# Healing Cocoon — An EPS@ISEP 2026 Project

**Abstract.** This paper presents the Healing Cocoon, a European Project Semester project developed at the Instituto Superior de Engenharia do Porto to improve children's emotional well-being before medical consultations. Clinical environments are often optimised for efficiency rather than comfort, which can increase anxiety among young patients. The project explores how a semi-enclosed, multisensory, projection-based system can create a calmer pre-consultation experience without relying on wearable devices. Preliminary studies on healing environments, digital distraction, ethics, marketing, and sustainability guided the design requirements. The proposed solution combines immersive 180° visual content, sound, scent, environmental monitoring, and a web application for staff interaction. A scaled prototype was built using a lightweight structure, an ESP32-based control approach, and a supporting web interface. Functional tests showed that setup, environmental monitoring, data upload, and automatic fan control worked as intended, while user notification requires improvement. Web application load tests indicated stable behaviour under the tested conditions, and usability feedback provided early validation of the interface concept. The results suggest that the Healing Cocoon is a promising patient-centred alternative to conventional distraction tools, although further work is needed on scalability, technical integration, and clinical validation.

**Keywords:** Engineering Education, European Project Semester, Healthcare, Well-Being, Innovation, Multisensory.

## 1 Introduction

The European Project Semester is a multicultural, multidisciplinary teamwork and project-based learning framework offered by a network of European universities [3]. The Healing Cocoon project, developed by six EPS students at the Instituto Superior de Engenharia do Porto (EPS@ISEP), aims to improve children's well-being during the pre-consultation phase in clinical environments.

Medical environments are often designed for clinical efficiency rather than patient comfort, which can make them cold and impersonal and increase stress and anxiety, especially among children. Research on patient-centred healthcare design shows that calming visual environments, natural elements, visual stimulation, and restorative spaces can support emotional well-being and stress reduction. However, many medical areas still lack accessible solutions for creating more comforting and engaging environments for patients.

The project explores how immersive projection technology can improve the emotional experience of patients, particularly children, by proposing personalised, calming spaces that reduce anxiety and improve the overall patient experience. The team aimed to design and validate a supportive hospital concept, culminating in the development and testing of a proof-of-concept prototype. The Healing Cocoon solution combines projection-based visualization, multisensory stimulation, and a semi-enclosed spatial design to create a controlled and calming environment that balances immersion, comfort, hygiene, and practicality.

After this introductory section, this manuscript describes the preliminary studies, the proposed solution, the prototype and draws the conclusions.

## 2 Preliminary Studies

This section analyses existing work and key constraints that inform the design of the Healing Cocoon. It reviews related approaches, ethical requirements, market positioning, and sustainability considerations.

### 2.1 Related Work

Evidence-Based Design treats healthcare environments as active contributors to patient outcomes. Spatial, sensory, and interaction factors influence both psychological and physiological states [10,4]. Clinical settings often create sensory overload through noise, lighting, and social exposure, which increases stress. Effective design reduces these effects through acoustic control, adjustable conditions, and spatial privacy [4,8,10]. Semi-enclosed environments further improve perceived safety and limit exposure to external stimuli [10].

Multisensory stimulation supports emotional regulation. Visual, auditory, and olfactory inputs influence mood and relaxation. Evidence highlights the benefits of adaptive lighting, nature-based imagery, and calming scents for anxiety reduction [4,10,16,11]. Combining these modalities creates coherent environments that improve comfort and prepare patients for treatment.

Digital distraction extends these principles by redirecting attention through immersive experiences. Virtual reality and interactive media reduce anxiety, especially in paediatric care [14,5,9]. However, wearable systems raise concerns related to hygiene, comfort, and usability [1]. Projection-based solutions overcome these limitations by enabling contactless immersion.

Cocoon-like environments integrate enclosure, multisensory stimulation, and projection-based immersion to create protected and calming spaces [4,10,12]. The Healing Cocoon adopts this approach to provide a controlled, adaptive, and hygienic environment. Table 1 compares related works and Healing Cocoon.

### 2.2 Ethics

The design must ensure safety, reliability, and positive impact. The system targets vulnerable users, including children, and must reduce anxiety without introducing risks. It must remain accessible, inclusive, and suitable for clinical settings.

**Table 1.** Comparison of related approaches.

| Approach | Enclosed | Multisensor | Wearable | Immersive | Accessible | Hygienic |
|---|---|---|---|---|---|---|
| Interactive media [9] | No | Partial | No | Medium | High | High |
| Projection systems [12] | No | Yes | No | High | High | High |
| Sensory rooms [8] | Partial | Yes | No | Medium | Medium | Medium |
| Virtual reality [14,5] | No | Yes | Yes | High | Low | Low |
| Waiting rooms [4] | No | Limited | No | Low | High | High |
| **Healing Cocoon** | Yes | Yes | No | High | High | High |

Communication must remain accurate and responsible. The system should be presented as a supportive tool and avoid unverified medical claims. This ensures trust among patients, caregivers, and professionals.

Environmental responsibility follows a life-cycle approach. The design prioritises durable materials, energy efficiency, and end-of-life strategies such as repair, disassembly, and recycling.

The system must also comply with safety and regulatory requirements. Electrical, structural, and operational risks must be mitigated. Compliance with European directives, such as Low Voltage Directive, Electromagnetic Compatibility, Radio Equipment Directive, and Restriction of Hazardous Substances, as well as the General Product Safety Regulation, ensures safe deployment.

### 2.3 Marketing

The Healing Cocoon targets the Smart Health and Well-being domain as a multisensory solution for paediatric clinical environments. It reduces anxiety during pre-consultation periods, particularly in dental and therapy contexts.

The system delivers immersive, non-wearable environments using projection, audio, and optional scent. This improves emotional comfort for children and supports clinics by enhancing cooperation and service quality.

The solution follows a business-to-business-to-consumer model, where clinics act as customers and children as end-users. Revenue combines hardware installation with a subscription for digital content and consumables. The target segment is specialised private paediatric practices, where patient experience is critical.

Compared to passive entertainment or virtual reality systems, the cocoon offers hygienic, accessible, and contactless immersion. Market drivers include growing demand for child-centred care and decreasing technology costs.

The strategy focuses on pilot validation, expansion across specialised clinics, and partnerships with healthcare providers. The analysis indicates a viable niche with a differentiated and scalable solution.

### 2.4 Sustainability

The Healing Cocoon integrates environmental, economic, and social sustainability. The design prioritises durable materials, resource efficiency, and user well-being. Recyclable materials, such as aluminium and brass, are combined with low-emission, cleanable textiles suitable for clinical use. Local sourcing reduces transport impacts.

A modular design enables maintenance, repair, and component replacement, which extends product lifetime and reduces waste. Energy-efficient electronics and simplified packaging further reduce environmental impact.

The system also promotes inclusive, child-centred care. It reduces anxiety and supports accessibility, including wheelchair use. Economically, it ensures long-term viability through durability and a service-based model.

This approach provides a lifecycle-oriented solution that reduces environmental impact while maintaining clinical effectiveness and user benefit. The design contributes to SDG 3 (Good Health and Well-being) by reducing anxiety in clinical settings, SDG 10 (Reduced Inequalities) through accessible design, and SDG 12 (Responsible Consumption and Production) by promoting durable and recyclable materials.

## 3 Proposed Solution

This section presents the Healing Cocoon concept, including the designed structure, smart control system, web application, and packaging. The design was guided by the project objectives–reducing anxiety, supporting sensory regulation, ensuring hygiene, and maintaining accessibility for children with different needs–and the preliminary studies.

### 3.1 Concept

The Healing Cocoon is a semi-enclosed multisensory pod that transforms clinical waiting areas into calm and immersive environments. It delivers visual, auditory, and optional olfactory stimulation to support stress regulation in children prior to medical, dental, or therapeutic procedures. The design avoids wearable devices and relies on spatial immersion, which improves comfort, hygiene, and usability.

The system integrates a projection-based visual environment with 180° coverage, combined with calming audio and optional scent diffusion to promote relaxation. The structure ensures wheelchair-accessible entry and use, while its interior employs cleanable, antimicrobial materials suitable for healthcare settings. The semi-open configuration reduces claustrophobia and maintains visual contact between the child and caregivers, which supports both safety and emotional reassurance. Figure 1 illustrates the proposed concept.

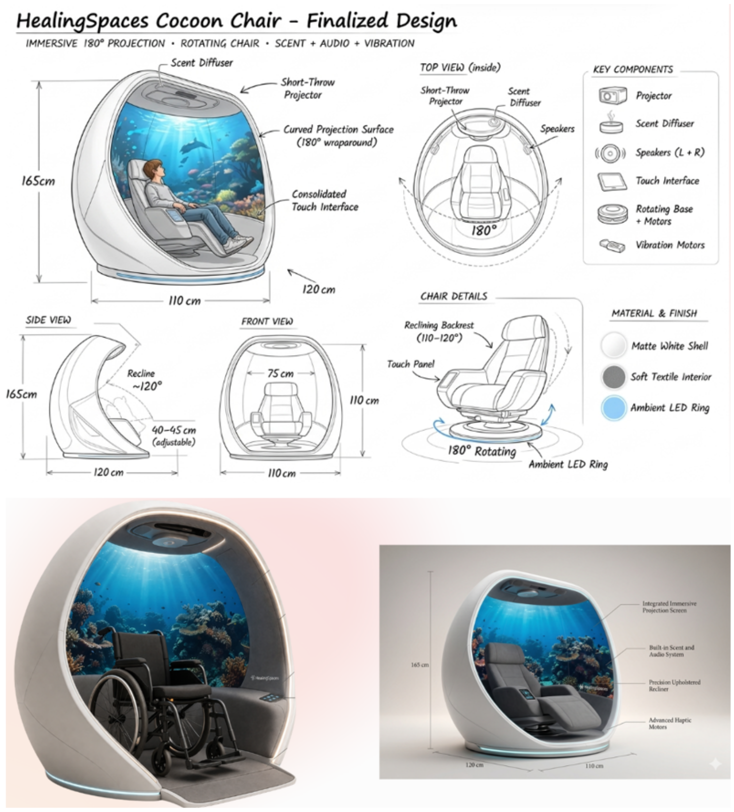


**Fig. 1.** Healing Cocoon concept

### 3.2 Design

**Structure** The cocoon adopts a layered structure based on a rigid aluminium frame with curved arches, selected for low weight, affordability, ease of fabrication, and recyclability [7]. The exterior uses brushed brass panels to provide a warmer appearance [6], while the interior integrates acoustic panels and an antimicrobial textile to improve sound absorption and ensure hygiene in clinical environments [2,13]. The semi-open configuration avoids claustrophobia, maintains visual contact with caregivers, and supports accessibility, accommodating both a movable chair and direct wheelchair use. The structure combines an external metallic shell, aluminium frame, acoustic layer, and antimicrobial finish, with local air gaps that improve acoustic and thermal performance.

A preliminary static analysis in SOLIDWORKS evaluated stress distribution and displacement under external loads to assess structural integrity. The results indicate stable behaviour, with maximum stress below the material yield strength and limited displacement, confirming sufficient rigidity for a proof-of-concept prototype. Future work should update the model with final material properties, connection details, and safety factors, particularly after defining the thickness of the aluminium arches and brass panels.

**Smart Control** The system monitors environmental conditions and regulates the cocoon's sensory outputs through an ESP32-WROOM-32 microcontroller, which integrates wireless connectivity and enables low-cost control of sensors and actuators. The system acquires ambient light, air quality, temperature, and humidity data to drive adaptive audio playback and scent diffusion. The electronic schematic specifies the interconnections between sensing, actuation, and control components, including a relay for safe atomiser switching, and defines the electrical architecture. The design prioritises affordability and availability, achieving a total hardware cost of 229.75 € while maintaining adequate functionality. Power analysis indicates a nominal consumption of 3.62 W and a peak of 14.8 W, which supports operation with a 5 V, 2 A supply for the control subsystem, while the projector draws power separately from the mains.

**Web Application** The software web application ensures the interaction between the user and smart system. Specifically, it enables environment selection (e.g., nature, fantasy, or breathing-guidance scenes), regulates audio and scent, monitors temperature, humidity, light, and air quality, and provides simple controls for clinical use while preventing unsafe operation, such as excessive scent release or unattended actuation. The ESP32 acquires environmental data, processes relevant values, and controls audio playback and scent diffusion according to the selected scenario.

**Packaging** The packaging protects the cocoon structure, electronic hardware, and interior materials during transport while supporting recyclability and reuse. It uses corrugated cardboard with biodegradable cornstarch-based cushioning, which is lightweight and reusable. In the waiting room, children can reuse the cushioning though moisturing, assembling and shaping to create simple figures or play structures. The design positions cocoon panels vertically to reduce stacking loads and minimise impact damage. A main box contains the panels and a secondary hardware box, with internal inserts that separate components and limit movement. Both boxes follow the FEFCO 0201 standard[1]. The main box provides a robust folding structure with good stacking and impact resistance, whereas the hardware box uses a hinged lid and interlocking tabs for adhesive-free assembly and easier recycling [15].

## 4 Prototype Development

### 4.1 Assembly

**Structure** The prototype uses a scaled-down simplified structure of 50 cm height, with just the external shell. The supporting frame is constructed from

[1] https://www.fefco.org/technical-information/fefco-code

PVC electrical conduit tubes, which provide a lightweight and low-cost solution for rapid prototyping. The shell uses coloured paperboard, selected for ease of cutting, forming, and assembly. Figure 2 illustrates the structure of the prototype.

**Fig. 2.** Built prototype structure.

**Smart Control** The only differences between the designed and the implemented control system are that the sound and projection are not directly controlled, but via a laptap. It follows a simple input–process–output structure where the ESP32 microcontroller receives inputs from the user, cloud content, and environmental sensors. Sensors measure light, motion, air quality, $CO_2$, humidity, and temperature to characterise the cocoon environment.

The controller processes these data and drives the actuators, including the projector, speaker, and scent sprayer, to deliver visual, auditory, and olfactory stimulation. Power is supplied directly by the mains to high-demand components, such as the projector and speaker, while the controller manages low-power devices.

**Web Application** The web-based prototype supports interaction with the Healing Cocoon system, focusing on user experience, session flow, and staff–child interaction. It includes a lightweight backend that emulates system communication, enabling functional validation beyond a static mock-up.

The application adopts a modular three-layer architecture comprising a frontend interface, a backend API, and a data and authentication layer. The frontend uses HTML, CSS, and JavaScript to implement structure and interaction without external frameworks. The backend uses Python with FastAPI to manage data exchange and support future hardware integration. SQLite provides local data storage, Clerk handles authentication and access control, and GitHub supports version control. This structure ensures simplicity, clarity, and ease of extension.

The system defines two user roles. Staff users configure and monitor sessions through a dashboard, including environment selection, duration, and sensory settings, while child users interact with a simplified visual interface. The workflow remains straightforward: staff authenticate, define session parameters, and submit them through the frontend; the backend stores the data and prepares system actions, while the active session interface enables monitoring and control. In future versions, the backend will interface with the control system to operate lighting, projection, audio, and scent systems.

### 4.2 Tests & Results

**Cocoon structure** A static simulation was performed in SOLIDWORKS to evaluate the cocoon structure under external loads, using copper as the selected material. As shown in Figure 3, the analysis focused on stress distribution and displacement to verify whether the structure could withstand the applied forces without failure or excessive deformation.

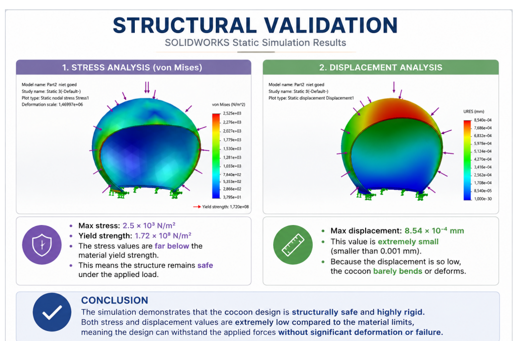


**Fig. 3.** Stress analysis of the Cocoon structure

The results indicate safe structural behaviour: the maximum stress remained well below the material yield strength and displacement was very small. This confirms that the design is rigid, mechanically stable, and suitable for the proof-of-concept prototype.

**Smart Control** The smart control system was tested to verify that all intended functions operated correctly. Each function was executed under normal operating conditions, and the system response was observed and recorded. The test results are summarized in Table 2 below.

Table 2: Device: functional results

| **Function** | **Result** |
|---|---|
| Switch on/off | Pass |
| Setup | Pass |
| Monitor environment | Pass |
| Upload data to cloud | Pass |
| Operate fan automatically | Pass |
| Notify user automatically | Fail |

Core functions worked (device switching, setup, monitoring, cloud upload, fan control). However, user notifications failed, likely due to connectivity, configuration, or module errors. This may prevent timely alerts. The notification system requires debugging, configuration checks, and retesting to ensure reliable delivery.

**Web Application - Technical tests** To test the stability and response time of the web application, a simple performance test was conducted using k6. The application ran in a Docker-based environment, with Docker Compose used to manage the services and to run the k6 test runner.

The test simulated 5 virtual users continuously using the application for 2 minutes. The k6 script sent HTTP requests to the backend/API endpoints and checked if the responses returned the expected status codes, such as 200, 201, or 401. Table 3 summarises the main load test results.

Table 3: API: load results

| | | | | | | **Latency** | |
|---|---|---|---|---|---|---|---|
| **Test** | **Operation** | **VUs** | **Req.** | **Checks** | **Fail (%)** | **Avg. (ms)** | **p95 (ms)** |
| 1 | API load test | 5 | 1130 | 1130/1130 | 0.00 | 34.21 | 95 |

The results show that the API processed 1,130 HTTP requests with a failure rate of 0.00 %. All checks were successful, and the p95 latency remained well below the configured threshold of 2000 ms. This indicates that the web application remained stable and responsive under the tested load. However, because the test was limited to 5 virtual users, it should be considered an initial performance validation rather than a full-scale stress test.

**Web Application - Usability tests** A small online usability test was conducted to collect early feedback on the Healing Cocoon web application, focusing on layout clarity, ease of use, main functions, and suitability for children aged 6 to 13.

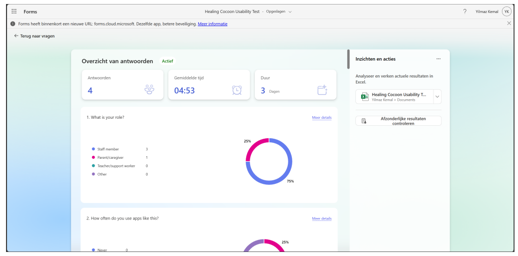


**Fig. 4.** Overview of the responses to the Healing Cocoon usability test

Figure 4 shows results from 4 participants (average time: 4 min 53 s). Feedback was positive: the interface was clear, functions easy to use, and the breathing exercise helpful. Suggested improvements include a more visible "Start" button and more options. Due to the small sample, results are preliminary.

# 5 Conclusion

## 5.1 Project Outcomes

The Healing Cocoon positions itself as a high-quality alternative to conventional distractions such as tablets or televisions. By combining soothing colours, scents, sounds, and immersive 180° projections, it creates a supportive environment that can reduce stress before medical procedures and help children form more positive associations with medical visits.

A key outcome is its focus on accessibility: the ground-level design supports wheelchair access without a ramp, and the adjustable chair casters allow the chair to be replaced by a wheelchair. The accompanying app also improves usability for clinic staff by simplifying interaction with the system.

The main limitations are the floor space required, the initial investment cost, and the need for technical maintenance and staff training. In summary, the prototype successfully illustrates the main smart features and inclusive design principles, while scalability remains constrained by spatial and economic factors.

## 5.2 Personal Outcomes

The students' testimonies show that the EPS@ISEP experience strengthened leadership, organisation, problem solving, communication, and conflict resolution skills through the coordination of tasks, shared decision-making, and continuous adaptation during the project. The healthcare context also reinforced the importance of user-centred engineering, requiring the team to balance technical feasibility with patient comfort, safety, usability, emotional well-being, sustainability, and ethical responsibility. Its multicultural and multidisciplinary nature further improved collaboration in an international engineering environment, helping the students develop both technical confidence and interpersonal awareness.

### 5.3 Future Development

Future developments should focus on immersion, scalability, and sustainability by expanding the library of 180° environments, adding interactive or AI-driven personalisation, and optimising the Cocoon through modular, space-saving, and cost-efficient design solutions. Further technical work should improve hardware integration, real-time monitoring, and content customisation so that clinical staff can adapt the experience more easily to each child. Future research should also explore adaptations for neurodivergent children, broader healthcare applications, circular material strategies, recycled resources, and smart textiles with antimicrobial and sensory-feedback properties.

## References

1. Al-Nerabieah, Z., Alhalabi, M.N., Owayda, A., Alsabek, L., Bshara, N., Kouchaji, C.: Effectiveness of using virtual reality eyeglasses in the waiting room on preoperative anxiety: A randomized controlled trial. Perioperative Care and Operating Room Management **21**, 100129 (2020). doi:10.1016/j.pcorm.2020.100129
2. Artnovion: Soundpet range absorption products. https://www.artnovion.com/product-categories/50-absorption/products/1116-soundpet-range (2026), [Accessed in May 2026]
3. Budzinska, G., Hansen, J., Malheiro, B., Fuentes-Durá, P.: European Project Semester. In: Malheiro, B., Fuentes-Durá, P. (eds.) Handbook of Research on Improving Engineering Education With the European Project Semester, chap. 1, pp. 1–22. IGI Global (2022). doi:10.4018/978-1-6684-2309-7.ch001
4. Devlin, A.S., Arneill, A.B.: Health care environments and patient outcomes: A review of the literature. Environment and Behavior **35**(5), 665–694 (2003). doi:10.1177/0013916503255102
5. Eijlers, R., Utens, E.M.W.J., Staals, L.M., de Nijs, P.F.A., Berghmans, J.M., Wijnen, R.M.H., Hillegers, M.H.J., Dierckx, B., Legerstee, J.S.: Systematic review and meta-analysis of virtual reality in pediatrics: Effects on pain and anxiety. Anesthesia & Analgesia **129**(5), 1344–1353 (2019). doi:10.1213/ANE.0000000000004165
6. F. Marques da Silva S.A: Chapa de latão. https://www.fms.pt/pt/latao/chapas/chapa_de_latao.html (2022), [Accessed in May 2026]
7. F. Marques da Silva S.A: Tubo retangular de alumínio. https://www.fms.pt/pt/aluminio/tubos/tubo_retangular_de_aluminio.html (2026), [Accessed in May 2026]
8. Hamed, S., El-Bassiouny, N., Ternès, A.: Evidence-based design and transformative service research application for achieving sustainable healthcare services: A developing country perspective. Journal of Cleaner Production **140**, 1885–1892 (2017). doi:10.1016/j.jclepro.2016.09.161
9. Hua, Y., Qiu, R., Yao, W.Y., Zhang, Q., Chen, X.L.: The effect of virtual reality distraction on pain relief during dressing changes in children with chronic wounds on lower limbs. Pain Management Nursing **16**(5), 685–691 (2015). doi:10.1016/j.pmn.2015.03.001

10. Huisman, E.R.C.M., Morales, E., van Hoof, J., Kort, H.S.M.: Healing environment: A review of the impact of physical environmental factors on users. Building and Environment **58**, 70–80 (2012). doi:10.1016/j.buildenv.2012.06.016
11. Lehrner, J., Marwinski, G., Lehr, S., Johren, P., Deecke, L.: Ambient odors of orange and lavender reduce anxiety and improve mood in a dental office. Physiology & Behavior **86**(1–2), 92–95 (2005). doi:10.1016/j.physbeh.2005.06.031
12. Li, H., Ding, Y., Zhao, B., Xu, Y., Wei, W.: Effects of immersion in a simulated natural environment on stress reduction and emotional arousal: A systematic review and meta-analysis. Frontiers in Psychology **13**, 1058177 (2023). doi:10.3389/fpsyg.2022.1058177
13. Monteiro Fabrics: MEDIFLEX Collection. https://www.monteirofabrics.com/pages/mediflex (2026), [Accessed in May 2026]
14. Neerincx, A., Hiwat, T., de Graaf, M.: Social robot for health check and entertainment in waiting room: Child's engagement and parent's involvement. In: Adjunct Proceedings of the 29th ACM Conference on User Modeling, Adaptation and Personalization. pp. 120–125. Association for Computing Machinery (2021). doi:10.1145/3450614.3463413
15. Olejniczak, N., Jarzabek, P.: FEFCO standards: From 0201 to 0427 with packQ. https://www.packagingdesignsoftware.com/post/fefco-standards-explained-packq (2025), last updated September 9, 2025. [Accessed in May 2026]
16. Wang, Y., Deng, X., Xu, J.: The impact of color-light interaction design in hospital waiting areas on emotional relaxation. In: Proceedings of CISAI '25. pp. 1085–1092 (2025). doi:10.1145/3773365.3773537