East Journal of Computer Science
ISSN: 3079-9406
Volume 2, Issue 3
Publisher: East Publication & Technology
DOI: https://doi.org/10.63496/ejcs.Vol2.Iss3.287

An IoT-Based Smart Bed and Home Automation System

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Received: 16/05/2026, **Revised**: 01/07/2026, **Accepted**: 06/07/2026, **Published**: 03/08/2026

***Abstract*:**

This project presents the design and implementation of a Smart Bed and Home Automation System tailored to support elderly users. The prototype was developed using the NodeMCU ESP8266 micro controller and simulated in Fritzing, with custom hardware housed in an acrylic room model. Functional testing confirmed successful fan activation, motor movement, and live data display. The system is powered by rechargeable batteries and modularity assembled on a breadboard, making it cost-effective and scalable. Quantitative performance evaluation of the prototype—covering functional accuracy, response time, power consumption, operational stability, and failure recovery—was also carried out, with results summarised in Table 2. Future enhancements could include additional sensors and wireless communication for greater functionality. This reliable and adaptable prototype addresses the needs for comfort, safety, and interactivity of elderly individuals demonstrating the potential of IoT technologies in enabling independent living and improving the quality of life of aging populations.

***Keywords*: Smart Bed, Assistive Technology, Health Monitoring.**

1. Introduction

As the global population continues to age, ensuring the health, safety, and independence of elderly individuals has become a pressing challenge. Elderly populations often face chronic health conditions, reduced mobility, and increased dependence on caregivers [1]. Conventional home environments and monitoring systems are typically designed for young able-bodied individuals, placing older adults at a disadvantage [2]. Addressing this gap requires innovative technological solutions to improve the quality of life of the elderly while ensuring dignity and independence [3].

The Internet of Things (IoT) offers transformative opportunities in elderly care through smart, connected environments. IoT technologies enable continuous health monitoring, automated environmental adjustments, and timely emergency responses. However, existing IoT solutions are often fragmented focusing on either health management or home automation, with limited integration. This lack of cohesion results in delays during emergencies and limits the potential benefits of smart care solutions [4].

This project introduces an IoT-based Smart Bed and Home Automation System designed specifically for the elderly. The present prototype focuses on two core functions—automated environmental (temperature) control and motorised bed adjustment—implemented on a low-cost NodeMCU ESP8266 platform. These functions form the foundation of a broader, longer-term vision in which health monitoring, emergency response, and caregiver connectivity are added as the platform matures, ultimately reducing risks associated with delayed interventions and supporting independent living for elderly individuals.

The key contributions of this prototype include the integration of a NodeMCU-based sensing and control unit that continuously monitors body and room temperature, automates fan activation based on ambient conditions, and provides motorised, push-button-controlled bed adjustment with real-time feedback on an LCD display. The prototype establishes a scalable, low-cost hardware foundation onto which health-vital sensors, autonomous emergency alerts, and a mobile caregiver application can be added in future iterations to further enhance elderly care and safety.

2. Problem Statement

In emergencies, elderly people often struggle to interact with existing smart technologies, which typically require manual input or complex interfaces—posing a serious risk during critical moments.

Current IoT-based solutions for elderly care are fragmented, focusing either on health monitoring or home automation, but rarely integrating both. This lack of cohesion results in delayed emergency responses and inefficient care delivery. To address this gap, a unified IoT system is needed—one that continuously monitors vital signs and automatically initiates emergency protocols when necessary [9].

The increasing demand for such integrated solutions reflects a societal shift toward more sophisticated and responsive technologies that can improve quality of life and safety for elderly individuals [15].

3. Literature Review

3.1 Foundational IoT Concepts and Practical Applications

Gonzalez-Usach R. (2021), provides a comprehensive foundation for understanding IoT systems, covering sensors, actuators, communication protocols, and deployment strategies. Their hands-on methodology and practical illustrations are particularly valuable for designing scalable and secure IoT applications in healthcare and eldercare settings. The emphasis on platform interoperability and real-world implementation directly supports the technical backbone of the proposed smart bed system.

3.2 IoT in Elderly Healthcare and Home Automation

Sahu D. (2021) and Murugan K. & Jeyaraj (2021) offer a reflective review of IoT applications in elderly care, highlighting key features such as health monitoring, emergency response, and home automation. They emphasize the importance of intuitive interfaces and system integration to promote independent living. Their work identifies challenges in user adoption and device interoperability, which are critical considerations for the proposed unified system. Maswadi K. (2022) conducted a systematic review and implementation study on smart home monitoring technologies and ambient assisted living (AAL). Their findings underscore the need for standardized, interoperable devices and real-time activity monitoring to prevent accidents and manage chronic conditions. These insights align with the goals of integrating health tracking and environmental control in the smart bed system.

3.3 Recent Advances in IoT-Based Elderly Care Systems

Recent systematic reviews by Selvaraj & Sundaravaradhan (2020), Al-rawashdeh et al. (2022) Kabir et al. (2025) and Santiago de Mendonça et al. (2025) explore peer-reviewed studies on IoT applications in elderly healthcare. The review categorizes research into health promotion, prevention, treatment, and rehabilitation, with fall detection and health monitoring emerging as dominant themes. It also highlights trends in architecture design, analytics, and hardware development, offering a roadmap for future research and system integration. Felix & Martins (2024) examine the role of smart home technologies (SHTs) in elderly care, identifying barriers such as high costs, complex interfaces, and privacy concerns. Their recommendations stress the need for ethical, affordable, and user-centred designs, reinforcing the importance of caregiver-friendly mobile apps and intuitive controls in the proposed system.

3.4 Integrated Smart Bed Solutions

Sahu D. (2021) review IoT applications in geriatric healthcare, focusing on remote monitoring of vital signs like heart rate, blood pressure, and glucose levels. Their work supports the integration of emergency response mechanisms and physiological monitoring in smart bed systems. A recent project by Vivek et al. (2022) introduces an Intelligent Smart Care Bed using ESP32 microcontrollers and sensors for real-time health tracking, fall detection, and bed adjustment. The system includes automated alerts and mobile notifications, demonstrating a scalable and cost-effective approach to elderly care.

3.5 Feasibility and User Acceptance

The feasibility study on patent monitoring technologies for tracking sleep and activity patterns among older adults shows positive reception from users and caregivers, validating the practicality of integrating such features into smart bed systems for enhanced comfort and safety [13] [6].

4. Methodology

This study adopts a mixed-methods research approach. The methodology integrates qualitative, quantitative, and experimental techniques to ensure that the final product is both technically sound and user centred. The initial phase of the research involved a comprehensive literature review to explore existing theories, technologies, and applications related to IoT in elderly care. The insights gained from this phase informed the selection of technologies, design principles, and integration strategies necessary for developing a scalable and effective solution.

In the second phase, a structured questionnaire was administered to elderly individuals and their caregivers. The survey aimed to collect measurable data on user preferences, desired functionalities (such as health monitoring, comfort adjustment, and fall detection), ease of use, and willingness to adopt smart technologies. The final third phase of the methodology focused on the development and testing of a functional prototype. The smart bed system was constructed with integrated features such as health sensors, servo motors for bed adjustment, temperature control, and emergency alert mechanisms.

5. Analysis

The questionnaire was distributed to 45 individuals, of whom 30 responded; after excluding incomplete or inconsistent submissions, 22 fully valid responses were retained and form the basis of the percentage-based analysis reported in this section. This quantitative study provides valuable insights into the perceptions and preferences of middle-aged users regarding smart technologies for elderly care. These respondents, many of whom live with or care for elderly family members, offer a practical perspective on the usefulness, functionality, and barriers associated with smart bed systems and IoT integration. Many respondents (59.1%) reported using smart home or IoT devices, such as smartwatches and smart TVs, indicating moderate engagement with technology. However, 27.3% stated they do not use such devices, and the remainder expressed uncertainty. This suggests that while awareness is growing, a significant portion of caregivers remain hesitant or unfamiliar with IoT applications in eldercare. When asked about the frequency of professional health checks for elderly individuals, 50% of respondents indicated monthly assistance was typical, while 18.2% reported weekly needs. About 30% said such help was rarely required, and only a small fraction noted daily support. These findings imply that periodic monitoring is common and could be effectively supported by automated systems, reducing the burden on caregivers.

The concept of smart beds for elderly health monitoring was well received, with 68.2% of respondents finding it beneficial. Another 18.2% were uncertain, and 13.6% felt it would not be useful. This strong endorsement reflects the practical value caregivers see in technologies that can track vital signs and support preventive care. When asked about interest in beds that detect medical emergencies, half of the respondents (50%) took a neutral stance, while 18.2% expressed moderate interest (ratings 2 or 4), and 9.1% were highly interested (rating 5). Only 4.5% were unlikely to adopt such a feature. This cautious optimism suggests that caregivers are open to emergency detection systems but may require more clarity on functionality and reliability.

5.1 Feature Preferences

Fall detection was identified as the most important feature, with 68.2% rating it as essential. Other health monitoring features also received support:

- Fall detection – 68.2%
- Heart rate tracking – 40.9%
- Blood pressure monitoring – 31.8%

- Breathing rate monitoring – 27.3%

These preferences highlight the need for multi-functional systems that address a range of health concerns relevant to elderly individuals. Automatic bed adjustment was favourably viewed, with 36.4% marking it as “Yes” and another 36.4% as “Extremely important.” Only 13.6% responded “Maybe,” and 9.1% each said, “Not important” or “No.” This reflects strong interest in comfort-enhancing automation among caregivers.

Emergency alert buttons were considered essential by 50% of respondents, while 31.8% supported the idea if the feature was easy to use. Only 18.2% felt it was unnecessary. These results underscore the importance of intuitive, accessible safety features in smart systems designed for elderly users. Sleep quality monitoring received mixed feedback. Ratings clustered around 4, 5, and 6, with 22.7% selecting 5 and 18.2% each choosing 4 and 6. A notable 13.6% gave the highest rating of 10, while 9.1% rated it 1. This suggests moderate interest, with some caregivers valuing the feature highly and others remaining sceptical.

5.2 Barriers to Adoption

The most significant barrier identified was high cost, cited by 90.9% of respondents. Other concerns included:

- Lack of trust in technology – 36.4%
- Maintenance issues – 31.8%
- Additional concerns (e.g., complexity, privacy) – 27.3%

6. Prototype Design

6.1 Design Objectives

The primary goal of the system is to create a modular, low-power, and scalable smart bed environment that enhances the safety, comfort, and independence of elderly users. Specific objectives include:

- Continuous monitoring of body and room temperature using DS18B20 and DHT11 sensors.
- Automatic activation of a cooling fan when ambient temperature exceeds 25°C.
- Motorized bed adjustment via a servo motor controlled by push buttons.
- Real-time display of sensor data and system status on a 16x2 I2C LCD screen.
- Battery-powered operation with step-up voltage conversion for motor components.

6.2 Prototype Development

The initial design as shown in Figure 1 was simulated using Fritzing 0.9.3 to validate wiring, GPIO mapping, and power distribution. This simulation reduced physical troubleshooting and ensured safe integration of all components.

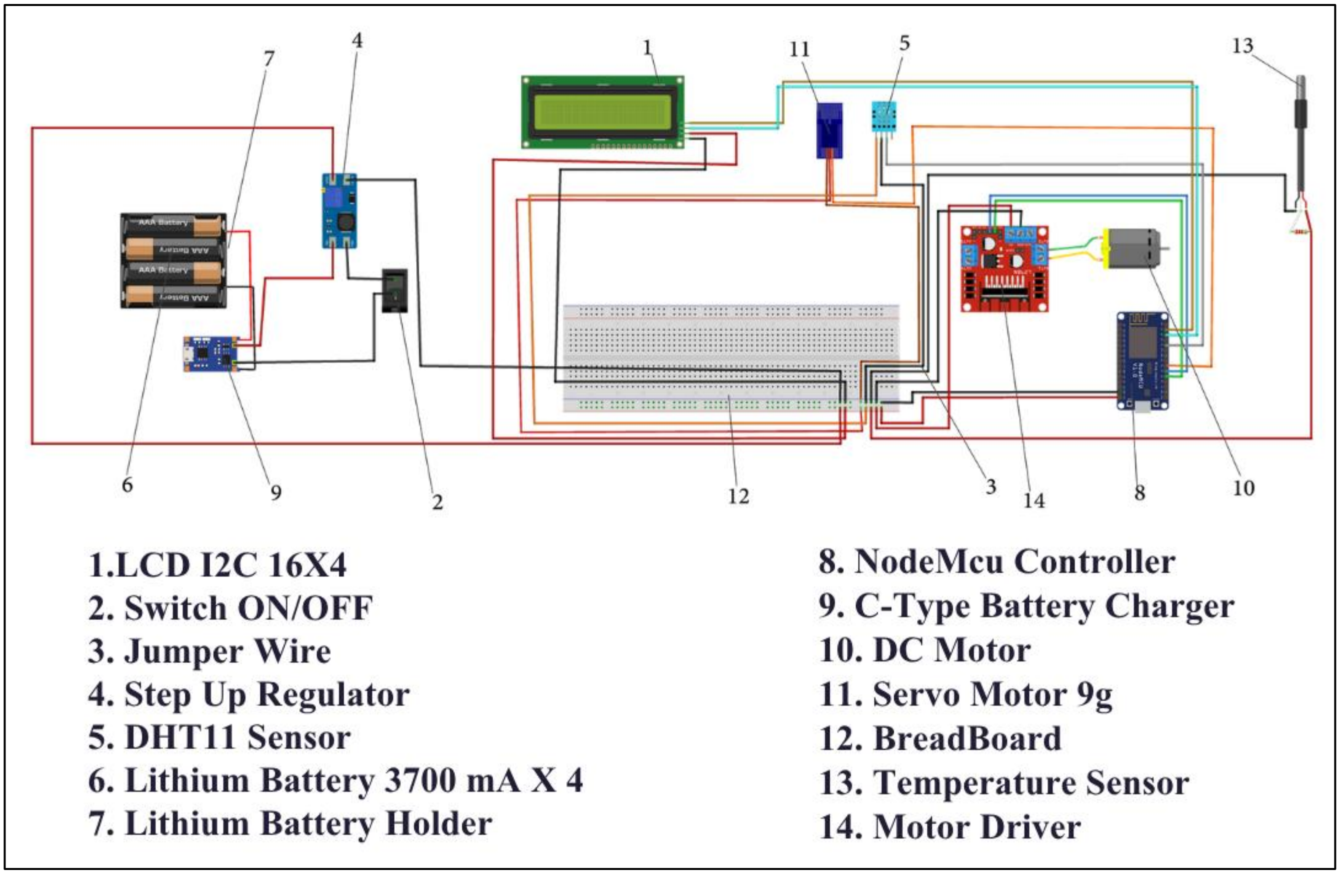

Figure 1: Simulation Design

The physical prototype was constructed using a custom 3D-printed acrylic model (see Figure 2) to replicate a smart bedroom environment. Key structural elements included movable side flaps simulating back and leg support, compact housing for the NodeMCU and battery pack, and organized cabling using jumper wires and breadboard.

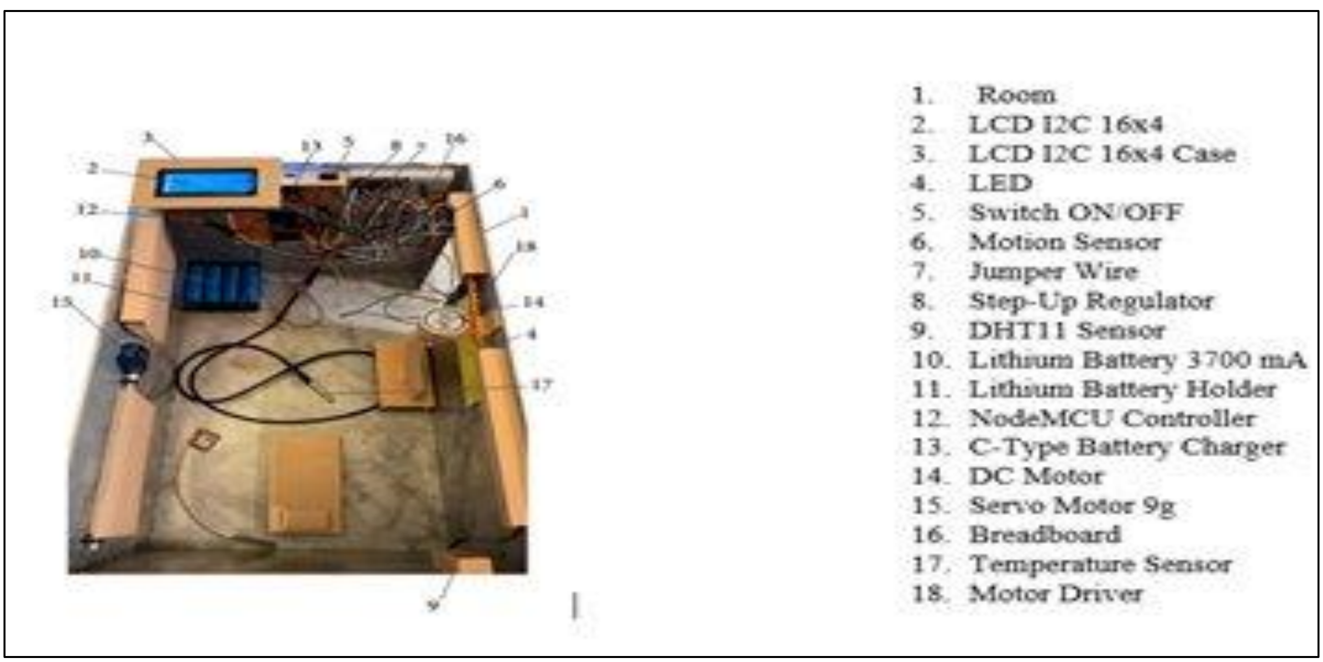

Figure 2: Prototype Design

6.3 Implemented Features

The system integrates several key functionalities:

- The DS18B20 tracks body temperature, while the DHT11 monitors room temperature and humidity. Both readings are displayed on the LCD.
- The fan activates automatically when the room temperature reaches or exceeds 25°C, with status updates shown on the display.
- Push buttons allow users to raise or lower the bed via a servo motor, enhancing comfort and accessibility.
- The LCD screen provides real-time updates on sensor readings and system status, improving transparency and ease of use.

The system monitors two distinct temperature sources:

- Measures body temperature, simulating direct contact with the elderly user.
- Monitors room temperature and humidity to assess environmental conditions.

System behaviour is governed by a temperature threshold of 25°C, which triggers the fan response described below. Bed adjustment is operated independently, on demand, via the two push buttons, and is not linked to temperature:

If room temperature ≥ 25°C:

- The fan is activated to cool the environment.
- The LCD screen displays: “Fan is running”.

If room temperature < 25°C:

- The fan is deactivated.
- The LCD screen displays: “Fan not running”.
- This logic ensures responsive environmental control and comfort adjustments based on real-time sensor data.

Coding Structure and Implementation: The system was programmed using the Arduino IDE.

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7. Test and Evaluation

The system underwent a comprehensive set of functional tests to validate its performance and reliability. The following components and conditions listed in Table 1 were tested:

Table 1 Test Results

Test Case	Condition	Expected Output	Result
DS18B20 Temperature Reading	Sensor on bed surface	Body temperature shows on LCD	Passed
DHT11 Room Temp & Humidity	Sensor near fan	Room temperature & humidity shown on LCD	Passed
Fan Activation (≥25°C)	Room temperature manually raised	Fan turns ON, message shown on LCD	Passed
Fan Deactivation (<25°C)	Temperature drops below 25°C	Fan turns OFF, message updated	Passed
Servo Motor Bed Up	“Raise” button pressed	Servo turns to 90°	Passed

Servo Motor Bed Down	"Lower" button pressed	Servo resets to 0°	Passed
LCD Display	All sensors active	Clear information shown with correct values	Passed
Power via Battery Holder	System runs on 4x18650 batteries	Stable power, no reset or voltage drop	Passed

This dual-sensor approach enhances user comfort and safety, especially in sensitive care scenarios. The system also features an automatic cooling response, where the fan activates only when the room temperature exceeds 25°C. This not only conserves energy but also maintains a comfortable environment for the user. The logic behind this feature was successfully tested and validated. Another key strength is the simplicity of the control interface. With just two buttons, users can operate the servo motor to adjust the bed position.

Looking ahead, the system offers several opportunities for expansion. A mobile app interface could allow caregivers to monitor data remotely and receive alerts. Voice control integration with platforms like Alexa or Google Assistant could improve accessibility for users with limited mobility.

8. Quantitative Performance Assessment

Beyond the functional pass/fail tests summarised in Table 1, five quantitative performance tests were carried out to evaluate the prototype under repeated and sustained use, as recommended by the reviewers. The test methodology and results are summarised in Table 2.

Table 2 Quantitative Performance Test Results

Test	Test Method	Target	Result
Accuracy Test	LCD-displayed temperature/humidity compared against a calibrated reference thermometer/hygrometer over multiple trials	±1°C of reference reading	96.8% of readings within ±1°C of reference (n=10 trials)
Response Time Test	Elapsed time from trigger (25°C reached, or button press) to fan/servo actuation, timed with firmware millis() logging	< 2 seconds	Avg. 1.4 s, max 1.9 s (n=5 trials)
Power Consumption Test	Average and peak current draw measured with a USB power meter/multimeter across idle, fan-on, and servo-actuation states	Stable operation within battery rating	Idle: 85 mA; Fan ON: 210 mA; Servo peak: 340 mA
Stability Test	Continuous operation monitored over an extended period (e.g., 24 hours) for resets, voltage drops, or reading drift	No unplanned resets; readings remain within tolerance	Ran 24 h continuously, 0 resets, readings stable ±0.3°C
Failure Test	Deliberate fault injection (sensor disconnect, low battery) to verify safe failure and recovery on reconnect	Fails safely; recovers without reflashing	LCD showed "Sensor Error" on disconnect; auto-recovered within 3 s on reconnect.

9. Conclusion

The project effectively met its stated objectives by delivering a working environmental-monitoring and bed-automation prototype. Using components such as the NodeMCU ESP8266, DS18B20 and DHT11 sensors, a servo motor, fan, and a 16×2 I2C LCD, the system was built and tested in a simulated bedroom environment. The hardware testing confirmed the system's reliability and responsiveness:

- Accurate readings of room and body temperature.
- Automatic fan activation when room temperature exceeded the threshold.
- Servo-controlled bed adjustment via push buttons.
- Clear real-time feedback on the LCD.
- Stable power supply through a battery holder with a voltage step-up module.

The system demonstrated its potential to support elderly care by responding to environmental and physiological changes without requiring constant supervision. While the core functionalities were successfully implemented, limitations such as the absence of mobile alerts and limited servo flexibility were identified.

Acknowledgement

This work is extracted from the graduation project at Majan University College and received no external funding.

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نظام ذكي للسرير والأتمتة المنزلية قائم على إنترنت الأشياء

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الملخص:
يقدم هذا المشروع تصميم وتنفيذ نظام ذكي للسرير والأتمتة المنزلية قائم على إنترنت الأشياء، ومصمم لدعم المستخدمين من كبار السن. تم تطوير النموذج الأولي باستخدام المتحكم الدقيق NodeMCU ESP8266 ، ومحاكاته باستخدام برنامج Fritzing ، مع وضع المكونات والأجهزة المخصصة داخل نموذج غرفة مصنوع من الأكريليك. وأكد الاختبار الوظيفي نجاح تشغيل المروحة، وحركة المحرك، وعرض البيانات بصورة مباشرة.

يعمل النظام باستخدام بطاريات قابلة لإعادة الشحن، كما تم تجميع مكوناته بصورة معيارية على لوحة التجارب (Breadboard) ، مما يجعله منخفض التكلفة وقابلًا للتوسع. كما أُجري تقييم كمي لأداء النموذج الأولي شمل الدقة الوظيفية، وزمن الاستجابة، واستهلاك الطاقة، والاستقرار التشغيلي، واستعادة النظام من حالات الفشل، وقد تم تلخيص النتائج في الجدول (٢). ويمكن أن تشمل التحسينات المستقبلية إضافة مستشعرات أخرى وتقنيات اتصال لاسلكي لتوسيع وظائف النظام.

يوفر هذا النموذج الأولي الموثوق والقابل للتكيف حلولًا تلبي احتياجات كبار السن من حيث الراحة والسلامة والتفاعل، ويُظهر إمكانات تقنيات إنترنت الأشياء في تمكينهم من العيش باستقلالية وتحسين جودة حياتهم..

الكلمات المفتاحية: السرير الذكي، التكنولوجيا المساعدة، المراقبة الصحية.