Urban Acoustic Simulation

Analysis of urban public spaces through auditory senses

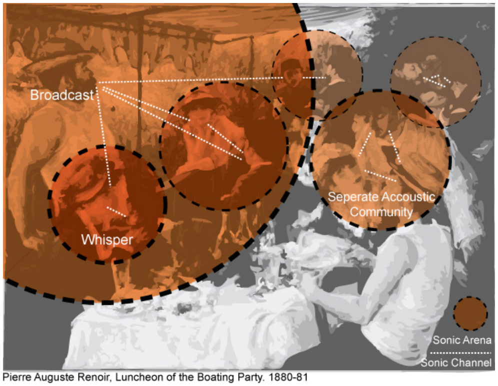
Merate Barakat
Architectural Association School of Architecture, United Kingdom.
http://meratebarakat.com
merate.barakat@aaschool.ac.uk

Abstract. *This paper explores the sonic characteristics of urban spaces, with the application of apprehending acoustic space and form theory. The theory defines auditory spaces as acoustical arenas, which are spaces defined and delineated by sonic events. Historically, cities were built around a soundmark, for example, the resonance of a church bell or propagation of a calling for prayer, or a factory horn. Anyone living beyond the horizon of this soundmark was not considered citizens of that town. Furthermore, the volume of urban sonic arenas depends on natural. Digital simulation is necessary to visualize the ephemeral and temporal nature of sound, within a dynamic immersive environment like urban spaces. This paper digitally analyses the different morphologies of old cities and forms of growth in relation to the sound propagation and ecological effects. An experiment is conducted with the aid of an ancient North-African city model, exposed to a point cloud agent system. By analysing how the sound propagates from the known soundmark through the urban fabric, with the wind pressure interference; the paper compares the theoretical concept of soundmarks and the known perimeter of the ancient city*
Keywords. *Urban Public Spaces; Aural Design; Auditory Arena Simulation; Soundmark.*

INTRODUCTION AND RELEVANCE

It may be argued that sound is essential to define the environment surrounding the human species (Sound: Exploring a Character - Defining Feature of Historic, 2007). Therefore, it does not come as a surprise that humans adapt to their acoustic environments as their early ancestors adapted to nature and the significant differences between aural and olfactory horizons. In architectural and urban context, the term aural design is a reverse adaptation, where the parameters of the physical phenomena of sound are employed to form their built environment. This paper analyses the urban morphology and growth basis its hypothesis on aural space and form theory. The argument is that there is a direct relationship between the acoustical 'signature' of a city and how its inhabitants form their environment (Thompson, 2002).

The study case examined in here shows that, among other delineating and directional factors of a city's growth, significant urban sounds have a similar relationship. It is important to note that this not a discussion of Islamic architecture history. However, cultural parameters, spatial awareness, and soundmarks theories will be concisely examined to draw deductions that help the overall research. Finally, an



Pierre Auguste Renoir, Luncheon of the Boating Party. 1880-81

Figure 1
This is a diagrammatic image super imposes various sonic connections established within a social space, over the Luncheon of the Boating Party, by Pierre Auguste Renoir. (1880-81).

acoustic simulation visualizes the mathematical delineation of the sonic factors that define the urban growth. The ancient town of Damascus is chosen as a study case for developing the simulation model, for its minimal factor variance.

THEORETICAL CONTEXT

Firstly, in order to define an understanding of how acoustic events may affect urban growth morphology, the theoretical context will be defined. Spatial awareness and the parameters that define the shape and size of an acoustical space will be discussed.

Acoustical space and form theory

Auditory Spatial awareness is a neurological conscious and unconscious reaction to spatial acoustics, which has three stages: detection, recognition, and consciousness. When a receiver /Listener detects the physical sound waves transformed into neural signals as a sonic event. Awareness is cognitive process transforms the raw sensation triggering a visceral response in an elevated state of mental and physical awareness. Thus, detection is a raw biological property, while recognition and consciousness are contingent upon environmental exposure. When a sonic event is powerful enough to be heard by a group of listeners, an acoustic arena is formed. Anyone unable to aurally detect this source is considered beyond the boundary of the arena. Thus, an acoustical arena is a volume centred on a sonic event.

A listener can receive information through various auditory channels when multiple sonic events exist within their acoustical horizon. The connection is contingent upon the sonic properties, proximity, and the broadcasted information. These phenomena exist at many scales, from intimate, personal, conversational, to urban scales. An arena's volume depends on the reverberation and frequency of the sound and the acoustical properties of the physical space. The volume of the acoustical space is contingent upon interference factors, the presence and strength of other acoustical arenas or wind interference (Blesser, et al., 2006) (Figure 1).

Urban sonic arenas

Urban arenas have significantly large diameters. Not only is the volume contingent upon the sonic property of the source, but also depends on natural and technological parameters. Geological formations can act as sound barriers or sound conduits. For example, steep terrain would cast large sound shadows, while valleys propagate a target sound across large distances. Vegetation is another auditory demarcation parameter. Grass reduces the sonic reflectivity of the ground and trees absorb airborne sound waves, casting large sound shadows. Thick vegetation at the outskirts of a town stops the propagation of any sonic event; essentially, delineating the urban auditory arena and aligning it with the visual boundary. Conversely, bodies of water act as sound reflectors increasing the size of the urban arena. While, high windshield factors and turbulence along coast lines cause high interference, shrinking the urban auditory arena (Blesser, et al., 2006).

Soundmarks

Soundmarks, like town clock, church bell, or prayer calls, occur in central locations of cities. People living beyond the acoustical arena of this soundmark were not considered citizens of that town. Individuals subjected to the same set of sonic events recognize these sounds and how they link the community's activities guided by distinct ideas infused in the built environment, regardless of their gender, age group,

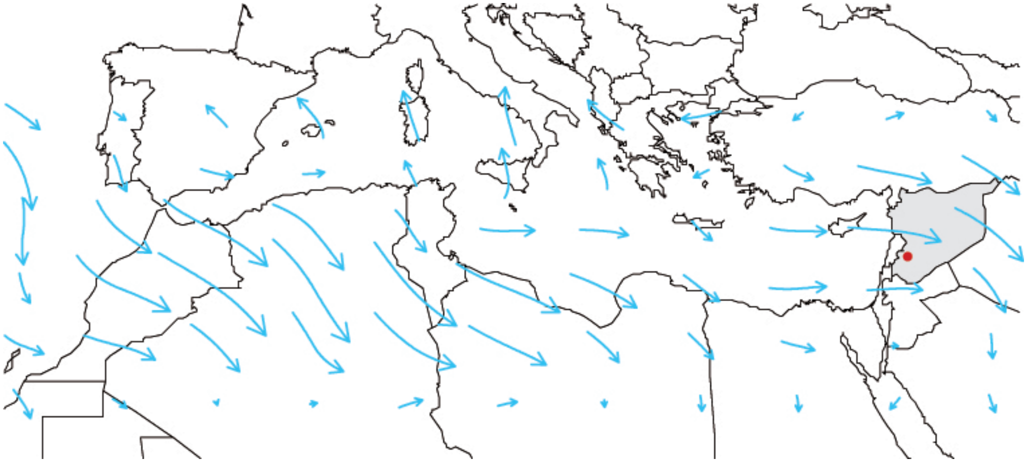


Figure 2
Mediterranean wind patterns diagram (Sound absorbing properties of different density local acoustic materials, 2010).

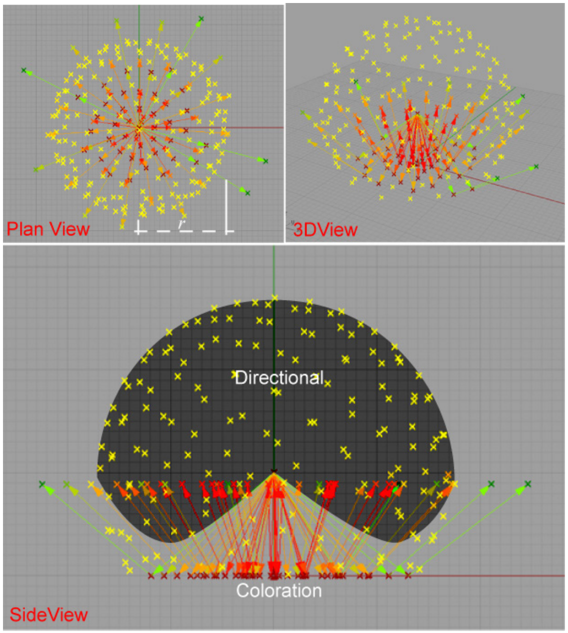
racial background, or socio-economic status (LaBelle, 2010). The earliest time pieces in Europe, 14th century, were invented to inform monks that mostly relied on the hour glass for morning prayers. Most of these early clocks became community centrepieces that were developed to sound bells at appropriate prayer hours (The Middle English word clok from the Dutch and German words for bell) (Levine, 2006). Similarly, prayer calls in the old Islamic cities were time telling sonic events that pre-existed any time piece. A side from its link with one of the five pillars of Islam, this sonic event had social and political significances (Bianca, 2000).

All humans experience a phenomenon that defines a specific sonic event as a soundmark, namely, 'Programmable music'. This is similar to Synesthesia (Synesthesia is neural connection anomaly between the visual cortex and other cortices; where they do not fully disengage), the perception through one sense can stimulus another (Turrell, 2002). For example, a sound can trigger an associated thought that the brain tries to create, by comparing visual patterns with aural ones (Campen, 2007). Humans that have lived within an urban setting can identify certain rhythms and frequencies with transportation, or high-pitched sounds with alarms and sirens. In these cases, the sonic event indicates time and social event.

North-African parameters

Ancient North-African cities have the clarity of a scientific experiment due to the minimal variables. Visibility is constant across the region due to its location on the flat valleys created by the drag of the tectonic plates. The terrain is either fertile or desert, surrounded with a large desert defining clear borders around the habituated areas (Gunz, 2011). Wind pattern remain fairly constant throughout the North-African and Mediterranean region. Western and North-western winds predominate most of the seasons at variable speeds; average from 10 Km/h in the summer to 30 km/h during winter (2007) (Figure 2).

Traditional Islamic cities did not have formally institutionalized planning resulting in amorphic patterns if growth emerging around built archetypes. Friday Mosques, embedded in a frame work of central markets fulfilled the institutional functions. Thus, there is no specific morphological growth pattern to Islamic cities, developing according to site constraints, community size, economic resources, and building materials. This research will compare the resulting edge with the acoustical arena centred on the soundmark. The study case is the North-African city, Damascus (Bianca, 2000).



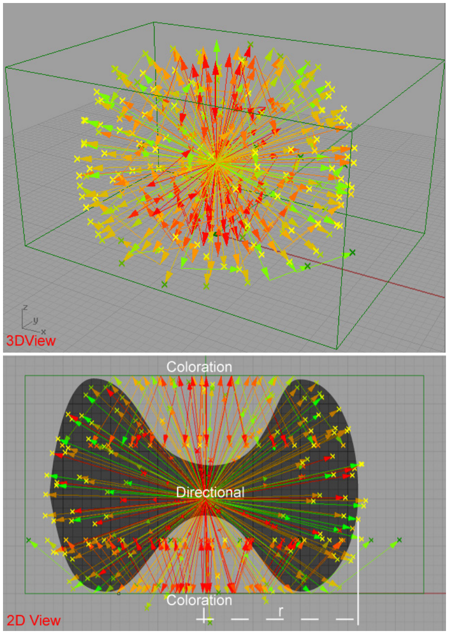


Figure 3 (left)
One sonic event located above a fully reflected surface.

Figure 3 (right)
In a bounding box with fully reflected interior surfaces. The side views show how the acoustical coloration changes the form of the arena.

Damascus retains the inner morphological affinities of earliest Arab cities. When appropriated, Damascus was planned per Roman traditional town planning; strict grid layout with main axial roads. With the Islamic adaptation, the grid no longer became the factor governing the morphology of public spaces or residential districts. The main roads started to secede into smaller pedestrian parallel paths around small market structures. Privacy was the driving factor creating a broken flow through successive hierarchal streets, usually ending in a courtyard (Islam qualifies the private sphere of the family as "harm" which means sacred, both inviolable and ritually forbidden to strangers) leading to inward-oriented autonomous units form around court yards (Bianca, 2000).

All traditional communities centred on religious beliefs materialise their environment to reflect the individual perception of the universal truth. It is important for the residents to hear the prayer call from within private residential districts. This research argues that the Friday Mosque minaret's location and built typology makes the muezzin's voice a defining factor the city's boundary.

COMPUTATIONAL MODEL

The mathematical logic employed to develop this model examines sound as wave disturbance in a medium. Damascus is located at sea level; where the atmospheric pressure is constant and the speed of sound is 340.29 m/s. The prayer call broadcasted from the mosques resembles a hypothetical scenario, where the sonic event occurs in an unbound homogeneous media with no physical obstacles. Directional sonic waves radiating uniformly from a point source are the only detected sound. The sonic event energy has power P, with a corresponding spherical acoustical arena of radius r. The periphery of the sphere, i.e. delineation, is where the power divided by the spherical surface area, P/(4πr2), equals to the least sound level aurally perceived.

Indirection sound waves occur when the waves reflect off a surface. (Figure 3-left). There are two factors (with corresponding formulas) in play, namely, the absorption and reflection of the sound when it comes in contact with a surface. Acoustical coloration occurs when sound waves are reflected off a surface. If a sonic event occurs near a more articulated surface, the acoustical coloration would be complex. In the case of Damascus, reflectivity of the landscape and vernacular rammed earth building materials' absorption coefficient is approximately 0.5 (Sound absorbing properties of different density local acoustic materials, 2010). The density of the urban fabric creates tight spaces resulting in sharp reflections that intensify coloration and amplify the sonic connection (Blesser, et al., 2006)(Figure 3-right).

If two sonic events of similar powers (P_1=P_2) occur in space (at points C_1 and C_2, respectively), their attenuation periphery will be of equal radii ($r_1 = r_2$). The sonic arena formed around each one is defined as follows. The arena associated with the event at C_1 (C_2) is delimited by the surface S_{12} that lies on the plane bisecting the line connecting C_1 and C_2, in addition to the dissipation periphery S_1 (S_2). When one sonic event increases in power P_1 the arena grows in volume, encroaching into the less powered P_2 sonic event's arena ($P_1 > P_2$). In this case, the radius of the attenuation peripheries will be unequal ($r_1 > r_2$) such that $(r_1/ r_2)2 = P_1/ P_2$. The boundary between the two arenas S_{12} will be defined by the surface $(\rho_1/\rho_2)2 = P_1/ P_2$. It could be shown that the separating surface S_{12} lies within the lens-like volume that is common to the two spheres (Figure 4).

Basic Particle Swarm Optimization (PSO) algorithms integrating these vectors simulate sound wave propagation here in. Each particle migrates from the its initial position (sonic event) through three-dimensional search space, adjusted by adding forces as vectors with different magnitudes and directions; such as sound wave propagational direction, gravity, and wind trajectory. The velocity vectors drive the optimization process that replicates the cognitive component (The cognitive component resembles individual memory of the position that was best for the particle (Engelbrecht, 2005)) of each particle and socially exchanged (The social component resembles the group norm or standard which individual particles seek to attain (Engelbrecht, 2005)) information from the particle's neighbourhood (Engelbrecht, 2005). The acoustical arena delineation is the culmination effect of all the position update of the particles until the magnitude of the acting vectors equals to zero.

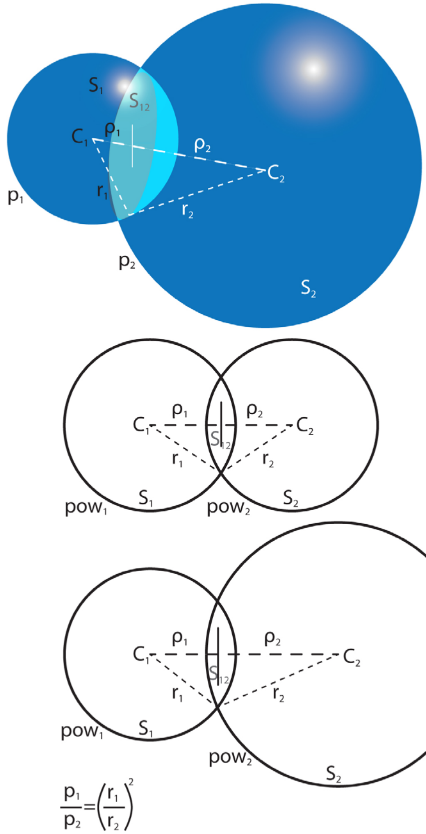


Figure 4
Sonic Event Equations: More than one arena can determine the form and size of the neighboring arenas.

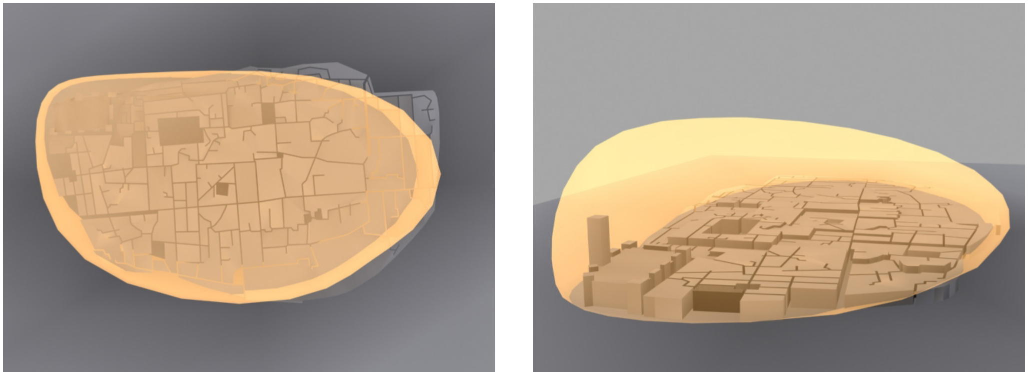


Figure 5
Visualization of a prayer-call (Soundmark) acoustic arena (Left: plan) (Right: View due East).

CONCLUSION

This acoustic simulation visualizes the delineation of acoustic arenas centred on soundmark. Directional Northwest winds create pressure differences deforming the acoustical space centred on highest point of the minaret. The observed acoustic arena's volume approximately aligns with the city's parameter. Using ecological and sonic data sets, the mathematical computation model prove to have a relation with the growth morphology of Damascus (Figure 5). Computational tools allow for mathematical and visual evaluation of auditory arenas. In exploring the sonic characteristics of urban spaces through acoustical space and form theory, we can analyse the different morphological growth of cities. Further experimentation for other types of cities that may have emerged from church bells and post-industrial fog horns can further validate this hypothesis. Comparing modern city morphologies with technological data sets help us understand how this phenomenon is linked with urban tissue morphology.

BIBLIOGRAPHY

Bianca, S 2000, *Urban form in the Arab world, past and present*, Thames & Hudson Ltd, 2000.

Blesser, B and Salter, L-r 2006, *Spaces speak, are you listening?* The MIT Press, 2006.

Campen, C van 2007, *The Hidden Sense: Synesthesia in Art and Science*, The MIT Press, 2007.

Engelbrecht, AP 2005, *Fundementals of Computational Swarm Intelligence*, John Wiley & Sons, Ltd, 2005.

Gunz, M 2011, *The Nile Valley: the Urbanization of Limited Resources*, San Rocco - The Even Covering of The Feild, 3.

LaBelle, B 2010, *Acoustic Territories: Sound Culture and Everyday Life*, Continuum, 2010.

Levine, R 2006, *Geography of Time*, ONEWORLD PUBLICATION, 2006.

Bethesda, M 2007, *Sailing Directions (Planning Guide): North Atlantic Ocean Baltic Sea, North Sea and The Mediterranean Sea*: National Geospatial - Intelligence Agency.

Asuquo, UEO, Obisung E and Faithpraise, FO 2010, 'Sound absorbing properties of different density local acoustic materials', *International Research Journals*, March 2010, Vol. 1(2), pp. 039-041.

Gaunderlach, J 2007, 'Sound: Exploring a Character - Defining Feature of Historic', 4, *APT Bulletin*, 2007, Vol. 38.

Thompson, E 2002, *The Soundscape of Modernity*, The MIT Press, 2002.

Turrell, J 2002, 'Spirituality', *ART:21*. 01 23, 2002.