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Hybrid Indoor Location Infrastructure based on BLE beacons, BLE Lighting Devices and Music Combination

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***Abstract*— This article reports the development of an assisted mobility application based by indoor localization system that uses a hybrid infrastructure defined by the combination of low-power Bluetooth 4.0 stand-alone beacons associated with Bluetooth 4.0 devices imbedded into smart led lamps. The autonomous beacons were chosen to define the location and tracking of the physical resources that exist in a building (people and objects), while the led lamps are used to define the fixed zoning of the building. The MAC number of the devices is used as the key to construct the spatial reference identifiers. In the first part of the article are detailed the technical principles of the location system, that was programmed in C# within Xamarin development environment for Android devices. In the second part are described the theoretical assumptions for designing spatial qualifiers using music, towards an orientation system that combine all this infrastructure elements.**

Keywords*— Beacons; Assisted mobility; Indoor Positioning System; BLE Lighting devices; Music

I. INTRODUCTION

Indoor Positioning System and micro location systems have been programmed using infrastructures with varying degrees of accuracy (Wi-fi networks, sensors, etc.). The Low Energy Bluetooth technology (BLE), which emerged in 2010, came to stand out as an alternative to traditional indoor location systems. It can be said that this technology began to be widespread during the last few years. Developers of Bluetooth Smart, Bluetooth Low Energy or Bluetooth 4.0 observe that this technology enables the emission and reception of RF signals consuming low amounts of energy. It allows designing BT emission devices that can be powered by power sources such as small 3V CR 2032 batteries. Bluetooth Smart has enabled the development of small and economical broadcasters (Beacons).

Since 2010, they have occupied a larger space as a technological alternative in the field of indoor location systems development. Developers of this technology indicate that one of the features that differentiates traditional Bluetooth from Bluetooth BLE is the capacity of allowing connections between the devices that does not have to be performed through pairing. This type of Bluetooth allows the passive and continuous discovery of near devices and applications [1]. Interoperability between suppliers and the possibility of extending the reach radio are other features that make BLE attractive compared to traditional BT [2].

Based in its experiments, some researchers observed that with the use of BLE, compared to the traditional BT, can be achieved performance savings of only just 10% [3]. However, one of the characteristics of the known indoor location infrastructures is that they generally use heterogeneous equipment, such as Wi-Fi access points (AP) or traditional Bluetooth which emit RF signals, but that were not specifically designed to perform location functions. These services are a sub product that Wi-Fi offers. Indoor localization systems use the existent infrastructure of APs as it is, adapting its algorithms and methods to them, but the position and distribution design of RF broadcasters for location purpose is inexistent or need to negotiate with other requirements. In other words, the localization techniques and methods as geo-fence or maps creation are adapted to the infrastructure not the contrary.

In general, several services can be customized to provide context information for the permanent or temporary population of buildings or urban environments. The facilities management databases containing the resources allocated in buildings can be integrated within tracking and localization systems. The purpose of this integration is to have information assistants for scheduled maintenance operations in buildings that require a high degree of commitment to their operational control, such as large shopping centers, museums, health centers, schools, universities and administrative centers.

In recent research conducted by Lymberopoulos *et al* [5] are listed some conclusions about the precision of indoor location technology: a) Sub-meter accuracy is feasible today, even in Wi-Fi based approaches; b) Environmental changes affect accuracy between calibration and real-time operation. It can degrade by as much 3m due to environmental changes; c) in unfamiliar or no controlled environments, the average of accuracy degrades can be 1m to 4m; d) localization accuracy can widely vary across different evaluation points; e) most or almost any indoor system can achieve low error; f) the choice of evaluation test points is critical, and it reveals the difficulty of objectively evaluating indoor location systems.

The use of smart-devices is getting better the real-time data capture needed to analyse human-behaviour in buildings [27]. The more accurate is the location system, the more reliable is the captured data in real-time. For this work is a reasonable assumption that BLE technology would be a strategic asset specially when embedded in lighting fixtures. BLE capacities added in smart LED bulbs lamps allow them to be controlled by applications installed on smartphones or mobile devices. Changes on intensity and light tonality can be performed remotely by people. But this type of control is just the visible aspect the technology permits.

Luminaires are devices closely associated with buildings form and function. It can be said that, in general, the geometric distribution of this elements reflects the geometric determination implied in the architectural spatial form. The space design and artificial lighting design are intimately bonded by the form. Aside that, the luminotechnic design usually distributed all the lamps to achieve functional requirements for people’s safety, locomotion, visual comfort or aesthetics fruition. So, the association of a hybrid infrastructure of BLE beacons and BLE lamps seems to be an attractive option to having a heterogenous and controlled infrastructure for indoor location services that, fundamentally, born within an integrated design process and from the early design phases. In addition, to gaining energy efficiency and reducing maintenance costs, LED bulbs integrated with BLE devices enable more precise economic management of the building lifecycle as they can be integrated with building control and monitoring systems.

II. ELEMENTS OF THE SYSTEM.

Fig. 1. Beacons and smart led Light bulbs.

Because it is a hybrid and heterogenous infrastructure, beacons and light bulbs will be herein after referred to as broadcaster devices. Cell phones with the monitoring application installed in it will be called central devices. Although there are specific identification codes recorded in the beacons, these codes do not exist on the lamps, so the MAC address is a unique common data that can be used to determine the tag between the device and the space.

A. *Considerations about the distribution of broadcasters and peripherical devices.*

In previous work, it was pointed out the need to replace beacons' batteries as a complication factor for scheduled maintenance operations. This observation relates to the amount of broadcasting elements needed to cover a building without leaving blind spaces. Periodic replacement of the batteries would entail additional maintenance work and costs. We estimate that for an inference accuracy of 3.0 to 5.0 meters, the beacons mesh should have a roughly density of 100 m^2/beacon. Therefore, for large buildings this factor would not be negligible. Depending on the use of the network of broadcasters, the interruption of services would be a risk factor for the safety of users who depend on the continuity of these services, such as the orientation of people with visual impairment, for example. Another way of calculating the quantity of broadcasters required by cover the building is by counting the rooms and all the strategic places in it (access, spaces of interest, internal obstacles, etc.). In this case, the quantity of broadcasters improves the accuracy of inference, that could be less than 1 meter, but consequently the difficulty of scheduled maintenance grows up too.

B. *System time response.*

The mean velocity of Brazilian people can vary between 1.02 m/s to 1.35 m/s depending the age and genre [15]. Considering that the system can be used as a mobility assistance, it was initially programmed to perform short time scans intervals (T_s) of 250 milliseconds, totalizing four readings per second or approximately 4.5 scanning for meter in normal walk velocity. This requirement, however, has a negative impact on the battery's power consumption. So, two modes of operation were configured: stationary and navigation. To achieve a sustainable continuous operation, it was follow the recommendation of [3], permitting that in the stationary mode the interval scan can be reduced to 5000 or more milliseconds. Another factor to consider is the density of the beacons infrastructure [4]. The tests were conducted in a linear distribution, with a beacon distance each other of 10 meters.

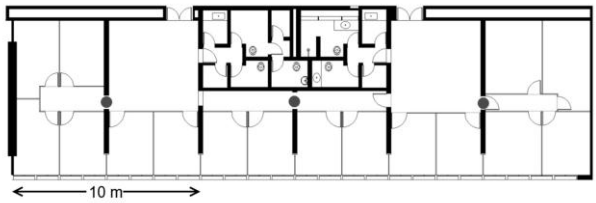

Fig. 2. Experimental area.

The application in a navigation mode was configured to work on a low latency mode to obtain quick advertising responses of the broadcasters. The readings are ordering by the lowest RF signal strength to the receiver. To verify the performance of the system in a sub-meter condition, the application was tested by aligning three beacons within a short distance to the server (D=30 cm) and swapping its position quickly after 60 seconds of scanning. The operation was repeated for the tree beacons.

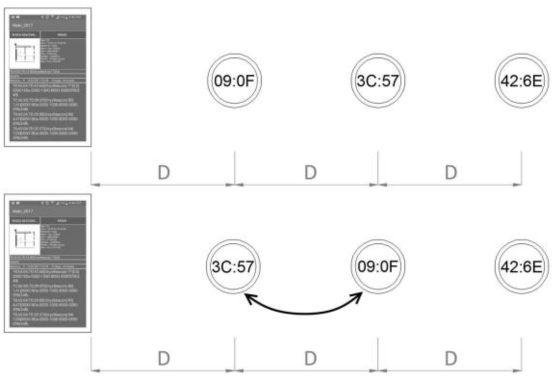

Fig. 3. Test of beacons responses.

The numbers of the beacons indicated in the Fig 3. are the last part of the MAC address. All the scan results were recorded in a text file to verify the stability of the scanning.

The Crono function indicates the current time of the reading alongside the relationship between the seconds elapsed and the scans performed in that interval.

```
public string Crono (int n, int m)
{
        t = DateTime.Now.ToString("dd:MM:yyyy:HH:mm");
        string s = (n/m).ToString();
        string r = s.Split(',').ToList().First();
        return t + "    " + r + " segs.  " + n.ToString() + " scans.";
}
```

Below is showed some of the recording results. The readings reported here were taken with a Samsung S5 smartphone running Android 6.0 (API 23) and configured a T_s in 250 msec. The tree beacons used were Onixbeacon.

```
….
7C:66:9D:7D:09:0F  17:02:2017:16:54  6 secs. 27 scans.
7C:66:9D:7D:09:0F  17:02:2017:16:54  7 secs. 28 scans.
78:A5:04:7D:42:6E  17:02:2017:16:54  7 secs. 29 scans. error
78:A5:04:7D:42:6E  17:02:2017:16:54  7 secs. 30 scans. error
78:A5:04:7D:42:6E  17:02:2017:16:54  7 secs. 31 scans. error
7C:66:9D:7D:09:0F  17:02:2017:16:54   8 secs. 32 scans.
7C:66:9D:7D:09:0F  17:02:2017:16:54  8 secs. 33 scans.
7C:66:9D:7D:09:0F  17:02:2017:16:54  8 secs. 34 scans.
7C:66:9D:7D:09:0F  17:02:2017:16:54  8 secs. 35 scans.
….
```

TABLE I.

Localization errors				
Position	*Distance D*	*Time*	*Scans*	*Errors*
1°	0.30 cm	60"	240	12
2°	0.30 cm	60"	240	5
3°	0.30 cm	60"	240	3

C. *Information model.*

The data associated with the broadcasters are divided into three categories:

- Environments;
- Human Resources;
- Physical Resources;

They are stored in an XML file located on a cloud server. When the application runs, it takes care of transferring the XML file to the mobile device. The first attribute of each record (mac) is the broadcaster Mac code address. This code works as the inference key for real-time location purpose. The other attributes can change depending the category of each element. There is no need to use the same attributes in all the records. Records are independent each other. A physical resource such as a luminaire may have a power attribute ("Potência") while a physical resource of furniture may have its dimensions as registered fields. Therefore, the presence of "Midi" and "Photo" attributes is mandatory and common to all categories. These information work as UI helpers. The specified Midi file is executed when the user enters in the broadcasters' area of influence. The main task of the Midi file, which is associated to the architectural spaces, is to be the sound qualifier of the space. Their intent is to help blind people to orient themselves by memorizing sounds associated with spaces. In this sense, the application is a music landmark identification system. The second goal, is to alert blind people where are dangerous situations that require special attention, like the proximity of stairs or obstacles. The third goal, is to promote an aesthetical fruition during the move.

As an alternative to this sound interface, it was programmed a voice interface to inform the users the name of the space where they are or some other characteristics of it.

```
<Mapeamento>
<Predio> <Id>POLI</Id></Predio>
<Bloco> <Id>Bloco_D</Id></Bloco>
<Beacon mac= "78:A5:04:7D:39:8B"
Midi="Midi_01"
Elemento= "Sala"
Setor= "Exp. Gráfica"
Foto="E_01.png"
Uso="Aula"
Piso="Taco"
Rodape= "Madeira"
Parede="Pintura branca"
Teto="Gesso">Sala 101</Beacon>
….
<Beacon mac= "B4:99:4C:76:EB:87"
Midi="Midi_02"
Elemento= "Luminária"
Local="Quarto"
Setor= "D"
Foto="Lum_flc.png"
Fabricante="FLC"
Tipo="LED Smart"
Potência="10W">Luminária A</Beacon>
….
</Mapeamento>
```

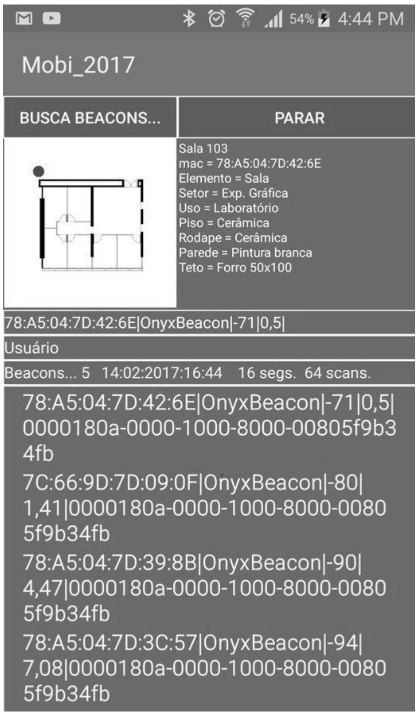

Fig. 4. Interface.

III. THE MUSICAL BOX.

A third element of the infrastructure proposed is made of a database of musical pieces created by an algorithmic compositional technic entitled Musical Box. Each piece of music is associated to a zone or a spatial situation. The

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musical box is a three-dimensional virtual box configured by 3 axes graduated in modular units which represent musical attributes. Its finality is the generation of a music by performing a translation of geometric objects. To graduate each musical axis, the following correspondences were arbitrarily established:

Axis X = duration and dynamic.
Axis Y = musical scales and dynamic.
Axis Z = height and dynamic.

The graduation of the axes is determined by alphanumerical series whose values reflect sound properties chosen arbitrarily, so that the Y axis, for example, can be graduated with the traditional musical scales and modes, with the range of Debussy whole-tones scale or with diverse series in agreement with the serial composition technique.

To translate one spatial coordinate to a musical coordinate are applied modular arithmetic's operations. The Autolisp function Cx:Imod calculates the modular index #m of a whole number #n within a defined series of musical attributes.

(defun Cx:Imod (#n #m) (abs (- #n (#m (rem (/ #n #m))))))*

Where parameter #n is the number to be translated to a modular value and parameter #m is the value of the modular limit. From the list of notes '("C" "D" "E" "F" "G" "A" "B") with a modular limit of 7 it can be capture the element of the modular index *#n* with the LISP function *nth.*

(Cx:Imod 12 7) = 5 =>(nth 5'("C" "D" "E" "F" "G" "A" "B")) = "A"

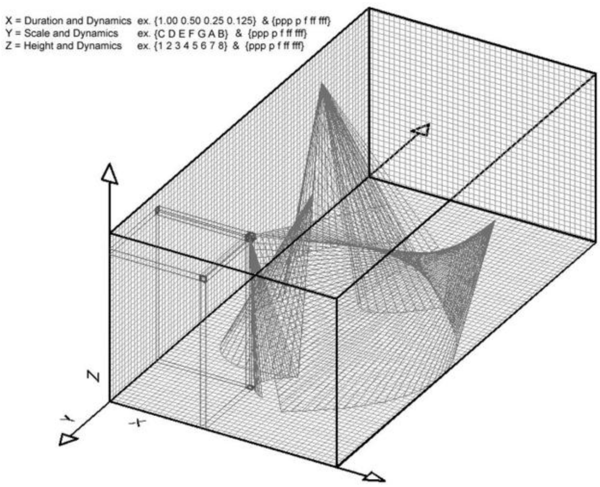

Fig. 5. Musical Box configuration.

Different procedures are programmed to perform the scans over the geometry to create the sequence of points to be translated and extracted. Once the points are translated, the values obtained are joined in a Lisp file with the syntax of the Compo Music software.

(:hei :c7 :dur 0.50 :dyn 2)
(:hei :f7 :dur 0.25 :dyn 3)
(:hei :f7 :dur 0.25 :dyn 3)

The list of notes is then processed by Compo Music to produce a Midi file.

IV. THE SOUND SPATIAL IMAGINABILITY.

A central aspect of this work concerns the definition of sound qualifiers of the architectural space, aiming to establish another possibility of imaginary nexus for the people who walk through architectonic spaces. Two authors were used as argumentation support: Kevin Lynch [16] and Victor Consiglieri [17] [18]. In the 1960s, in his book The Image of the City, Lynch conceptualized the idea of "spatial imaginability". This concept has been widely used as a foundation for the analysis of visual perception in urban contexts. In the present work, it was assumed that the concept can be expanded and adapted to the auditory perception of the architectural space. Consiglieri, for his part, did a detailed historical study of the analytical approaches used by the theorists who studied the architectural morphology of the twentieth century.

While this research pursues the musical qualification of space, the musical composition becomes a relevant issue to be articulated during the sound qualification project of space. The concepts of these authors will help to delineate reflections in this sense. From them will be used some formal notions that allow to establish the articulation between architectural composition and musical composition or, in other words, the bonds between imagination and space. Per Lynch, increasing the imaginability of the urban environment means facilitating its identification and visual structuring [16]. Similarly, it can be argued that increasing the imaginability of the environment also means facilitating its identification and structuring through sound. It is understood as imaginary nexus all the qualities or spatial situations that allow to establish temporal differentiations from analogical oppositions of the type (anterior/posterior, near/far, small/ large, open/closed, dynamic/static etc.). In this sense, sonic qualities, artificially designed, would define auditory reference frames or, in other words, sound architectural details that would help a person to understand, to enjoy, to move or to be oriented in space.

The proposal of qualification of space by means of sound attributes has as its allies the mobile devices and micro-location systems. Such a combination can help make the qualifying attribute mobile. In other words, the qualification attribute could move along with the person throughout the course, and can be further modified by the spatial characteristics.

To produce the differentiation of spatial situations it necessary mapped an architectonic space into submodules and registered the regions and the Midi files into the XML file. This type of translation is called "mapping by region". Thus, each defined region may be responsible for activating changes in the musical parameters used or to be associated with a differentiated sonority. One could distinguish adjacent areas with different timbres, various *tempos*, modular *ostinatos*, alterations of the rhythm or of the series of heights used. Consiglieri divides the theoretical approaches of the studies on architectural morphology into three phases that alternated during the 20th century:

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- Gestalt phase.
- Topological phase.
- Phenomenological Phase.

At the beginning of the 20th century, Gestalt currents analyzed form based on the concepts of boundary and contour, genesis, equilibrium and movement. The formal analysis was oriented to the study of the groupings of masses, surfaces and lines, ignoring the historical and social determinations. What interested the Gestalt was to highlight the laws that contributed to maintaining formal cohesion or to producing a perceptual pregnancy of perception. The topological current coincided with the need to treat complex surfaces such as laminar structures and paraboloids. The formal complexity of the Philips Pavilion or the structures proposed by Félix Candela, Eero Saarinen and Frei Otto, challenged theorist to imagine methods and approaches that used organizational schemes based on the definition of places, proximities, routes, contiguities, regions and closures. The phenomenological current would incorporate the symbolic and social dimension of the form in the morphological studies.

Since the intend to obtain a degree of accuracy in the spatial sound image is out the goal of the present work, it is believed that the three approaches are valid to begin a process of conceptualization and projection of sound qualities of space. Hence it is more important to question how to base strategies for the sound qualification of spaces. What could be done with the musical colors, textures and rhythms? How would a cacophonic space sound? How to materialize a sonic focal point? How could dilation or spatial contraction effects be produced through music? The answers to these questions belong, in a great extent, to the realm of imagination and subjectivity.

One feature of the indoor location system application is that it has been programmed to play the Midi file in two ways. The first one executes the midi file individually. The second, can overlay sound sequences from independent midi files, allowing to configure an overlap of sound layers that would help to qualify various spatial aspects (a percussive ostinato, for example, could indicate the presence of a colonnade, while a superimposed string melody could indicate the existence of a spatial continuity). In this sense, the combination of sound situations becomes a communication design challenge.

```
public void TocarLocal1 (string midi)
{ if(midi != "") { PararMusica(); TocarMusica(midi); } }
public void TocarLocal2 (string midi)
{ if(midi != "") {TocarMusica(midi); }}
```

Running in this mode the application assigns one music per architectonic space. Each space has its own music as a qualifier.

Space1	Space2	Space3	Space4	Space5	Space6
Music1	Music2	Music3	Music4	Music5	Music6

```
public void TocarMusica (string midi)
{ string mus ="https://sites.google.com/","a/poli.ufrj.br/mapas/"+midi;
  Android.Net.Uri s = Pega_Uri(mus);
  player = MediaPlayer.Create (this, s);
  player.Start(); }

public void PararMusica ()
{ AudioManager A= GetSystemService(Context.AudioService);
  if (A.IsMusicActive)
   { player.Stop(); }}
```

Space1	Space2	Space3	Space4	Space5	Space6
Music1	Music2	Music3	Music4		Music6
Music4			Music3		
Music5					Music2
Music8					

Running in this mode the sequence of musical qualifier can be interlaced forming a counterpoint map of sounds qualifiers. This mode of operation allows qualify common aspects of different spaces maintaining a continuity of sound flux.

	<----- user move ----->	
Space1	*Space2*	*Space3*
Music1	*Music2*	*Music3*
Voice 1		
Voice 2		*Voice 3*
Voice 3		*Voice 5*
Voice 4		*Voice 6*

V. THE SOUND SPATIAL QUALIFIERS

Luminaires are always present in the form of the spaces. The visual qualities of the architectural spaces generally are designed to respond functional aspects of the interior activities. This means that spaces to leisure, work, study or meeting rooms are designed with distinctive light effects, chromatic and geometric qualities that help people to get meanings and sensations within the environment. Certain visual qualities of the light, as its chromatic or geometric nature, prepare the people's gaze to remain in a room for a long period or to circulate avoiding put in them elements that can attract people attention. Since music is a kinetic base experience, it is believed that it would be possible to explore the sensations of acceleration, deceleration, rest, change of direction as a kind of temporal flow of information. In this section are illustrated some aspects of the architectural spaces that could be qualified with music. The spatial qualities described below are not intended to exhaust the repertoire of possibilities, nor to be declared as an objective musical description of the space. There is, indeed, margin for subjective feedback or interpretation by the users. It is also emphasized that spaces can be musically qualified by more than one quality associated to them. All the scores examples presented were created with a Musescore R. 2.0.3 software from a Midi files of compositions created with a Musical Box mechanism.

A. Amplitude. Forte and piano spaces.

The sound amplitude is related to the intensity, the volume and the dynamics of the sound. It would be possible to relate amplitude with spatial magnitude or with spatial intensity. So, a large space could be perceived as intense. But should it sound stronger than a small space? Or would the intensity be associated with the prominence that a certain space acquires in relation to the others? Despite its size, should a space that have been positioned strategically at a focal point sound

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stronger than a secondary peripherical space? Could a focal architectural element be translated with a highlighted timbre, like the sharp voice of the clavichord in E32_t5 play? This music was generated automatically from a geometric elements of a 3D architectural model. It is intended to answer these questions transmitting sensations using sound qualifiers. The form of a spatial projection of an architectural element can give the character to the space. In these examples, *forte* spaces are those whose architectonic elements are projected shapes and tend to be read as active elements. The piano spaces, on the contrary, are characterized by forms that transmit calm, rest and tend to be perceived as passive or serene forms.

Fig. 6. Forte space. City of Music, Rio de Janeiro.

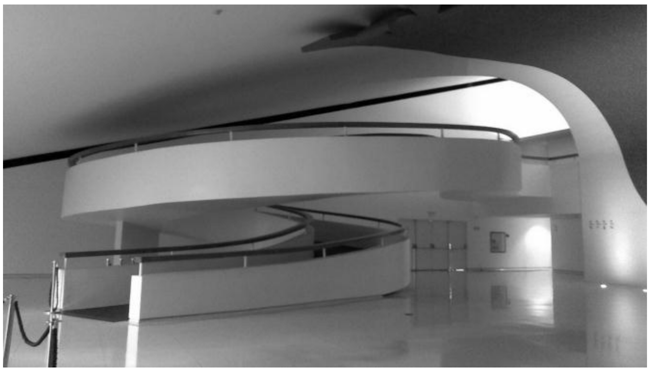

Fig. 7. Piano space. Ibirapuera Auditory, São Paulo.

B. Spaces of contrast.

The spatial contrast caused by the adjacency of multi-story spaces and low spaces of circulation, or by an open light-filled space adjacent to an obscure space, can generate a perception of acceleration or vertigo. This perception could be summed up as a strong emotion. In the Fig 8, the excerpt from the E29_06 score illustrates the moment when the sensation of speed of a music is modified, producing an acceleration through the technique of global gradation. The example can be heard to illustrate the concept.

Fig. 8. Excerpt from E29_06 score example.

Fig. 9. Narrow bordering of focal spaces. a) City of Music, Rio de Janeiro. b) Kirchner Cultural Center, Buenos Aires. c) Shopping Cidade, São Paulo.

C. Cacophonic spaces.

There are architectonic spaces that have a clear structuring lines of force as well as obvious and orderly boundaries. All these factors contribute to organize circulation flows. But there are freely-structured spaces, in which circulation flows can be random. How to qualify these spaces? The musical example E32_503 may serve to illustrate a cacophonic spatial situation. The piece begins with a defined order of voices and rhythm. Until the 4th minute, these voices seem to be in solidarity, complementing each other to form a cohesive sound assembly. Between minutes 4 and 5 begin to appear unbalanced and accelerated elements that break the initial coherence. This effect is caused by the modification of the series of durations during the piece. Instead of using a series whose elements maintain a proportional ratio of ½, at some point a series with numerical ratio 1/10 was used, which would seem to be responsible for causing rhythmic instability. Of course, a Midi sample library would need to use short musical sequences because a time consuming to pass through a 10m space could be of 10 seconds or less.

Fig. 10. Cacophonic expansive spaces. City of Music, Rio de Janeiro.

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Fig. 11. Cacophonic profound spaces. City of Music, Rio de Janeiro.

Fig. 12. Score Excerpt of a dodecaphonic piece Mtv_23 with dense and multidirectional sounds.

D. Density. Dense spaces – rarefied spaces.

This quality is related to the quantity of architectural elements that are distributed inside the space (columns, partitions, furniture, etc.) In musical words, such type of spaces could be qualified as a polyphonic space. Proportionally, the more objects distributed in the space, the more voices participate in this polyphony.

Dense Space
Voice 1
Voice 2
Voice 3
Voice 4

On the contrary, the rarefied spaces could be compared with monophonic music or a participation of a soloist voice in a music.

Rarefied Space
Voice 1

In musical term, the move from one type of space to other could be characterized by the action of mute some voices or, on the contrary, to add some ones to the melody. This can be accomplish varying gradually the quantity of voices as the user transit between adjacent and different places. The pieces Rare.mid and E32_70.mid can be serve as examples of what could be consider a rarified space and a dense space.

< ---------- user movement ------->		
Dense Space	Extremally Rarefied Space	Rarefied Space
Voice 1	Voice 1	Voice 1
Voice 2		Voice 2
Voice 3		

Voice 4

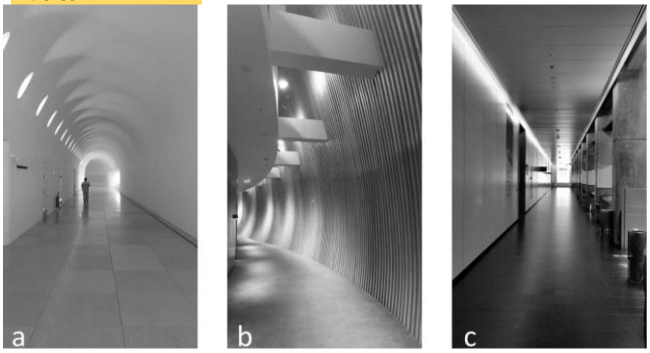

Fig. 13. Rarefied directional spaces. a) Rectilinear space. City of Music, Rio de Janeiro. b) Curve space and c) Rectilinear space. Kirchner Cultural Center Buenos Aires.

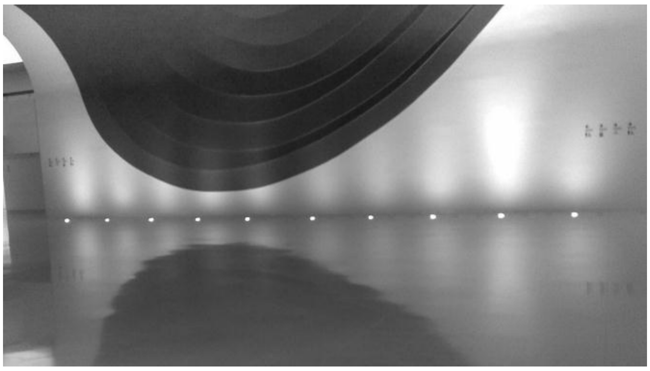

Fig. 14. Rarefied static / free spaces. Ibirapuera Auditory, São Paulo.

Fig. 15. Dense spaces. Caixa Cultural Museum, Recife.

TABLE II. MUSICAL EXAMPLES IN MP3 (DOUBLE CLICK TO PLAY).

Rare_01.mp3	Rarefied space
Mtv_23.mp3	Cacophonic dense and multidirectional sounds.
E32_503.mp3	Transition to cacophonic dense space.
E32_t5.mp3	Focal architectural element.
E29_06.mp3	Speed of a music.
Circular.mp3	Focal circular.

VI. CONCLUSIONS.

The article summarizes the relevant aspects of a work in progress. Conceptually, three lines of action can be highlighted. The first one, treated the problems related to the configuration and assembling the physical and logical interfaces of the micro location infrastructure. At the present stage, lighting devices with embedded BLE beacons were combined with a logical interface programmed for Android device.

The second line of action, relates to the problems of combining architectural design and musical composition. And the third one is related to the qualitative aspects, since it must deal with the subjective feedback of the people that will do free interpretations of the music and space combination. This is a behavioral aspect of the project, so could be call it, following [24] as a domestication aspect, meaning that people would be invited to embody a new habit of experiment a building. The fist problem requires constant attention because new Bluetooth BLE chips are being constantly embedded in new devices boards. The industry is also undergoing by a standardization process which is aiming interoperability between systems [24]. The same can be said about smartphones devices. They are constantly adapting new functionalities. One aspect that is clear is that any infrastructure could get benefit by new possibilities in a short time. However, to count on a continuous, safety and easy to maintain indoor location service infrastructure, some requirements extremally important are not available yet. One of the main problems faced with this technology concerns the consumption of the external power supply unit. Although the replacement period of the beacon batteries, declared by the manufactures, may be one year, in our tests we found that this time can be shorter, in addition to the fact that the battery consumption is not uniform even for the same type of beacon. Even though some manufacturers offer beacon models that can be plugged to the electrical power, this research has focused on the use of beacons embedded in luminaires, because lighting devices are organically bonded to the spatial form of the building.

In large buildings, with dense granularity requirements, the efforts to replace beacons batteries became critical task to take in account. The integration of beacons within LED lamps is beginning to drive the problem to a solution. But this issue hasn´t been resolved yet, because in the lamps tested the emission of RF signal is interrupted when the lamp is off. This would be an unacceptable condition for a safety environment where the location service would need to remain uninterrupted. Until the present time, no LED light bulbs with a continues and uninterrupted emission of RF signal have been found, at least at the Rio de Janeiro local market of lighting products.

The next step of the research will be to prepare a largest scenario to test the response of users in a controlled environment. It´s important to note that although this work is an attempt to link the architectural design project with the musical composition, such an approach does not mean looking for the existence of a univocal and universal equivalence between architecture and music. It is a trial of putting together the raw material with which each of the two arts is modeled: space, time and memory. It´s an integrated compositional process where the new devices and technics of micro-location are strategic tools for designing and adding artificial acoustical qualities to the architectonic spaces to help people to move guided by their hearing capacity and memory, experimenting, at the same time, a kind of ludic activity.

References

[1] Smart Card Alliance Mobile and NFC Council. Bluetooth Low Energy (BLE) 101: A Technology Primer with Example Use Cases.
[2] Bluetooth developer portal. Bluetooth Smart Technology. https://developer.bluetooth.org/TechnologyOverview/Pages/BLE.asp.
[3] Radhakrishnan, Archan Misra, Rajesh Krishna Balan, and Youngki Lee. Smartphones & BLE Services: Empirical Insights. Meera. 2015. IEEE 12th International Conference on Mobile Ad Hoc and Sensor Systems.
[4] Yuan Zhuang, Jun Yang, You Li, Longning Qi and Naser El-Sheimy. Smartphone-Based Indoor Localization with Bluetooth Low Energy Beacons. In Sensors 2016, 16, 596.
[5] Lymberopoulos, D., Liu, J., Yang, X., Choudhury, R.R., Handziski, V., Sen, S. A Realistic Evaluation and Comparison of Indoor Location Technologies: Experiences and Lessons Learned. ACM SIGMOBILE
[6] Poldma, T. Transforming Interior Spaces: Enriching Subjective Experiences Through Design Research School of Industrial Design, University of Montreal. C.P. 6128, succursale Centre-ville, Montreal, Quebec H3T 1B9, Canada.
[7] Dholakia, N., & Zwick, D.(2003,April). Mobile technologies and boundary less spaces: Slavish lifestyles, seductive meanderings, or creative empowerment? Home Oriented Informatics and Telematics conference (HOIT2003), The Center for Research on Information Technology and Organizations (CRITO), University of California, Irvine, CA. Retrieved February 5, 2011.
[8] Chen, L., Pei, L., Kuusniemi, H. et al. Bayesian Fusion for Indoor Positioning Using Bluetooth Fingerprints. Wireless Pers Commun (2013) 70: 1735. doi:10.1007/s11277-012-0777-1.
[9] Muñoz Organero, M., Muñoz Merino, P. J., Delgado K.C. Using Bluetooth to Implement a Pervasive Indoor Positioning System with Minimal Requirements at the Application Level.
[10] Bruno, R. & Delmastro, F. Design and Analysis of a Bluetooth-based Indoor Localization System. Personal Wireless Communications, Lecture Notes. Computer Science. 2003.
[11] Gu, Y., Lo, A., Niemegeers, I. A Survey of Indoor Positioning Systems for Wireless Personal Networks. IEEE Communications Surveys & Tutorials. Vol. 11, N° 1. Pg.13 – 32. IEEE. 2009.
[12] Andersson, M. Use case possibilities with Bluetooth low energy in IoT applications. White Paper. In www.u-blox.com.
[13] Lamarca, A., Chawathe, Y., Consolvo, S. Hightower, J. Smith, I. Scott, J. Sohn, T. Howard, J., Hughes, J. Potter, F., Tabert, J.,
[14] Ni, L. M., Liu, Y. Lau, Y.C. Patil, A. P. Landmark: Indoor Location Sensing Using Active RFID. Wireless Networks. Vol 10. Issue 6. Pg. 701-710. Kluwer Academic Publishers, 2004.
[15] Supeala, D. Testing in the park: real-time simulation of our Smart Public Transport project. http://www.onyxbeacon.com/blog.
[16] Lynch, K. A imagem da cidade. São Paulo: Martins Fontes, 2006.
[17] Consiglieri, V. A morfologia da arquitetura. Vol I. 1920-1970. Lisboa: Estampa, 1999.
[18] Consiglieri, V. A morfologia da arquitetura. Vol II. 1920-1970. Lisboa: Estampa, 1999.
[19] Rômulo D. Novaes, Aline S. Miranda, Victor Z. Dourado. Velocidade usual da marcha em brasileiros de meia idade e idosos. Usual gait speed assessment in middle-aged and elderly Brazilian subjects. Revista Brasileira de Fisioterapia, São Carlos, Brazil. v. 15, n. 2, p. 117-22, march/april. 2011.
[20] Vincent K. Ramsey, Bruce B. Blasch, Akio Kita, Benjamin F. Johnson. A biomechanical evaluation of visually impaired persons' gait and long-cane mechanics. Journal of Rehabilitation Research and Development Vol. 36 No. 4, October 1999.
[21] Jyri Rajamäki, Petri Viinikainen, Julius Tuomisto, Thomas Sederholm and Miika Säämänen. LaureaPOP Indoor Navigation Service for the Visually Impaired in a WLAN Environment. Proceedings of the 6th WSEAS Int. Conf. on Electronics, Hardware, Wireless and Optical Communications, Corfu Island, Greece, February 16-19, 2007.
[22] Rosen Ivanov. Indoor Navigation System for Visually Impaired. International Conference on Computer Systems and Technologies - CompSysTech'10
[23] Dhruv Jain. Path-guided indoor navigation for the visually impaired using minimal building retrofitting. Proceedings of the 16th International ACM SIGACCESS conference on Computers & accessibility

[24] Hargreaves, T., Wilson, C. and Hauxwell-Baldwin, R. Learning to live in a smart home. Building Research & Information. 2017.
[25] Hyunwook Park, Jaewon Noh and Sunghyun Cho. Three-dimensional positioning system using Bluetooth low-energy beacons. International Journal of Distributed Sensor Networks. 2016, Vol. 12(10).
[26] Kai Hansen. Designing responsive environments through User Experience research. International Journal of Architectural Computing. 2016, Vol. 14(4) 372–385.
[27] Francesca Stazi, Federica Naspi and Marco D'Orazio. A literature review on driving factors and contextual events influencing occupants' behaviours in buildings. Building and Environment. Volume 118, June 2017, Pages 40–66.