HATHOR – Accessible Automation and Interaction in a Hydroponic Garden for People with Disabilities

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Abstract: This paper presents the design and implementation of an intelligent hydroponic garden, remotely controlled via mobile devices and automated through sensors and actuators integrated into Home Assistant. The system enables automated irrigation through programmable electromagnetic valves, as well as control of the hydroponic solution conditions, temperature via fans and light through motorized blinds and heat lamps. The developed app was specifically designed to facilitate interaction for individuals with intellectual disabilities, prioritizing accessibility, autonomy and positive reinforcement. This intervention was implemented in a Care Center for People with Disabilities aiming to enhance users' motivation in meaningful activities related to plant care, irrigation and environmental control.

1 Introduction

Hydroponic agriculture, the cultivation of plants in soil-free nutrient solutions, has consolidated over the past decade due to advances in sensing, automation, and remote monitoring. Several studies indicate that eliminating the need for soil enables precise monitoring and adjustment of parameters such as pH, electrical conductivity (EC), temperature and humidity, thereby optimizing water use and increasing production efficiency. A recent review highlights that hydroponic systems employ different sensors which are integrated into IoT device networks to remotely monitor and control cultivation Deshan et al. (2024); Yaqin et al. (2022). These technical features have facilitated the expansion of hydroponics beyond intensive production to educational and therapeutic domains.

The American Horticultural Therapy Association emphasizes that horticultural therapy involves guided participation in gardening or cultivation activities with the purpose of supporting physical, cognitive, and emotional rehabilitation AHTA (2025). In addition to the physical activity associated with cultivation strengthens muscles and enhances coordination, balance, and endurance. Horticultural interventions have been used in the rehabilitation of veterans, older adults, and individuals with intellectual disabilities Lai et al. (2017). These benefits are attributable to the combination of multisensory stimulation, contact with nature, and concrete responsibilities involved in plant care Kim et al. (2025).

In parallel, the field of technological accessibility has evolved rapidly. Assistive technology (AT) is defined as any device or system that enables a person with a disability to perform daily tasks and to maintain or enhance their abilities. It encompasses a wide spectrum, ranging from low-cost tools to more complex electronic systems, as well as training and maintenance services. Recent intervention programs have combined AT solutions with sensors and mobile applications to increase the autonomy of people with intellectual disabilities Lang and McLay (2023). These developments promote more inclusive environments by providing adapted tools that reduce access barriers and promote participation.

Traditional therapeutic gardens have been used as resources in occupational centers. However, because they are based on conventional horticultural models, they often pose barriers related to physical effort or task complexity. The lack of automation limits the participation of individuals with intellectual disabilities or reduced mobility, who require additional support Nikhil et al. (2023). The integration of hydroponics, home automation, and accessible applications offers the potential to enable more autonomous and rewarding interaction with the environment Joy et al. (2020).

1.1 HATHOR project

In this context, HATHOR (Hydroponic Automated THerapeutic ORchard) emerges as an initiative within the original TICARE Project of the Research Center on Information and Communication Technologies (CITIC) at the University of A Coruña (UDC). The project focuses on the design and implementation of an accessible therapeutic hydroponic garden, equipped with sensors and actuators integrated via Home Assistant and controlled through an application adapted to the cognitive needs of users with intellectual disabilities. The technological layer incorporates devices for measuring parameters, as well as electromagnetically controlled valves and pumps that regulate irrigation and the recirculation of the nutrient solution.

In addition, an accessible mobile application has been developed, prioritizing simplicity, the use of pictograms and positive reinforcement. This app enables users to participate in garden care both onsite and remotely: they can activate irrigation, check the status of the plants or adjust lighting with a single tap, while the system records who performed each action and for how long. The first installation was carried out at the CCPD in A Coruña in April 2025, with the cultivation of padrón peppers, strawberries, and aromatic plants. This intervention has made it possible to assess both the technical feasibility of the system and its therapeutic potential.

The present study describes the design and implementation and reports preliminary conclusions , highlighting its implications for socio-healthcare intervention.

2 Design and implementation of the system

The HATHOR project was designed following a modular approach, enabling the integration of different components of sensing technologies, home automation, and software into an accessible and replicable environment.

2.1 Physical structure of the garden

The installation of the hydroponic garden was carried out in an indoor room of the CCPD, specifically adapted for this purpose. As you can see in Figure 1 The structure consists of a high-resistance wooden frame that supports parallel PVC cultivation pipes, perforated with circular openings for the placement of plants.

Figure 1: Physical structure showing the wooden frame, PVC cultivation pipes and protective panels.

At the base, a high-capacity nutrient solution tank is connected to a pressure pump that drives the water into the cultivation pipes through a system of tubing and solenoid valves. The modular design facilitates access to both the hydraulic system and the control elements, allowing simple and safe maintenance operations. The structure is complemented by ventilation and climate control systems, integrated at the top with fluorescent lamps and a fan that regulate the temperature and humidity of the space. In addition, the installation is partially enclosed with wooden panels to protect the components and tanks. The vertical arrangement of the pipes, combined with lateral accessibility, allows users to interact directly with the plants, thereby reinforcing the therapeutic component and encouraging active participation in garden care.

2.2 Hardware infrastructure: sensors and actuators

The hydroponic garden is equipped with a heterogeneous set of sensors and actuators that enable the monitoring and regulation of environmental and cultivation conditions. Among these are devices from the Sonoff family (DUAL R3, Switchman R5W, 4CHR3, Mini R4, and THR316D), as well as specialized water multimeters. Figure 2 illustrates the overall system architecture, showing the arrangement of the tank, valves, pumps, sensors, and their integration within the hydroponic structure.

The main parameters recorded and controlled include:

- Water conditions: pH, EC, oxidation-reduction potential (ORP) and salt concentration.
- Water flow and level: flow meters and level sensors ensure proper circulation and availability of the nutrient solution .
- Solenoid valves automatically regulate the flow of water into cultivation pipes.
- Environmental conditions: temperature, humidity, atmospheric pressure sensors, as well as CO_2 meters, help maintain a stable microclimate.
- Supporting devices: a ventilation system with extractors and fans, heat lamps and motorized blinds contribute to regulating temperature and lighting.
- Safety and monitoring: the system incorporates a surveillance camera (TP-Link C520WS) and a central control unit based on Home Assistant OS.

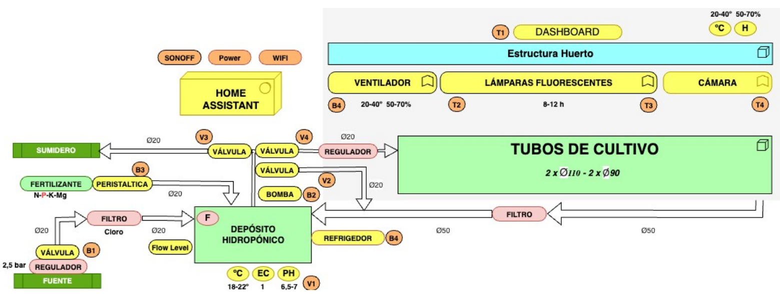

Figure 2: Schematic representation of the HATHOR hydroponic system, including sensors, actuators, and their integration through Home Assistant.

2.3 Control and automation layer

All devices are integrated through the Home Assistant automation platform, which serves as the communication hub between sensors, actuators, and mobile applications. This intermediate layer enables:

- Automating periodic tasks, such as opening and closing irrigation valves.
- Autonomously adjusting parameters, for example, activating fans if the temperature exceeds a predefined threshold.
- Storing and visualizing historical data on garden conditions, facilitating decision-making.
- Sending notifications and alerts to administrators when deviations in critical parameters are detected.

In addition, the application incorporates a user registration feature that identifies who is operating the system at any given time. This is achieved through the creation of personalized profiles with photographs, and the system automatically records variables such as user identity, date, start time, session duration, and specific actions performed. This functionality not only supports individualized monitoring of garden use but also provides a tool for analyzing user engagement, reinforcing autonomy and delivering feedback to both therapists and researchers in future evaluation phases.

The integration of low-cost, easily programmable IoT devices was an essential design criterion to ensure the scalability and replicability in other similar centers.

2.4 User Interface: Accessible Application

One of the distinguishing features of the project is the development of an accessible mobile application, designed in two versions: one aimed at administrators/professionals and another simplified version for users with intellectual disabilities, see Figure 3.

- Administrator version: This version enables the management of all garden parameters, calibration tasks, and the configuration of irrigation, lighting, and ventilation routines. It provides real-time data visualization, operational history, and remote access from any network-connected device.
- User version: This version was designed with a cognitive accessibility approach. Its interface incorporates pictograms, large buttons, simplified messages, and positive reinforcement after each interaction. In this way, users can perform specific actions (watering, switching on lights, checking plant status) without needing to manage complex technical information.

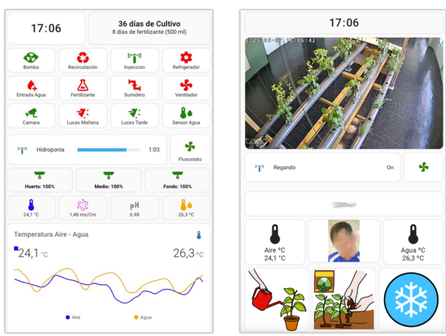

Figure 3: Administrator and user interface of the HATHOR hydroponic system.

The dual structure of the application supports both the technical management of the system and the meaningful participation of end-users, aligning with therapeutic.

2.5 Maintenance and calibration procedures

The proper functioning of the garden requires a series of periodic operations, designed to be simple and safe within the environment. The main procedures include:

- Cleaning and replacement of filters in the inlet and recirculation water lines.
- Priming and purging of the pump after periods of inactivity or when air enters the system.
- Calibration of pH and electrical conductivity sensors, performed quarterly.
- Adjustment of the water chiller to maintain tank temperature parameters.

3 Outcomes

The first implementation of the HATHOR system at the CCPD allowed for the collection of preliminary outcomes.

From a technical perspective, the system proved reliable and no major malfunctions were reported beyond occasional sensor errors and connection issues. The visualization of historical data was considered clear and useful for monitoring purposes. Although maintenance procedures were not directly applied during the pilot phase, professionals reported the need for further training to manage the administrator interface and technical protocols effectively.

With regard to the usability of the application, professionals emphasized the accessibility oriented design as one of its most valuable features. The co-design process, which involved engineers, occupational therapists, healthcare professionals and maintenance staff, facilitated an interface that was intuitive for users. However, participants suggested that expanding user-accessible functionalities would further promote responsibility and engagement in garden management.

A total of six individuals took part in the activity. Users showed high levels of spontaneous interest, particularly in the care and harvesting of strawberries, which emerged as the most engaging plant species. Motivation remained strong throughout the implementation, with users frequently anticipating their turn to attend the garden and demonstrating proactive behaviors such as monitoring plant health and removing dry leaves.

Regarding therapeutic outcomes, professionals observed improvements in autonomy, routine adherence and cognitive skills, alongside an increase in self-esteem. The activity was perceived as relaxing rather than stressful, and users expressed a genuine interest in plant care rather than viewing it as an imposed obligation. The garden also fostered a sense of responsibility and integration, while promoting a new interaction between users and professionals. Reported therapeutic goals included sustained attention, motivation and adherence to schedules.

From an organizational standpoint, the integration into the center's daily dynamics presented challenges, particularly in terms of coordinating group schedules and ensuring access to the designated room. Despite this, professionals highlighted the learning opportunities derived and recognized the system's potential for scalability.

Finally, the project was considered viable for continued use with a larger number of participants and professionals agreed that it could be replicated in similar centers.

4 Discussion

The preliminary results of the implementation demonstrate a positive effect on both the technological and therapeutic levels. When comparing these findings with existing literature, similarities emerge that enrich the field of horticultural therapy and assistive technology.

The reliability of sensors and actuators is consistent with studies on IoT-based hydroponic systems. Professionals valued the ability to collect and visualize historical data, reinforcing the relevance of automated records for adjusting cultivation routines, as reported in other IoT-enabled horticultural applications.

The co-design approach aligns with recommendations which emphasize the cognitive benefits of horticultural activities. The adapted interface improved task comprehension and user autonomy, supporting the idea that AT should expand skills and promote active participation of people with intellectual disabilities. The individualized session logging also mirrors recent studies advocating simple digital tools and sensors to enhance autonomy and learning.

Findings agree with prior evidence that horticulture fosters intrinsic interest, responsibility, and self-esteem. The preference for strawberry harvesting and plant monitoring echoes research linking horticulture to productivity and work skills, while its perception as a relaxing activity aligns with studies reporting reductions in anxiety and improvements in emotional well-being.

Finally, the organizational difficulties identified, such as logistics for accessing the garden classroom and the need for additional technical training, reflect common challenges in horticultural and AT programs, where ongoing support is key. Still, professionals expressed willingness to expand and replicate the project, this highlights HATHOR's scalability and aligning with calls for low-cost, replicable solutions to improve quality of life for people with disabilities.

4.1 Future research lines

The HATHOR project is currently in an early phase of implementation and validation, which highlights the need to establish research avenues:

- Record indicators such as sensor/actuator failures, system stability, and ease of calibration and cleaning protocols to optimize the system before wider deployment.
- Conduct longitudinal assessments with users with intellectual disabilities through adapted usability questionnaires and semi-structured interviews.
- Use structured observation logs to track frequency of use, types of activities, and levels of support required to detect engagement patterns and barriers.
- Assess improvements in autonomy, socialization, self-esteem, and emotional well-being, supporting the garden's role as a complementary therapeutic tool and its replicability in other centers.

5 Conclusions

The HATHOR project demonstrates that the integration of hydroponic gardens, home automation, and accessible applications can provide an effective and technologically reliable therapeutic intervention in care centers. The system enabled precise control of cultivation parameters and facilitated user participation through an adapted interface. Professionals reported high satisfaction with the accessibility and ease of use of the application, consistent with the philosophy of AT, which seeks to enhance the abilities of people with disabilities.

From a therapeutic perspective, users showed strong interest in garden care, particularly in fruit harvesting and monitoring plant status. The activity was perceived as relaxing and motivating, and improvements were observed in autonomy, adherence to routines and cognitive skills, findings aligned with literature on horticultural therapy. User engagement also reinforced self-esteem and fostered greater interaction with professionals, highlighting the social and emotional value of the project.

At the organizational level, identified challenges included the need for additional technical training to manage the administrator interface and the integration of the garden into the center's daily routine. Nevertheless, professionals agreed that these limitations are surmountable and that the garden could be replicated in other centers, broadening the number of participants. In summary, HATHOR provides a promising foundation for the expansion of accessible therapeutic hydroponic gardens, underscoring the importance of further research into its long-term impact and its adaptation to diverse socio-healthcare contexts.

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Bibliography

AHTA. About horticultural therapy. *https://www.ahta.org/about-horticultural-therapy*, 2025. [Online; accessed 23-September-2025].

H. L. H. Deshan, K. T. Y. Mahima, M. P. C. K. Divyanjalee, T. A. Perera, D. Sandaruwan, L. N. C. D. Silva, R. Pushpannda, C. I. Keppitiyagama, and T. N. K. D. Zoysa. Hyposense: An integrated sensor device for hydroponics farm monitoring. *KDU Journal of Multidisciplinary Studies*, July 2024. doi: 10.4038/kjms.v6i1.108.

Y. S. Joy, A.-Y. Lee, and S.-A. Park. A horticultural therapy program focused on succulent cultivation for the vocational rehabilitation training of individuals with intellectual disabilities. *International Journal of Environmental Research and Public Health*, 17(4):1303, 2020. doi: 10.3390/ijerph17041303. Publisher: Multidisciplinary Digital Publishing Institute.

D. Kim, E. Park, H. Yun, Y. Baek, H. Jin, and H. Cho. Qualitative evaluation of a garden-based healing and learning program for young adults with intellectual disabilities. *International Journal of Environmental Research and Public Health*, 22(2):206, 2025. doi: 10.3390/ijerph22020206. Publisher: Multidisciplinary Digital Publishing Institute.

C. K. Y. Lai, L. Y. W. Ho, R. Y. C. Kwan, C. Y. Y. Fung, and Y. W. Mak. An exploratory study on the effect of horticultural therapy for adults with intellectual disabilities. *Journal of Therapeutic Horticulture*, 27(1):16–32, 2017. URL *https://www.jstor.org/stable/26111988*. Publisher: American Horticultural Therapy Association.

R. Lang and L. McLay. Technological innovations in the education and treatment of persons with intellectual and developmental disabilities. *Advances in Neurodevelopmental Disorders*, 7 (3):311–313, 2023. doi: 10.1007/s41252-023-00349-y.

N. Nikhil, M. Rafeekhar, and G. K. Beela. Accessible garden structure to impart horticultural therapy for differently abled population. *International Journal of Intellectual Disability*, 4(1): 01–03, 2023. Country: India.

N. Yaqin, A. F. Zuhri, and T. Hariono. Automatic Control of Hydroponic Plant Ph Levels Using Sensor Sku Sen 0161. *NEWTON: Networking and Information Technology*, 1(3):125–131, feb 2022. ISSN 2797-0728. doi: 10.32764/newton.v1i3.2094.