Outdoor Intelligent Shader – An EPS@ISEP 2018 Project

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Abstract. This paper presents an overview of the development of SetSun, an outdoor intelligent shader, by a team of five Erasmus students within the framework of the European Project Semester at Instituto Superior de Engenharia do Porto, in the spring of 2018. The major goal of this project-based learning experience was to design a new type of parasol, granting a novel wellness and luxury experience, by combining the functionalities of smart electronics with that of a traditional parasol, while providing the participants with a meaningful learning experience for their future professional life. The Team conducted multiple studies, including scientific, technical, sustainability, marketing, ethics and deontological analyses, and discussions to derive the requirements, design the structure, specify the list of materials and components and develop a functional system. Following these studies, the Team assembled, debugged and tested the SetSun prototype successfully.

Keywords: Collaborative learning, Project based learning, Technology, Engineering Education, Outdoor Intelligent Shader

1 Introduction

The European Project Semester (EPS) is a project based learning capstone programme for students, especially with an engineering background. This one semester offer is provided by 19 European universities[4] with the aim to prepare future engineers to work in international multidisciplinary teams [8]. The EPS providers not only comply with the core rules defining the programme, but have the freedom to implement EPS with their own imprint.

The Instituto Superior de Engenharia do Porto (ISEP) is an EPS provider since the academic year of 2010-2011 and has since welcomed students from three continents and from engineering, product design, management and health

[4] http://www.europeanprojectsemester.eu/

sciences B.Sc. and M.Sc. degrees on a yearly basis. The EPS@ISEP implementation offers a syllabus which combines the Project core module with four project supportive modules – Project Management & Team Building, Ethics & Deontology, Eco-efficiency & Sustainability, Marketing & Communication – and the Portuguese Language & Culture module. To provide students with the best support, the EPS@ISEP project is supported by a panel of supervisors from different areas. At ISEP, each team embraces and runs a multidisciplinary project for the duration of one semester, involving tasks such as project management, product design, product development and complementary project supportive studies.

This paper reports the work of Team 4 of the 2018 class from the perspective of the team members. Table 1 shows the members nationality and background.

Table 1: Background of Team 4 members

Name	Country	Field of Study
Christopher Mahon	United Kingdom	Electric, Electronic and Energy Engineering
Manuel Baptista	Portugal	Mechanical Engineering
Marta Majewska	Poland	Logistics
Melanie Tscholl	Italy	Media Technologies
Sven Bergervoet	Netherlands	Industrial Product Design

Team 4 chose the outdoor intelligent shader from the 12 different project proposals available, after discussing the advantages and disadvantages of every proposal. The main goal of this project is to foster teamwork, cross-cultural communication, project management and problem solving skills as well as ethical and sustainable development practices, while designing, developing and testing an outdoor intelligent shader prototype. The project details are available at the project's wiki [9].

This paper is organised in five sections. Section 2 describes the background studies; Section 3 presents the design and development of SetSun; Section 4 reports the tests and results; and Section 5 draws the conclusions.

2 Background

The idea behind the design of an outdoor intelligent shader is to create a new market for shaders by combining in a single product the functionalities of a traditional parasol with those of smart electronics, *e.g.*, enabling the connection, interaction and sharing with the user or other smart devices. The motivation of the Team to embrace this challenge was based not only on finding an attractive design and a sound technical solution, but also on the collaborative and multicultural learning experience.

2.1 Related Work

The survey of similar products includes intelligent and non-intelligent shaders, since the market share of intelligent shaders is still reduced and has few solutions. The analysis of the advantages and disadvantages of related products is essential to identify and transform opportunities into innovative ideas, designs and functionalities.

Parasols: There are two main kinds of parasols, the ordinary beach parasol, usually seen at beaches and pools, and the larger more robust type of commercial parasols of Figure 1a. These are normally used for restaurants, cafés, hotels, etc. The functionality is the same, what changes is the application context.

Canopies: A canopy is more robust and usually a fixed structure, it is used normally in terraces and public spaces. A canopy can be made of various materials, such as, vinyl, acrylic, polyester or canvas. Figure 1b displays a garden canopy.

Awnings: The structure of an awning can be stationary (Figure 1c), retractable (Figure 1d) or hybrid (Figure 1e). Usually, awnings are made of materials like aluminium, cloth, vinyl, or wood. They are placed on the outside of a building, usually supported by a wall. It prevents that the full spectre of heat enters the building and it decreases the need for air conditioning.

Smart Shaders: Smart shaders follow the Sun to provide a consistent shade, as well as comfort with some high-end features, such as built in speakers, Wi-Fi, Bluetooth, high definition (HD) camera or solar panels for renewable energy source. Figure 1f displays the smart ShadeCraft Sunflower.

2.2 Marketing

The release of a new product requires the preparation of a marketing strategy for presentation and commercialisation based on a thorough analysis of the target market and of its surroundings.

The outdoor intelligent shader will definitely cost more than an ordinary sunshade umbrella, conditioning the profile of the potential customers. People between 25 to 70, owning a house or summer house with a large garden to place the shader, will be the potential clients. The target are then affluent households which value comfort, technology and new products. Such people invest in their lifestyle and comfort, including buying a smart shader instead of an usual umbrella or canopy to improve the quality of their quality time.

Team 4 decided to focus on Europe since the shader will be developed in Portugal, using local components and materials. The fact that the team is European means that it is easier to establish the needs and expectations of people in different European countries regarding smart shaders. However, for the time being, the Team decided to consider just Portugal. Thanks to its good location, good weather and low costs of living, people with different nationalities decide to live and invest in Portugal. A big advantage is that, as far as the team knows, the proposed product has yet no rival on the market. Not only it combines smart technology and modern design canopy, but provides an environment friendly solution (see next subsection).

(a) Commercial Parasol [1]

(b) Garden Canopy [2]

(c) Stationary Awning [7]

(d) Retractable Awning [5]

(e) Hybrid Awning [3]

(f) ShadeCraft Sunflower [6]

Fig. 1: Shading Solutions

2.3 Sustainability

Lifestyle in many countries is unsustainable, *i.e.*, the consumption economy is depleting Earth's resources. For the team it is very important to construct the product in an eco-efficient and sustainable way. Another point is also to consider the amount of effort it takes to process the material. The carbon intensity is measured in the amount of CO_2 which is arising for producing one kg of material.

Figure 2 shows the emissions of CO_2/kg of produced material, considering both the recycled and virgin versions of the material. The recycled bars display the amount of CO_2 produced when the material is created from pre-existing products. The virgin bars shows the amount of CO_2 generated when the material is produced from raw materials (the very first stage of winning materials). The difference, in terms of CO_2 emissions, between the virgin and recycled material versions is striking.

Based on this analysis, the team chose low carbon steel, stainless steel and copper as the main materials for building the product. Low carbon steel has a rather low CO_2 percentage and is simultaneously strong, malleable, ductile and

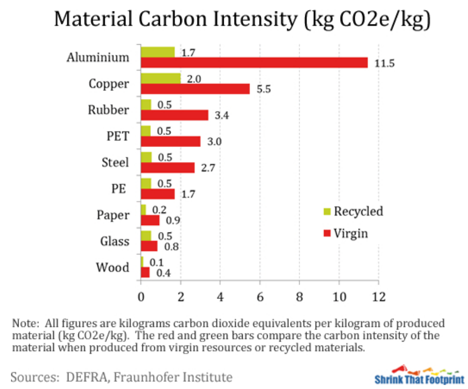


Fig. 2: CO_2 (in kg) emissions per kg of material produced [4]

very cheap. Stainless steel alloys are made mainly from iron, chromium, nickel and additional four or five elements. Stainless steel is easily recycled and also has a low CO_2 percentage. Copper, which will be used in the electrical wiring between the electronic components and the power supply, is a soft, malleable, ductile and highly conductive material.

2.4 Ethics and Deontology

The ethics and deontology studies made the team aware of the potential risk of creating environmental and interpersonal ethical issues. The risk of triggering environmental ethical problems is tightly connected with sustainability since the product must be, not only, efficient, but also recyclable and environmentally friendly. To minimise interpersonal ethical problems, the team adopted a code of ethics considering moral correctness. For the development of the prototype, the team chose to use licensed or open sourced software and comply with the applicable EU directives. Considering the written deliverables, the team included explicit references to all used sources. In terms of marketing ethics, the team made a commitment to create a safe product and never make false claims or promises. ISEP, on its hand, enforces a strict policy regarding the mandatory selection of local suppliers with ethical standards, *i.e.*, which fulfil their social responsibilities, namely, while tax and social security contributors.

3 Design and Development

3.1 Proposal

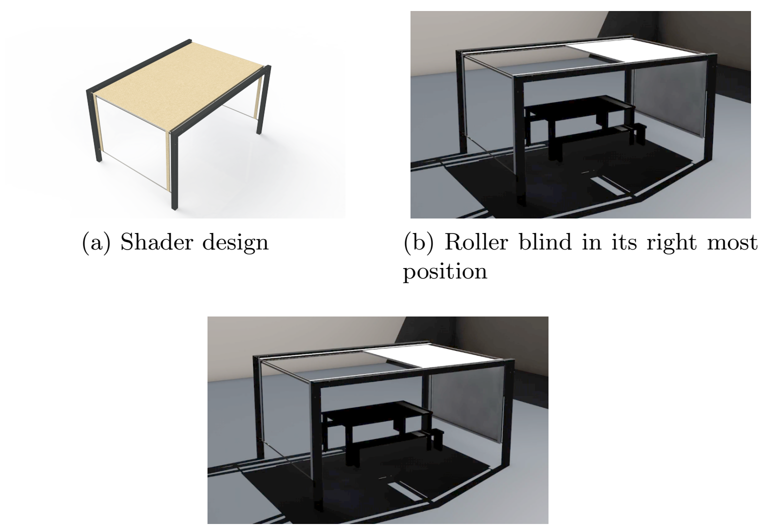
The project proposal challenged the team to "Design, build and test an intelligent shading system for private or public open spaces. The target user segment and the full set of device requirements are to be defined by the team based on the marketing, sustainability and ethical analyses" [8]. In terms of requirements, it specified: (i) use hardware solutions and open source software; (ii) adoption the International System of Units; and (iii) compliance with the 2006/42/CE 2006-05-17, 2004/108/EC 2004-12-15, 2014/35/EU 2016-04-20, 2014/53/EU 2014-04-16 and ROHS European Union Directives.

3.2 Functionalities

The operation of the device will be automatically governed by a micro-controller. The algorithm, first, calculates the position of the Sun relative to the location of the shader. Then, based on this information, it determines the position of the roller blind. Finally, if the current position of the blind needs to be adjusted, it commands the actuator accordingly. The algorithm is implemented on the Arduino board, and the program runs with a pre-defined frequency.

3.3 Structure

The final design idea was to create a roller blind system, which rolls on both sides, projecting the shade over the intended area (Figure 3). The blind is displaced using a single motor and two belts. When the motor rotates, the belts move, rolling/unrolling the mesh blind.



(a) Shader design

(b) Roller blind in its right most position

(c) Roller blind in its right most position

Fig. 3: Artist rendering of the Intelligent Shader design and its planned operation

Aesthetically, the product is identified by the clean straight lines of the structure and the planned available blind colours: white, grey, burgundy and beige.

The straight design optimises the space underneath the shader. The different colours allow a perfect blending with the surroundings and other outdoor equipment.

The overall structure includes six square hollow rods (four vertical and two horizontal) and four corner-pieces, plus four horizontal roll-bars with a circular section for the blind to roll and wrap around. The square hollow rods are structural parts and are pre-assembled as two construction bows. All vertical structural rods are similar, except the one housing the motor. The only visible difference is that it includes holes to attach the motor using bolts. Figure 4 displays the exploded view of the motor parts and horizontal roll-bar, including (from left to right) motor, coupling, belt, gear, bar, bearing, screws and mesh strap. There are slots in the back vertical poles to move the roll-bar up and down to tighten or loosen the mesh. Additionally, the electronics are placed in the interior of the structural hollow rods.

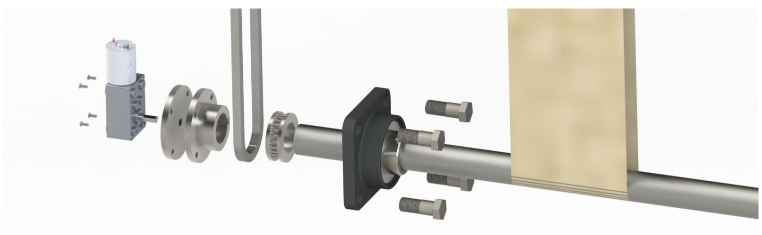
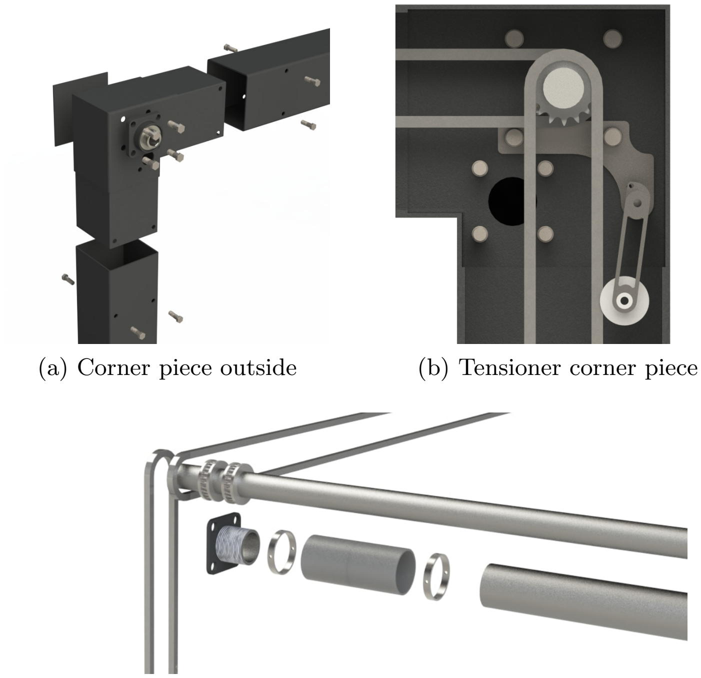


Fig. 4: Motor, belt and roll-bar

The corner-pieces depicted on Figure 5 have an inner diameter equal to that of the structural bars, allowing the perfect fitting and bolting of the structure. Additionally, they have holes to access the bearing, and bolts to connect the parts of the construction bow. There is a lid, closed with magnets, for easy access to the gears and bolts in the interior of the structure. Since the bolts are placed inside, the structural rods display a flat and smooth surface. Figure 5a details the exterior of the corner piece, including the lid (on the back), bars, corner piece cover, poles and screws. Figure 5b shows the interior of the corner piece, with the belt and belt tensioner. The belt tensioner ensures that the rubber belt remains positioned over the gear. This is done by an arm which has a small cylinder with a slot of the width of the belt. The tension is provided by a torsion spring attached between the plate and the arm. Figure 5c displays the exploded view of the corner piece and of the connected parts, showing the belts and the connected parts.

Based on the previous studies, the team decided to build the structure in Carbon steel. It is the ideal steel for the product as it can be recycled, easily welded and very cheap. To prevent corrosion, the team chose to apply powder coating. The blind mesh, which will be exposed to sunlight, needs to roll easily and withstand different weather conditions. The choice was to make the blinds



(a) Corner piece outside (b) Tensioner corner piece

(c) Exploded view of the internal corner piece connection

Fig. 5: Corner piece design

from acrylic mesh since it resists well to ultraviolet (UV) radiation, discolouration and water.

The structure is intended to be shipped with two pre-assembled construction bows, comprising one top and two vertical square hollow rods plus two top corner pieces, and four horizontal circular roll-bars. This approach simplifies the transportation and assembly at the customer premisses. The fact that the two bows are similar also simplifies the manufacturing process.

3.4 Control

The control of the outdoor intelligent shader SetSun is automatic. Figure 6 shows the electrical schematics of the control system.

The 12 V power supply is connected to an H bridge module to ensure the motor rotates bi-directionally. The H Bridge powers the Arduino microprocessor and the motor. The Real Time Clock (RTC), which has a 3 V battery, is connected to the Arduino by three inputs (two analogue and one digital), which provides the time used by the sun tracking algorithm. There are two proximity sensors, powered by the Arduino 5 V output and connected to two analogue en-

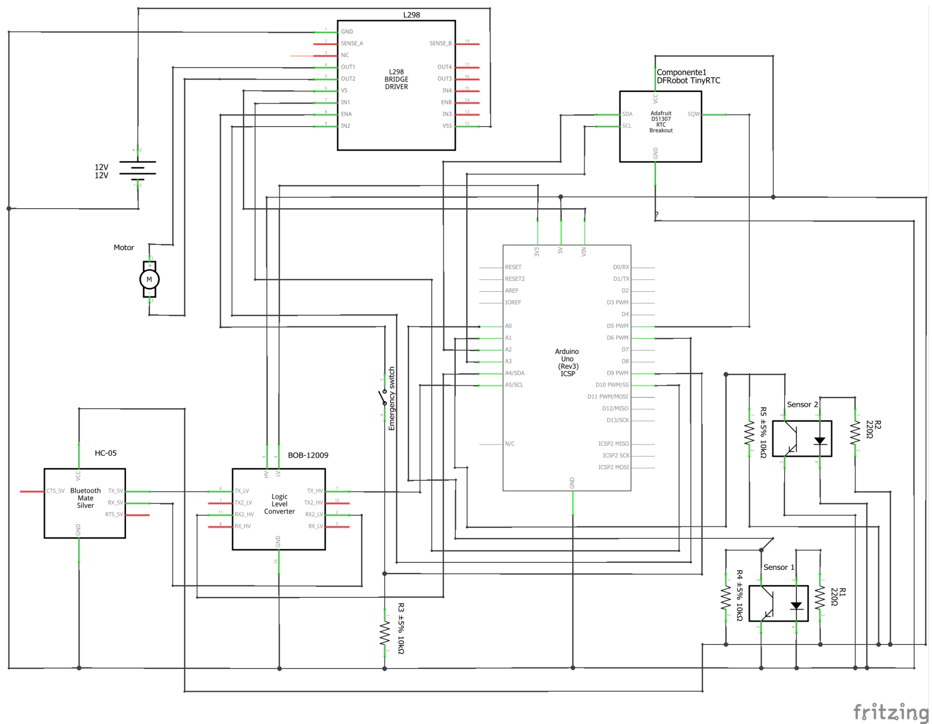


Fig. 6: Control system electrical schematics

tries, to determine the position of the blind. Finally, the Bluetooth receiver was included for future developments, *i.e.*, to connect and control the shader via a smartphone.

Automatic shading The blind is positioned automatically with the help of two algorithms. The first algorithm determines the position of the Sun relative to the shader, while the second uses this information to control the motor and position the blind, ensuring that the shadow is projected over the intended area. Figure 7 shows the flowchart of the automatic shading control algorithm. After plugging in SetSun, the system determines where to position the mesh over the structure based on the time of day (provided by the RTC) and the geodetic location of SetSun. Each day, between sunrise and sunset, the algorithm periodically determines the position of the mesh and instructs the motor to rotate accordingly. The proximity sensors, installed on the top corners of the structure, ensure the motor stops turning from sunset till sunrise.

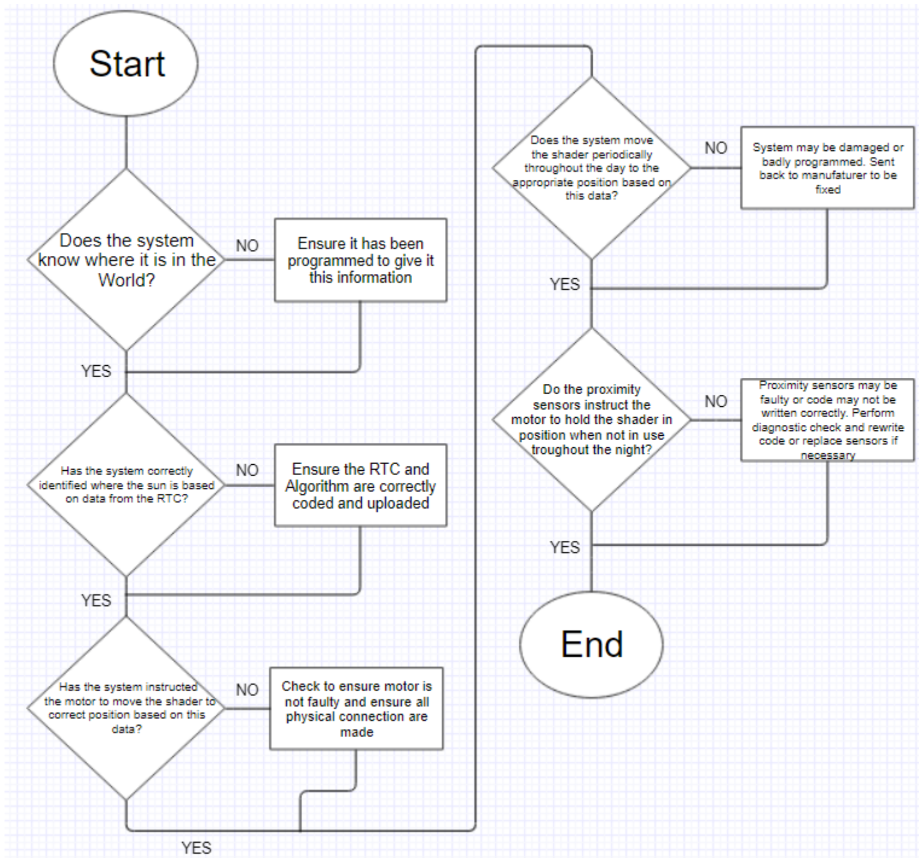


Fig. 7: Flowchart of the automatic shading control algorithm

4 Tests and Results

The Team evaluated and tested the prototype to verify its operation and check if there were safety risks or problems not anticipated during the design stage (Figure 8). The tests included checking if the motor had enough torque to move the shader, making sure that there was an acceptable delay between the controller order and the actuator response, validating the gear functionality and, last but not least, testing if the structure was safe. This test was done using a simulation software since the construction material of the prototype (wood) is different from the one of the actual product (steel). Each electrical component and related Arduino code was tested individually before reaching the final software version.

The construction bow was modelled in SolidWorks as a single part made of a hollow square steel rod with 130 $\times$ 130 mm and 3 mm thickness. The simulated

Fig. 8: Final Intelligent Shader assembled prototype during undergoing its tests

structure showed a deformation of less than 1.4 mm when a 1000 N force was applied to the middle of the bow (shown in Figure 9).

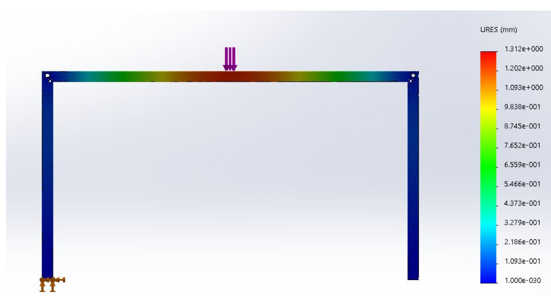


Fig. 9: Force study

The motor rotated properly in both directions, but did not change the speed as expected due to a wrong cabling connection. Once corrected, the motor worked properly in both directions with different speeds. Next, the team realised that the motor did not developed enough torque and ordered one with higher torque. The L298N H-bridge works as it provided power to the motor.

The sensors recognized the presence of nearby objects from a distance of approximately 5 cm. This is less than initially expected but still enough for the outdoor intelligent shader, since the distance will be only around 3 cm.

The RTC worked as expected. Although it was 15 s behind real time, this is accurate enough for controlling the blind, which moves very slowly.

Each individual part of the positioning algorithm worked independently but, when all parts of the code were placed together, it did not work as initially expected. The Team were unable to rectify this problem because its was found too late.

5 Conclusion

On the one hand, the goal of this project was to design, develop and build an outdoor intelligent shader, *i.e.*, one which moves automatically the blind according to the position of the Sun. The scientific, technical, sustainable and ethical standards followed throughout the project not only make the team proud, but also help promote the image of the product in the market. It can be concluded that developing an outdoor intelligent shader is to protect people from the sun and let them feel comfortable because they don't have to move their shader. What the team wanted to achieve is that people will feel more comfortable in a greener planet which cares for sustainability.

On the other hand, the goal of EPS@ISP is to foster a project-based student centred framework, with students who are able to work well in a team and to learn to cooperate in a multicultural environment. The European project semester was also about observing deadlines and working responsibly together. This process was not always easy, since at this educational level students are not usually used to collaborating with colleagues from different nationalities and from different engineering backgrounds. Working as a team forced them to divide tasks and trust in each other, while learning from each other and about themselves.

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