Urban Lighthouses and a Tactile City - Bristol

(1) Fabio D'Agnano, Carinna Parraman, Paul Goddard (2) Nat Roberton

(1) The University of The West of England, Bristol [UK]

(2) Bristol Legible City, Bristol City Council [UK]

Introduction

Bristol is promoted as a vibrantly connected and social city, but it is also busy, noisy, dense and complex. Radiating from the centre is a network of roads, one-way systems, rivers and bridges, pedestrian areas and cycle paths. Bristol was heavily targeted by the Luftwaffe in the second world war, demolishing the medieval heart of the city, and since then its infrastructure has been subject to many revisions and reconstructions. Roads and paths are constantly repaired or rebuilt and public transport is regularly redirected. For any visitor, therefore, Bristol city may be considered as too difficult to navigate and perceived as unwelcoming and overwhelming. The aim of this chapter is to use Bristol as a case study to understand the complexity of the city from a social perspective to understand how people access and navigate our city. For the purpose of this research we have concentrated on a sector of the community, the visually impaired, who find it very hard to access places and information that are taken for granted by sighted people. As part of this case study Bristol Legible City has collaborated with and described a number of projects that are underway. The underpinning question considers: how can cities become more inclusive and welcoming for everyone?

Case study of Bristol

With a population of around 463,400, Bristol is the largest city in the South West of England.[1] It is situated at the corner of the M4 and M5 motorway corridor, is a central rail hub for the Great Western Railway, and the Severn Bridge provides a major link to Wales. Bristol is both a city and a county, and borders with Gloucestershire and Somerset, the west coast, Avonmouth and the River Severn. The Rivers Frome and Avon feed into the River Severn's estuary which in 1809, established Bristol as an innovative port city. The civil engineer William Jessop with his floating harbour, enabled ships to sail into the heart of the city. The location made it ideal for early voyages to undiscovered lands, including the first European to land in North America, John Cabot. Bristol's rich history started with settlements dating back to the Iron Age and gained momentum from the woollen trade in the Middle Ages; in the early 1900s regional specialism in aviation began, focusing on aerospace in the 1970s and in the high-tech industries in micro-electronics in the 1980s. More recently, television and film industries thrived, including the BBC, Aardman Animations and Bottle Yard Film Studios. Popular tourist destinations include the Bristol Zoological Gardens - the oldest provincial zoo; Clifton Suspension Bridge (Figure 1) and the SS Great Britain - both of which were designed by Isambard Kingdom Brunel (1806-1859).[2] Cultural places include the Arnolfini Gallery (Figure 1), Watershed and Pervasive Media Studios, and Spike Island artists' studios, all of which contribute to the arts, cultural and social sector of the city.[3] It is now a city that is an essential hub for creative clusters, networks and resilient cultural ecologies.[4]

The research is part of a larger body of work that seeks to understand how the city of Bristol responds to the demands of different cultural, socio and economic groups. Our past research has sought to understand how design adds value to a city,[5] exploring issues of resilience and sustainability and the impact of re-distributed manufacturing (RDM) at the scale of the city and the regions.[6] Bristol was named as one of the first 100 resilient cities.[7] Our research has studied these issues from several disciplinary perspectives, bringing together experts in manufacturing, design, logistics, operations management, infrastructure, resilience, sustainability, engineering systems, geographical sciences, mathematical modelling and beyond. We have used a combination of co-design and action research as part of our research methodologies. Action Research has been used to address the qualitative aspects of the project. This has included, site visits to museums and public spaces, collecting material information, visitor surveys, working with different user groups to gain feedback, workshops material exploration and feedback of maps and interfaces. Using a circular approach, feedback has been used to inform how we co-design with different stakeholders, namely in this instance with the visually impaired to build products and services. The following examples are ideas and methods that could be modified for different environments including, open spaces, museums and historic houses.

Bristol Legible City

Bristol Legible City is a unique concept to improve people's understanding and experience of the city through the implementation of projects exploring identity, information and transportation. Bristol Legible City began in the 1990s, prompted by large scale regeneration within the city's central area. An opportunity enabled by this investment was to directly address some of the historical barriers presented by the city to address navigation. Bristol has a complex history and built form that is defined by successive periods of significant change. The city's legacy of nineteenth-century engineering, war-time bombing, and post-war road infrastructure has resulted in Bristol being a somewhat fragmented city with more than one centre, bisected by two watercourses, and featuring large fractures in the urban fabric resulting from large-scale road building during the 1960s and 1970s. All these factors created significant barriers to movement across the wider city area and creating a sometimes illegible and disorientating environment. As with several other UK cities in the 1990s, development in Bristol was subject to a renewed emphasis on city centre living, growing the leisure economy, and providing a high-quality public realm.

Bristol Legible City was instrumental in delivering this vision with a programme of public realm enhancement projects, a series of public art commissions, and the development and delivery of a coherent and consistent wayfinding and city information system. It is this last element of the project that most people encounter when travelling about Bristol. The project is designed to be intuitive, to be used by visitors and residents, and is resolutely user-centred in its development, and innovative in its information design and presentation. This design innovation has since been adopted by cities both across the UK and internationally. The most obvious manifestation of the project is the on-street pedestrian wayfinding system, which can be found throughout Bristol's central area. Extensive development work in information design, cartography and graphic representation was undertaken to ensure an accessible, connected and intuitive wayfinding system was provided. Much of this work was founded in, and directed by, a detailed exploration of how users apprehend, retain and make use of rich spatial information to negotiate the complexity of the built city.

In recent decades, Bristol has seen a huge investment in the physical regeneration of its central and eastern districts. The regeneration is mainly concentrated on the harbour side, where large disused containers have been available for new activities. Another important area of development comes from the transformations initiated by the construction of the M4 motorway to the east of the city.

Bristol's population is growing rapidly, as are the numbers of people visiting the city. There is a growing emphasis on providing a welcoming, sociable, high-quality public realm, that is more sustainable, with walkable neighbourhoods, and a desire for a city that works better for all residents. Critically this vision for the city has a strong basis in local, city policy with a drive to provide a fairer, fully inclusive city that recognises and responds to the needs of all of its residents and visitors: resolving the city to be more welcoming and accessible.

Bristol tactile projects

Wayfinding strategies for the visually impaired are fundamental for providing social inclusion, a better quality of life, a level of independence and urban accessibility for people with special needs. Recent digital technologies can provide significant benefits, such as GPS localisation and text-to-speech, for example for the visually impaired, by improving their interaction and navigation on unfamiliar routes. During the summer of 2019, we undertook a series of activities to understand accessibility issues and barriers to Bristol city and its museums. Our first exercise involved preliminary desk-research contacting museums about provision for the visually impaired. We asked a series of questions: if there was any accessible information present upon arrival and location; whether there were other accessible formats to assist people with visual impairments, whether the ground was level or placement of wayfinding signs or lighting. Responses ranged from, special guided tours on certain days, audio guides and optical ID pens, and ‘nothing to offer at the moment’.

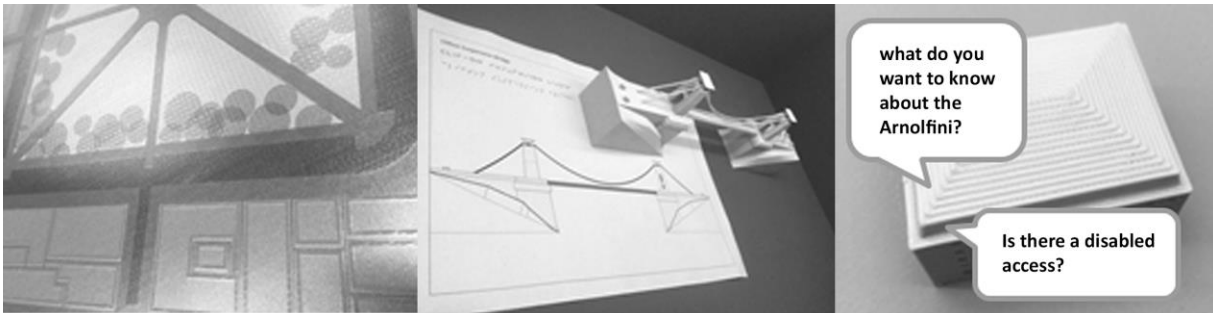
The second exercise involved a researcher, who was visually sighted, to visit many of the popular museums, test the veracity of the information, the availability of any guides, and photograph the journey around the exhibition. Although Bristol is an old city, significant provision was made for wheelchair users, including accessible entry points and uniform floor surfaces. Some museums provided interactive exhibits that were specially designed for children. Many information boards were well designed but were not multi-functional. One museum did have optical ID pens, but unfortunately, these were not working (due to no batteries). A third exercise involved short to long walks between arrival and destination points, for example, Bristol Bus Station or Bristol Temple Meads to the Eye Hospital or Bristol Royal Infirmary. The researcher recorded these walks, who is visually sighted, and took photographs and notes along the journey. A typical 1-minute walk from the Bus Station to the Eye Hospital included several obstacles and trip hazards.

Bristol mapping and a tactile city

In consultation with RNIB, Bristol Legible City and CFPR (Centre for Fine Print Research) [8] addressed several core themes of the government’s Industrial Strategy Green Paper.[9] In doing so the focus was on sectoral needs in the health, tourism and heritage industries with an enquiry into the uses of digital technologies.

The project scoped and researched appropriate methods of tactile map-making and maps for the visually impaired that could improve their navigation around the city of Bristol. As part of this project, we sought to understand what a city feels like, that without the aid of sight, what different perceptions could be used to translate these sensations?

Figure 1 (left) Tactile map of Queens Square, (middle) printed replica of Clifton Suspension Bridge with embedded sensors, (right) interactive prototype of the Arnolfini Gallery (CFPR)



We used computer-based modelling and CNC rapid prototyping technology to develop methods that incorporated 3D printing and embedded RFID technology, linking 3D printed objects and tactile paper maps to the city's street signposts and cultural information. It explored different materials, 3D and relief printing (fig. 2), and casting methods that could convey different sensations. It explored creating a tactile taxonomy for map prototypes that could be cheaply produced using recycled paper, but robust enough to incorporate Braille dots and raised textured symbols. This project has sought to collect tangible and tactile resources that can assist visually impaired people in navigating and recalling information about complex city environments, in particular, large public spaces and city cultural institutions and that could improve their navigation around the city of Bristol.

Bristol Sensory Mapping

Building on this existing work, a brief was set by Bristol Legible City and CFPR for designers and artist's Studio Meineck and Splash & Ripple to explore the development of low-cost tactile mapping resources for users with a visual impairment to navigate the city and access cultural destinations. This collaborative research between Studio Meineck, Splash & Ripple, PECo Theatre, Bristol City Council, CFPR, and a cohort of visually impaired people (VIP) explored sensory mapping for VIP and their relationship to the City of Bristol, memory and storytelling. Through the sensory mapping project, designer Chloe Meineck and a visually impaired companion entered into a discursive walk around the city and talking about their journey whilst Meineck highlighted the no-go areas and obstacles. They then worked together, recalling the journey and mapping emotions and sensory delights. By embedding their stories as a physical and textural walk on their map, they could retake the journey with their fingertips; as part of the mapping process, Meineck combined swell-paper, and different textural materials and conductive ink.

Figure 2 Tactile maps and waymarking for recalling memories and storytelling – photo courtesy of Chloe Meineck.

Walking tours of the local area during which three to five discussions took place – informal interviews which were recorded as audio files. The content of these discussions was varied but related directly to the interviewee’s experience of being in, and navigating the city; their lived experience of moving about the city as a person with a visual impairment. Technical challenges, personal observations, emotional responses, using sensory cues – sound, which parts of the city were considered welcoming and those that were not. Working with this interview material Chloe Meineck developed an early prototype of a touch-activated map of a user-journey constructed using low-cost materials and technology - thermal paper, conductive paint, textural differentiation, audio storage, processing, and playback.

Technical Review

The following review highlights a range of technologies available, concerning their pros and cons and possible applications. From a wide survey, the available technology can be categorised as virtual (not related to the on-site experience, mediated through digital means), screen-based technology (mainly related to smart phones with aids for the visually impaired), tactile and analogue (standard media such as tactile maps, with no digital features), and relatively little that addresses the gap. These different aids use different senses (touch, hearing), often combined, and different infrastructures (physical and digital). The systems hold advantages for navigation both in research before visiting an area and the exploration upon arrival.

Preliminary navigation

Some aids could be applied in map-based exploration, usually before visiting an area. These aids can be used to plan a visit therefore building confidence of the area while on-site. Handheld tactile maps provide descriptive and spatial indications, allowing cognitive mapping of the area.[10] These maps make use of raised shapes, lines and Braille to convey information, while often blocks of colour are used along with the shapes for visual cues. Tactile maps are made from a range of materials, such as paper or 3D prints, and these maps are available as single sheets or in booklet formats making them portable and even suitable to send in the post. [11] [12]

Another solution are the Optical ID pens, that can detect recorded information from a unique printed microdot. A printed support stores the data, and when the pen cross-references this ID code with stored audio data, the information can be recorded and replayed, or over-written.[13] It is useful for a range of applications including object identification, such as labelling the name of a product (food item, hazardous substance), or a longer contextual description (museum display, points-of-interest on paper maps).[14] The system provides almost pin-point accuracy, are cheap and allow for the placement of different ‘tags’ in close proximity.[15] Despite the benefits however, our testing of these products shows that they are less effective under poor lighting and can be easily worn away or delaminate and the user needs to apply the pen almost directly onto the tag for its operation.

Among the various possible options, Conductive materials have been tested, such as paint, ink or cotton thread which can be triggered by a touch that activates an event, for example switching on a light or making sounds. These materials can be used in conjunction with tactile maps and connected to a computing device which handles the touch-trigger and plays the associated sound.[16] The materials can operate in any light, is cheap to produce and fun as a learning tool, but can become easily worn away, and when broken or cracked then the circuit is compromised.[17]

Real-time navigation

Other aids are useful for real-time navigation. These aids vary vastly in design and ability to address the needs of visually impaired people. On-site tactile maps are usually made from robust, long-lasting, materials with matt finishes to avoid wear and displaying fingerprints. These kind of maps are designed to be read by anyone, including those with visual impairments and used both indoors and outdoors. [18] These large maps have similar benefits to their hand-held counterparts with the addition of their enlarged size increasing readability.

Maps are installed at fixed points, so any person using them must remember its information to aid them until they reach another map.

Tactile pavements are present in the major pedestrian routes and used to convey important navigational data such as directions or hazard warnings.[19] These textured surfaces can be detected underfoot or via navigational (white) canes. However, up to 58% of this pavement is installed incorrectly and may pose as a trip hazard.[20]

Physical audio aids such as pelican or puffin traffic light-controlled crossings or talking elevators, provide clear indications of the direction and when to act.[21] Implementation is sparse due to the lack of legal requirement, for example, where two sets of traffic lights are set in proximity, conflicting noises may lead to confusion.[22]

QR codes affixed to points-of-interests (POI) provide information or redirect users to webpages containing further details are used for product searches and navigation. [23] Webpages can provide navigation details or information about the POI. QR Codes have been used as on-floor signage for smart devices to receive real-time location data. [24] However, navigation in open spaces requires covering the floor with numerous codes, for people to follow a predefined path. QR codes require a clear line-of-sight which becomes a problem in busy areas such as bus stations, where people may obscure the code. [25]

Near Field Communication (NFC) is a passive wireless communication protocol, that uses radio waves within a 13.56 MHz frequency band, that is accurate to a range of 4cm. Tags store machine-readable data and powered by the reading device, helping to keep them sticker-sized. [26] Tags are cheap to produce, do not need a direct line-of-sight so can be embedded inside objects, and detected by an NFC enabled reader such as a smartphone.[27] However, tags cannot differentiate between multiple readers within range and their signal strength can be affected by external elements such as nearby metals. [28]

Li-Fi (light fidelity) uses optical, rather than radio, frequency and used in devices such as remote-control units. To provide directions, units sending current positional information are installed at key navigation points, such as junctions, and receiver units are carried by the explorer. Light-emitting diodes (LEDs) have high intensities and therefore can achieve very large data rates. Li-Fi is not affected by radio frequency interference but requires a clean line of sight, therefore cannot work if obstructed by people or in bright sunlight. [29] [30]

GPS navigation systems triangulate the user based on the relative position of satellites, and the system’s logic overlays the position onto a mapping software. [31] GPS is commonly found in smartphones and globally available. However, GPS is more accurate outdoors and within the line-of-sight of at least four satellites, without interference from buildings or poor weather.[32]

Bluetooth (iBeacon) Tracking and Navigation is a proximity-based technology (rather than location information). The user carries a device such as a smartphone with a beacon-associated-app that relays information based on the identified Beacon. [33] The Beacons are easy to install and can be retrofitted to existing exhibits, or placed around a space to aide navigation and can localize the user more accurately than with GPS. A network of Beacons is required to prompt navigational systems and require a power source, commonly batteries, and maintenance.

Camera Tracking, as it suggests, is a device that registers and tracks the movement of the user's finger or hand over the 'hot spots' of an object. Other uses include detection of the body's proximity, providing different ambient sounds depending on how close the user is to the camera, for example. [34] This technology can be used to gather data as well as provide data. Two types of methods involve a depth camera that characterises movement based on contours of an object or surface, or an RGB camera that detects colour markers usually placed on the fingernails. [35] This method can be used for retrofitting to existing objects, works across any surface, and is very accurate. A range of hardware can be used, such as a fixed overhead camera or smartphone. However, the smartphone would need to be held by the user and this may be less effective. [36] It is also less effective for large objects or if the whole object is not wholly in the field of view of the camera.

Urban Lighthouses

The project uses the existing infrastructure of the wayfinding signage system (these are referred to as monoliths in the rest of the document). The monolith was provided by Bristol Legible City and is enhanced with embedded technologies and data, specifically designed for the visually impaired. Analogous to the lighthouses that guide sailors across unfamiliar water, the system provides useful and relevant information to users with a visual impairment, wanting to explore the city. The project aims to upgrade, extend, and expand the reach of standard infrastructures (public signage, bus stops, traffic lights), to an audience with special needs, by the use of digital means. The pilot project provides a focus for experimentation on accessibility, with the purpose of scalability for different networks and smart cities. The pedestrian wayfinding monoliths are being upgraded with a richer level of mapping repurposed with new technologies. The other purpose for the city council is to provide

environmental data, that will be open and available for use by the community. For this reason, monoliths are powered and connected to the Internet. In addition to this, monoliths interact with users by different means: medium-range localization (Beacons), and short-range interaction (touch-based sensors).
The range of adopted technologies goes from GPS, a long-range one way only (from satellite to the user) communication system to Bluetooth, a medium range (up to fifteen meters) bidirectional system, to touch, a short-range (arm reach) interactive system.

The system uses different available digital technologies to provide indications both indoors and outdoors, with different degrees of accuracy. It also allows a bi-directional (anonymous) interaction between the user and physical objects, which is normally not possible with technologies such as GPS. The project is under development with the collaboration of Toshiba (UK).

The pilot project

The indications for the design of more accessible buildings and cities differ worldwide and apply mostly to the functional part of navigation rather than to the descriptive part. Tactile paving, tactile maps, audio warnings signals (for example at traffic lights), are just some of the aids for the visually impaired.[37] These infrastructures require substantial economic investment and are therefore generally limited. In addition to these physical infrastructures, there are important steps forward towards the accessibility of the visually impaired by widespread technologies (see technical review).[38] Most physical infrastructures work on a tactile basis, while digital infrastructures prefer the audio component. It is important to note that although smartphone screens are called touch, the haptic portion is close to zero, being them flat. A quick analysis of the systems currently in use shows that no solution is exhaustive and that there is currently no interaction between the various systems except in a limited way (e.g. button/traffic light / tactile pavement) and within the same category. Moving from A to B in an unfamiliar path implies strategies for the visually impaired of different kinds that lead to different results, as indicated in the study Analysis of wayfinding strategies of blind people using tactile maps. [39]

The best results happen when with the aid of tactile maps, it is possible to build a mental map of space, and this is normally not possible with the only help of smartphones. As mentioned, the project aims to use the different infrastructures at the same time to facilitate urban navigation for blind people. Furthermore, it aims to overcome the only functional indication of the route from A to B (wayfinding) but proposes a narrative description of the city. The synergy between physical and digital infrastructure is optimal to enhance the awareness of space thanks to mental maps. The system uses GPS and widespread navigation systems such as google maps, to move from different points in the city called hotspots. Hotspots are points of interest, equipped with a technological infrastructure (beacon and touch) and specific content for the blind (audio descriptions and touch panels, enhanced with Braille tags). Once in the proximity of the hotspot, the app switches to Bluetooth mode and receives specific information about the location, both indoors and outdoors. When in Bluetooth mode, it is possible to interact, for example, by requesting that an object (the monolith) responds with a call-back sound from a phone, enabling immediate localisation. In the following illustration, we can follow how a visually impaired person can start to navigate an unfamiliar city from the exit point of an airport or railway station, arriving confidently at their destination.

Figure 3 Schematic diagram of the system

A visually impaired person in an unfamiliar environment has many distractions and cannot always obtain and locate dedicated aids. Beacon communication can transmit directly to the personal device, within a radius of about 15 metres. It is possible to connect device and aid (via Bluetooth communication) and to provide sound signals, which are particularly effective for localization, instead of using triangulation systems that are difficult to implement (beacon networks). When the device is shaken, the aid emits a sound, which is useful for localization. Once in close proximity of the aid (designed for everyone, and not only for the visually impaired), the visitor can touch it to receive relevant information and can provide spatial indications for mind maps (indicating real distances, oriented and comprehensible). The system will then provide necessary route indications using standard GPS platforms. En route, it is also possible to receive descriptive information, and not only functional information (turn right or similar). A network already available in the city, as demonstrated by Bristol Legible City, can provide a structured orientation system for people with visual impairments.

Development of the prototype

The prototype has been developed using low cost and open-source electronic boards, to ensure the project easily scalable and exportable in other cities. The main requirement is to allow Bluetooth communication between a portable device (Android operating system during the prototyping phase) and the monolith. The board that has been used in the prototype is called Arduino101[40] which has the main characteristics of a standard Arduino board, plus the built-in Bluetooth connectivity. In addition to this board, a second board called Bare Touch adds an array of capacitive sensors, useful for the haptic part. The two boards are interconnected through serial communication. When the mainboard (Arduino 101) is powered, it starts broadcasting a signal which contains the following information:
Under the protocol called BLE (Bluetooth Low Energy), the broadcast of this simple information is repeated continuously. When a personal device, with a special app running in the background receives the signal (normally if within the range of 15 metres) sent by the prototyping board, it sends a request to establish bidirectional and exclusive communication. When the connection is active, the user can interact with the monolith within the Bluetooth reach. When the user shakes his phone, a signal is sent to the monolith, and a sound alarm is triggered. This is an effective way to easily locate the monolith, as it is proven by other devices for the blind (i.e. traffic lights or elevators).
On the software side, a widely used open-source system is the MIT App Inventor.[41] This platform, available on-line, allows any user, even with no coding skills, to develop applications for digital devices such as smartphones and tablets. This solution has the advantage to use a visual programming approach, making it more accessible even for people with no background in coding.
This solution, on the software side of the project, was combined with another open source resource on the hardware side, which is widely documented and low cost: Arduino. Arduino is an ecosystem composed of hardware components, software development and support communities. The software component of the app was therefore developed with App Inventor, while the electronic part with Arduino, both of which are low cost, accessible, open source and widely used platform.

Conclusion - The future for the tactile city

A growing cohort of project partners is developing further work to test and evolve the creative potential of tactile interfaces and intelligent user-centred design for city navigation systems. In addition to upgrading Bristol's wayfinding street furniture and digital cartography to allow direct interaction and manipulation of environmental data and route information, project partners will be working directly with users to design a more responsive and user-centred methodology to grow city navigation and information system that responds directly to user-needs and provides an iterative and collaborative approach to providing city spaces and services that place accessibility and equity at their centre. Work continues with Toshiba and UWE's Department of Computer Science and Creative Technologies, to roll out the upgrade of the map units across the city, and also in collaboration with interaction designer Chloe Meineck to test and refine the user experience. The next phase of the project is an extensive testing activity, with a focus group of blind people, and is currently on hold due to the restriction of COVID-19.

The pandemic has also shown how a crisis condition can be even more serious for those who already have disabilities or frailties. Responses tend to be worked out for most people and sometimes minority communities do not fit within the parameters of emergency solutions. For example, safety distance is difficult to assess in the case of low vision, refraining from touching surfaces can be very difficult, and loss of sense of smell and taste has very serious consequences because they already suffer from deprivation of other senses. These limitations can lead to a reduction in outdoor activities and lead people with visual impairments to greater isolation.

For this reason, projects that use technology to facilitate urban navigation can be of great importance in ordinary and even extraordinary conditions, such as a pandemic.

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