Exploring the use of sound in hydrography and marine navigation

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Abstract

The sounding is the basic unit of bathymetric data. Historically, sounding has referred to the ancient practice of determining water-depth by feeding out a weighted line. In the last century the term has taken on a fuller meaning with the introduction of SONAR as a primary hydrographic data-gathering technology.

Although the use of sound has come to play a principal role in hydrographic data gathering, our interaction with the marine environment continues to be predominantly mediated visually (radar, charts, computer monitors).

Researchers from a range of disciplines have investigated methods for using sound to provide navigational cues and as a medium for analyzing complex data sets and representing complex spatial relations. Much of this research suggests that sound can enhance navigational tasks and significantly expand the cartographer's representational repertoire.

This paper will investigate the feasibility of adapting these studies to hydrography and marine navigation. It will consider the use of sound, hearing and audio technologies to represent and signal navigational variables. This paper queries whether such technology might be integrated with existing visually mediated information to augment navigational effectiveness and safety while enhancing understanding of the ocean environment.

Introduction

The sea
isn't a place
but a fact, and
a mystery
under its green and black
cobble coat that never
stops moving. *(Mary Oliver, The Waves)*

As Mary Oliver observes in this poetic piece, the sea never stops moving. For those of us who monitor the tides every day this should be obvious. The ocean is a complex space of circulating tides, currents, people, ideas, commodities, ships that move across its surface and fish that swim in its waters. The ocean is a space that is constituted by and constitutive of movement (Steinberg, 2013 p165).

Modes of representing ocean space are equally dynamic. Whereas the printed paper chart once conveyed at a glance a sense of authoritative and comprehensive understanding, it has now moved away from its role as the central frame through which humans, technology and the sea interact. Meanwhile, increasingly automated navigational tools present challenges for mariners who must rely on them to insure the safety of their vessels, their crews, their cargoes and the ecologies through which they travel. Similarly, as we experience profound environmental change, electronic and virtual representations of oceanic realities present new challenges to our understanding of the ocean environment.

A review of recent work in the fields of Auditory Display and Sonification (which concern themselves with technologies and methodologies for representing data with sound) can be considered together with studies in marine governance, cartographic design, data management, cognitive science, ecology and economics to reveal compelling connections between the nature of sound and hearing and the environmental, economic and technological realities of constant change.

Sound

The human faculties for listening and hearing have likely been called upon to inform marine decision-making since humans first took to the sea in boats. The Bajau Laut or 'sea nomads' of the archipelagos of South East Asia are able to recall all the permutations of offshore navigation through singing traditional sailing songs to the rhythm of their oars (Mack, 2013 p113). "Echo sailors" of the early 1900's relied almost entirely on hearing to navigate the foggy passage from Puget Sound to Alaska, determining their distance from shore by listening to the echo of their fog whistles off land features (Anonymous, 1927).

Yet the complexity, power, and flexibility of the human listening system, which operates relatively effortlessly even while sleeping is an under-developed resource as an interface for data transmission and analysis. Even under noisy conditions, humans are able to distinguish different sound sources, spoken words, and melodies. Our capacity for auditory pattern recognition in such circumstances surpasses that of our most finely tuned computers (Hermann et al, 2011 p23).

A fundamental distinction between vision and sound is expressed in the title of a paper written in 1969 by the cultural historian, Walter Ong. In 'World as View and World as Event", Ong observes that images are object- based, while sounds are event-based. Vision reveals surfaces while sound, as typically conceptualized, reveals the occurrence of events. Something must happen for sound to exist. A coastline marks space, while the beat of a drum marks time. An image establishes existence, while a sound indicates change. Understanding this difference could be crucial in an era of changing water levels, melting ice, contested offshore economic zones, and integrated marine governance models.

Western culture has come to associate different values with sound and hearing compared to

image and vision. In general terms visuality is fixed, detached, and quantifying while aurality tends to be fluid, participatory, and qualifying. In 2000, the geographer, Daniel Sui summarized these differences in the following table.

Ear/Sound	**Eye/Sight**
Aural	Visual
Multidirectional	Unidirectional
Impermanence	Permanence
Fluid	Fixed
Subjective	Objective
Qualifying	Quantifying
Both/and	Either/or
Concrete	Abstract
Time	Space
Present	Transcendent
Rhythmic	Timeless
Participatory	Detached
Communal	Individual

[Table 1.] Embedded Values in the Ear/Sound vs Eye/Sight (in Sui 2000:335)

While these associations are largely conceptual, they stem from concrete physical and physiological properties of sound and hearing, image and vision. This table will be referenced repeatedly as we examine how sound maps to the concerns of hydrography and navigation.

Sui observed that geography has witnessed a shift in modality and that auditory media are increasingly called upon to inform our spatial understanding. Referencing the ground-breaking work of Marshall McLuhan and Walter Ong, Sui says that communication as the central operator of human civilization has undergone two historic shifts. The first was marked by the move from the oral traditions of nomadic societies, which are auditory, to the more visual written and print cultures of the alphabet and printing press. For hydrographers, it's worth noting that the shift from auditory to visual ways of knowing was attended by revolutions in navigational technology, geographic knowledge and chart making.

A second paradigmatic shift began with the inventions of the telegraph and telephone and indeed, the echo sounder. For a little over a century human societies have been moving from print culture into our present electronic age. This is a shift to another, new and different aurality. As electronic media assume centrality in human communication, the auditory sense of hearing has regained prominence. The processes of navigational technology, geographic knowledge and chart making which heralded the earlier shift in modality are again positioned to play a leading role in our present cultural transition.

Environment

The central hydrographic accomplishment of the last 500 years was the delineation of the world's coastlines. In our present age however, we are challenged to chart a world where sea levels are predicted to rise at an unprecedented rate and coastlines will be marked by nothing so much as impermanence. In *Coastlines: How Mapmakers Frame the World and Chart Environmental Change*, Mark Monmonier notes that the anticipated flooding of coastal areas around the globe will necessitate creative economic, residential, and environmental responses. It will also demand a rethinking of cartography and the very definitions of terrestrial and marine environments. For stakeholders in Arctic development, the challenge is further complicated by ice, which is neither land nor sea (Gerhardt et al, 2010). The embedded values of aurality; multi-directionality, impermanence, fluidity, concreteness, presence, rhythm, participation and community; are all engaged by environmental query of the hydrographic process and hold promise for addressing the challenges of environmental change.

Navigation

In recent studies of bridge automation and marine accidents, it has been noted that integrated bridge systems and other navigational technologies can sometimes be the very cause of marine accidents as mariners struggle to integrate and understand these complex technologies. An aspect of this confusion has been the abstraction of data representation and the inability of bridge personnel to distinguish real-world data from its representations, particularly when data from several data sets are presented simultaneously. Among many recommended solutions to this problem we find that,

'… such representations should include three things. Firstly, they should be event-based, highlighting changes and events. Secondly, they should be future- oriented, to support the operators in knowing what to do and when, and thirdly, they should be pattern-based, to allow operators to quickly pick up abnormalities without difficult cognitive work (Lutzhoft, 2004).'

Referring yet again to Sui's table of embedded values, we can observe the values of concreteness versus abstraction, events rather than surfaces, and pattern-based rhythms versus timelessness are all implicit in Lutzhoft's proposed solution.

Event-based information management also appeals to the embedded values of sound - to events rather than surfaces - in the broader field of marine governance. In a recent issue of *The Journal of Ocean Technology*, an event-centric model of governance is proposed for complex marine settings. Jim Wyse writes,

'This has consequences for scientists, mariners and policy-makers alike. First, it provides a model that may inform researchers as to how to conceive of the data they collect, and how it may be integrated with other data. Second, it suggests how that integration ought to feature with regard to other databases, and be applied in policy-making. Third, it offers a theoretical model of how to conceive of nature and data – the event (Wyse, 2013 p74).'

As has been repeatedly noted, such events lend themselves to representation by sound.

Economy

In our generation, economic discussion has increasingly engaged ecological discussion. In the last few years the most often repeated word in these discussions has changed from 'green' to 'blue'. As we witness unprecedented climate change, shifting coastlines, and melting ice we also recognize the global interconnectedness of the world ocean, nations, peoples and economies. In Canada and globally, economists and policy makers are taking stock of the enormous potential of ocean related industry including fisheries, tourism, transportation and energy production. Oceanographer, Serge Demers has said, "In many ways, aerospace was to the twentieth century what oceanography will be for the twenty-first century" (Demers, 2013). Elisabeth Mann Borgese, founder of the International Ocean Institute stated, "If before you saw the sea and the sea floor as a continuation of the land, you now see the land as a continuation of the sea (Borgese, 1998)."

The concept of blue economy acknowledges that we live on one planet, up to 75% of which is ocean and the planet must be seen as an integrated whole, implying 'full interaction of humans living with the ocean and from the ocean in a sustainable relationship' (Behnam, 2012). The blue economy recognizes the ocean as the connecting space and resource base of the global economic system, and also recognizes that healthy economies begin with healthy oceans. Co-operation of national stakeholders, government, industry, and academia is integral to the sustainability of the blue economic model. Thus the blue economy, like sound and hearing, is multidirectional, impermanent, fluid, concrete, present, rhythmic, participatory and communal.

Design

The development of sound applications for hydrography and marine navigation cannot be realized without overcoming significant hurtles. Speaking to the advancement of Auditory Display and Sonification in general, the authors of the Sonification Handbook write,

'… the field faces the challenge of developing and using a common language in order to integrate many divergent "disciplinary" ways of talking, thinking and tackling problems. On the other hand this obstacle often offers great potential for discovery because these divergent ways of thinking and talking can trigger creative potential and new ideas (Hermann et al, 2011 p22).'

The Sonification Handbook offers the following figure to demonstrate the interdisciplinary nature of the design problem.

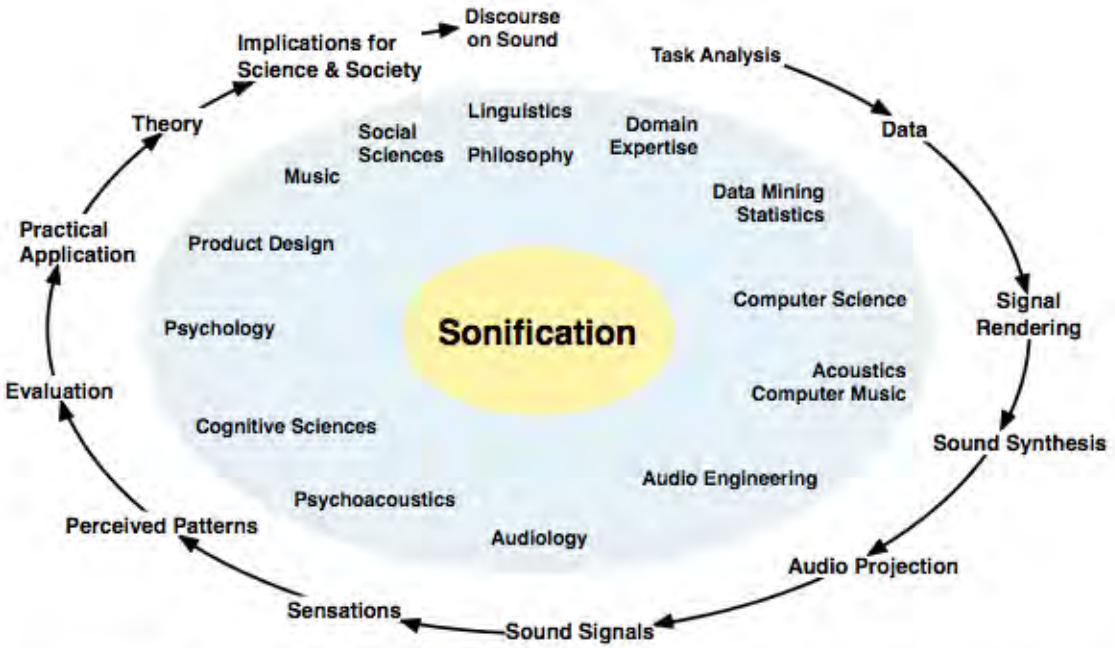

Figure 1.1: The interdisciplinary circle of sonification and auditory display: the outer perimeter depicts the transformations of information during the use cycle, the inner circle lists associated scientific disciplines. This diagram is surely incomplete and merely illustrates the enormous interdisciplinarity of the field.

To this we can add the many concerns and disciplines of hydrography and marine navigation.

The potential for triggering creativity and new ideas through this interdisciplinary pursuit is further frustrated by the persistence of a view which opposes the 'scientific' and the 'artistic' foundations of cartography, hydrography, and navigation. J. B. Krygier in *Cartography as an art and a science* concludes that no such duality exists. He suggests, '… we consider the function of art and science – however defined – to be similar, discarding the problematic reliance on the art/science dualism.' He then notes that ' … hypermedia, cognitive psychology, semiotics, GIS, and visualization all point to a process oriented means of understanding cartography,' and that 'such a process is culturally, historically, socially, and politically contingent and ever evolving, producing new questions, ideas, and issues which continually confront us. (Krygier, 1995 p 9)'

Hydrography, cartography and navigation are an integrated group of disciplines that facilitate human spatial understanding and spatial decision-making. Collectively they can and should be seen as a cultural process that is dynamic and is driven by change. The drivers of change are politics, economics, the environment and technology.

In about 1790, William Blake wrote, 'what is now proved was once only imagined.' About 50 years later, Victor Hugo wrote, 'All the forces of the world are not so powerful as an idea whose time has come.' Everything begins as an idea. This applies whether trying to find a sea route to Asia by sailing west, trying to project the coastlines of the entire world onto the Ptolemaic grid, whether initiating a Google search or sailing a vessel through the Northwest Passage, whether constructing a tidal model of the Arctic Ocean or just trying to make your way home.

And it applies to the hydrographer who listens to learn the way her discipline might serve the changing environmental, technological, political and economic realities of her world.

Conclusion / Hydrographic Service

This paper presents a general overview of writings on diverse topics which may inform the application of sound and sound technologies to the concerns of hydrography and marine navigation in the 21st century. In conclusion, I present three questions which may give focus to further consideration;

1. Can this be done?
   Developments in understanding of both sound cognition and sound technology have progressed at an unprecedented rate in the past century and even in the last few years.

2. Should this be done?
   Meanwhile environmental, political, and economic realities have changed in ways that ask for a response from those who collect and process and represent geographic information in the interests of the public.

3. Who should do this?
   Theorizing, developing and actualizing the technologies and methodologies of sound mediated hydrography will require input from many disciplines and many agencies. The Government of Canada and The Canadian Hydrographic Service may be well placed to lead the foundational work required for this project which holds the promise of increased understanding of Canada's waterways, increased development potential for the Canadian Arctic, enhanced marine safety, and economic development of Canada's ocean related industries. Further, and finally, the development of sound for hydrographic purposes by the Canadian government would align well with Canada's long history of excellence in the delivery of new ideas and technologies in geographic information and communication.

References

Anonymous, 1927, "Echo sailing in dangerous waters," *Popular Mechanics Magazine* 47: 794 -797.

Behnam, Awni, 2012, "Demystifying the Blue Economy," *2nd APEC Blue Economy Forum, December 6-7 2012, Tianjin, China*

Borgese, Elisabeth M. 1998, *The Oceanic Circle: Governing the Seas as a Global Resource,* United Nations University Press.

Currier, Katherine E., 2011, *Auditory Representation in Spatial Applications.* Unpublished master's thesis, University of California, Santa Barbara, USA.

Demers, Serge. 2013, "Ocean Smart: a question of technologies and data management," *The Journal of Ocean Technology* 8:3 v.

Gerhardt, Hannes and Steinberg, Philip E. and Tasch, Jeremy and Fabio, Sandra and Shields, Rob 2010, "Contested Sovereignty in a Changing Arctic," *Annals of the Association of American Geographers,* 100:4, 992-1002.

Hermann, Thomas and Hunt, Andy and Neuhoff, John G. (Eds.) 2011, *The Sonification Handbook.* Logos Verlag, Berlin, Germany.

Krygier, J. B. 1995, "Cartography as an art and science?," *The Cartographic Journal* 32: 3-10

Lutzhoft, Margareta 2004, *The technology is great when it works: Marine Technology and Human Integration on the Ship's Bridge,* Linkoping Studies in Science and Technology #907, University of Linkoping, Sweden.

Mack, John 2013, *The Sea: A Cultural History.* Chicago: The University of Chicago Press.Oliver, Mary 1986, "The waves," in Mary Oliver, *Dream Work,* Boston: Atlantic Monthly Press, pp.66-67.

Monmonier, Mark 2008, *Coastlines: How Mapmakers Frame the World and Chart Environmental Change.* Chicago, University of Chicago Press.

Ong, Walter J. 1969, "World as View and World as Event," *American Anthropologist* 71: 634-647.

Steinberg, Philip E. 2013, "Of other seas: metaphors and materialities in maritime regions," *Atlantic Studies* 10: 156-169.

Steinberg, Philip E. 2001, *The Social Construction of the Ocean.* Cambridge: Cambridge University Press.

Sui, D. Z. 2000, "Visuality, Aurality, and Shifting Metaphors of Geographical Thought in the Late Twentieth Century," *Annals of the Association of American Geographers* 90: 322-343.

Wyse, James E. 2013, "Event-centric information management for marine district governance," *The Journal of Ocean Technology* 8:3 74-85.

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