 microcontroller (STMicroelectronics, Switzerland). The Jetson Xavier handles high-level tasks such as computer vision, path planning, motion planning, and decision-making, while the RM Dev Board manages low-level tasks requiring high-frequency computing, such as feedback control and safety. The Neighbor Koala is powered by recycled drone batteries.

The software development is distributed across four computing devices, each responsible for distinct tasks to enable the robot's functionality described in Section II. On the robot's main controller, the Jetson Xavier, the Robot Operating System (ROS) is implemented to coordinate core operations. Next, YOLO v3 [19] is employed to detect nearby humans, and using depth information, it publishes messages to trigger state transitions. Additionally, LIO-SAM [20] provides odometry and mapping data. The navigation system remains in a preliminary stage, utilizing predefined destination points and the Time Elastic Band local planner [21] as its motion planner. A finite state machine (FSM) manages transitions among states such as 'Navigation', 'Arriving', 'Greeting', and 'Interaction'. The Jetson Xavier also handles serial communication with other devices, supported by a message processing module to manage inter-device communication effectively. On the STM32 microcontroller, a Real-Time Operating System (RTOS) is configured to run at $500\ Hz$. It receives command velocities from the navigation system on the Jetson Xavier and computes inverse kinematics to derive motor speeds. The Surface hosts a GUI developed in Python, which sends user inputs to the Jetson Xavier. Finally, the Arduino is programmed with a super loop to handle control of LEDs and door locks, receiving relevant messages from the Jetson Xavier. An interrupt mechanism processes input from a push button and triggers the state change in the FSM.

IV. Discussion

This research explores the possible role that robotics can play in cultivating community connections and fostering a sense of belonging within contemporary urban contexts, with a particular focus on communities in Australia. Existing study pointed out that the social belonging is the experience of social connection [22]. It covers social and emotional levels, reflecting the basic needs of individuals for social contact, interaction, support, and emotional communication throughout their lives. Interactive social technology can promote greater social participation and higher social capital and participation, thereby generating a greater sense of belonging within the community. To address social alienation and strengthen emotional connections, this study utilizes robots to create collective community memory and public narratives, shaping shared emotional experiences within communities.

Moreover, the Neighbor Koala robot was designed and prototyped with sustainability at its core, extending from its materials to its functionality. This sustainable approach embraces the concept of finding value in waste. On one hand, waste recycling is used to repurpose discarded materials and components for building the robot. On the other hand, the robot facilitates item exchanges to prevent unnecessary waste. Each year, countless items are discarded as they are no longer needed. By enabling the exchange of such items, the Neighbor Koala robot helps reduce waste while supporting municipal efforts to alleviate the challenges of hard garbage disposal. This dual focus on sustainability and functionality underscores the robot's contribution to community well-being and environmental responsibility. To better utilize the resources, even when the robot is not in use, it can be repurposed as a guide in local museums or libraries.

The Neighbor Koala will donate any unclaimed items to second-hand stores which are vital in extending the life cycle and re-evaluating waste as a resource [23]. In Australia, these second-hand institutions use specific discourse strategies of thrift and sustainability and not for profit. They are deeply rooted in the community and are widely recognized for their social work in the Australian context [24]. This service contributes to the sustainable cycle of production, consumption, and redistribution to support social well-being.

The current prototype demonstrates the feasibility of designing such a robot; however, several drawbacks and areas for future work worth further investigation. Firstly, the current interaction modalities are limited to the GUI, push button, and LEDs, which primarily serve as visual aids. Exploring how large language models can empower the robot with more diverse interaction modalities, especially for users who cannot read the GUI, presents an interesting challenge. From an engineering perspective, future iterations of the robot could incorporate advanced algorithms and more suitable mechanical structures, such as a tracked chassis for improved mobility. Additionally, while the current robot design reflects the work of designers and engineers, it would be valuable to investigate how participatory design processes involving users could better guide design decisions. Furthermore, an empirical study to qualitatively assess the robot's contribution to social cohesion is anticipated as a critical area for future research.

V. Conclusion

This work demonstrates the potential role that robotics can play in connecting communities and fostering a sense of belonging within contemporary urban contexts, with a particular focus on communities in Australia. Although the current prototype of Neighbor Koala is merely a proof-of-concept, it has demonstrated the feasibility of using technology for such applications and serves as a cornerstone for further studies.

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