COMMUNITY ACTIVITY: WORKSHOP REPORT

Synthesizing population, health, and place

Summary: This report on the Vespucci Institute on health geography in 2013 emphasizes the importance of research that connects population, health, and place from a holistic perspective. We review important trends related to Health GIS and highlight directions for future research in this area that were identified at the Institute.

1 Vespucci Institutes

Vespucci Institutes (http://www.vespucci.org) aim to advance Geographic Information in Science. Celebrating the fifth centenary of Vespucci's discoveries [1], the Vespucci Initiative recaptures his spirit of multi-disciplinary intellectual inquiry to explore new frontiers of knowledge and new territories. To that end it organizes and conducts a range of research and teaching activities, bringing together senior scientists and promising young researchers from around the world. This unique interdisciplinary mix creates what has been called the *Medici Effect* [2] and perhaps it is no coincidence that most Vespucci Institutes have been held in Florence, Italy since 2003. The topics covered in the past range from location-based services, spatial data infrastructures, geo-sensor web, and virtual globes to cognitive and linguistic aspects of geographic space [4], environmental modeling, volunteered geographic information, spatial simulation, and spatial ontology. Vespucci Institute participants share a special interest in the locational aspects of societal challenges. These aspects are being studied and exploited in the field of Geographic Information Science and are being implemented within the GIS, GPS, location-based services (LBS) and related industries (see http://www.giscience.org, http://www.agile-online.org, http://www.ucgis.org).

The Institutes and other events sponsored by the Vespucci Initiative are open to postgraduate researchers and graduate students at all stages of their careers in the academic, public, not-for-profit, and private sectors. Attendees get selected on a competitive basis through an open call for expression of interest. The unique atmosphere of the Institutes creates an environment where, in contrast to most conferences and other meetings, participants are especially encouraged to be creative and challenge the status quo in the respected area. This is supported through facilitators, slow food for thought, and a flexible time schedule.

After ten successful years of Vespucci Institutes in Florence, Italy[1], the Eleventh Institute in 2013 involved a week on Population, Health, and Place that was held on Catalina Island, located 20 miles off the coast of Southern California. The week consisted of keynote addresses by invited speakers from academia, science organizations, and the private sector, short presentations from participants, and ample discussion time in a stimulating environment.

2   Trends in Health GIS

Health research has taken a major spatial turn lately [5]. Progress in the areas of GIScience, spatial analysis, and geospatial technologies has led to increased intelligence in investigating the outbreak, transmission, and treatment of diseases on both local and global scales. Furthermore, technologies such as geospatial services and sensor apps provide people with the opportunity to monitor and influence their daily behavior with the goal of promoting a healthy lifestyle.

During preparation for the Institute it was observed that traditional notions of space and place offer only a limited view of what is needed in practice and do not prepare people for applications in the real world. To fill this gap, the Institute set out with the goal to draw on real-life experiences in a global setting, contrasting the approaches used by demographers, health, and spatial scientists.

Several important trends related to Health GIS can be identified:

1. the transformation of health data and its availability through new government initiatives (such as those at the U.S. Department of Health and Human Services) that seek to make data widely available and to encourage innovative use of the data— this, of course goes hand in hand with privacy concerns, for which solutions need to be found;
2. the development of new technologies for sensing of the environment related directly to health exposures such as miniaturized, wearable sensors;
3. new initiatives fostering development of cutting edge technologies for exploiting new data sources and analytical approaches for improving human health;
4. the emergence of games for health, that seek to encourage salubrious health behaviors through gaming, social networks, and goal-orientation; and
5. rapid advances in place-based "omics," that are providing geographically-referenced data on the genetic and biological determinants of human disease.

The convergence of these trends may be viewed through the lens of "genetic GIS," which seeks to increase our understanding of human health as the interactions between genetics "omics" writ large); behavior (the mediator of disease-related exposures through the major exposure routes, eating, drinking, breathing, and dermal); and the environments through which individuals pass over their life course (e.g., Schaerstrom's pathogenic paths [6]; daily, weekly, and life-long activity spaces).

The keynote addresses at the Institute reflected these trends in health geography. Geoffrey Jacquez presented a GIScience research agenda for Genetic GIS, centered on topics

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[1]The Vespucci Initiative on Cognitive and Linguistic Aspects of Geographic Space held in Las Navas del Marques in 2010 was the only exception to the rule.

such as case control, biomarkers, and personal energy budgets. Progress in this area will depend on how citizen science can be enabled by the various available sensors. Daniel Janies introduced the Supra Map Project (http://www.supramap.org). The goal of this project is to develop the means to analyze and share diverse types of data (e.g., genomic, evolutionary, geographic) on organisms. Such a platform can, for example, help us to understand outbreaks and spreads of illnesses through sequencing the genomes of the pathogens. New technologies for sensing the environment and health exposures were documented by David Balshaw, Program Director at the National Institute of Environmental Health Sciences. They are most relevant in the context of exposure, a multi-scale problem targeting the analysis of the exposome, the "environmental" correlate to the genome. The vision here is to integrate both exposure biology (through the development of technology and biomarkers) and genetics (by identifying genetic variants) in order to provide deeper knowledge on the relation between genes, environment, and health. It was impressive to see the diversity and power of newly developed devices and sensors that utilize location for temporal exposure data, ranging from personal aerosol sensors for children's asthma to wearable sensors for pesticide exposures. Chantel Sloan demonstrated how geography can be used as a tool for transdisciplinary research to advance our understanding of infectious disease such as human respiratory syncytial virus. A thorough overview of the wide variety of health games on the market was given by Ben Sawyer. Many of these games are based on their own geography and supported by maps, suggesting that players appreciate geographic visualization. So far location, sensors, and data are emergent concepts, but not prevalent, and some games seek to motivate their players to engage in healthy lifestyles. A long-term vision of the role of games in health exploits their utility in promoting durable, salubrious health behaviors in appropriate places and settings. The final keynote address by Myles Cockburn demonstrated how spatial science can support personalized (preventive) medicine and help in identifying at-risk populations using examples from cancer epidemiology and drawing on both the physical environmental and human behavioral perspectives.

3 Directions for future research

During group work and also fueled by ideas from several lightning talks, Vespucci participants explored various new ideas and approaches for understanding human health and disease. This resulted in four strands of potential future research directions.

3.1 Health behavior and landscape

In analyzing health behavior there is an obvious gap that needs to be filled, namely an impact analysis of environmental factors. Currently, the environment is dealt with rather poorly when studying people's health behavior and the various diseases and their causes and outbreaks. Analytical studies that compare individuals with a specific disease with individuals who do not have that disease (case-control studies) are not inherently spatial. Much richer (spatial) datasets could be utilized in the future to create so-called *health landscapes* with several *health layers* to be analyzed with the help of GIS operations and tools. This could lead to a new level of personalized health services, which monitor people's

behavior, perform multi-criteria analyses, and based on the results encourage their users to live healthier lives by suggesting concrete actions and/or options.

3.2   Spatial health marketplace

The future is expected to bring us an unprecedented avalanche of data and services. Most of these data will be gathered and communicated by mobile sensors and platforms, paving the way to personalized health information. How can we make sense of this data cloud? How can we best make use of the data? Which technologies will be needed? These questions must be answered in the context of a *spatial health marketplace*, driven by health informatics among other fields. The creation of such a marketplace brings with it obvious challenges, such as standards for data records, semantic interoperability, and importantly policies and protocols for dealing with data privacy. It is seen as a great opportunity to bring together health people as the domain experts and other groups such as spatial researchers, computer, social, and cognitive scientists. Spatial expertise is urgently needed in this process because everything is fundamentally spatial, and spatiotemporal analysis is different and likely to provide important new insights and discoveries for the health domain.

3.3   Latency and lag estimation

Disease latency estimation has been identified as one of the key problems underpinning space-time modeling in health geography. What is the relationship between space (e.g., locations of causative exposures and health events) and the biological and physical processes that mediate disease latency? How can we quantify space-time patterns without a fundamental understanding of disease latency? Such an understanding is required for us to have some idea of not only *where* to look but *when* to look. Several approaches are possible ranging from data-driven statistical methodologies such as Bayesian modeling to process-based approaches that seek to incorporate mechanics of the underlying processes into the model itself (e.g., compartmental analysis). Challenges include bridging the scales of temporal lags, from genomic, to cellular, to individual, to population; incorporation of genomic and exposure information into the disease latency model; and the derivation of appropriate modeling frameworks for capturing these diverse aspects. Domain expertise is required on the genetic and biological bases of health and disease, causative exposures, and the geographic expression of disease processes at the population level. With process-based latency models in hand, we expect quantitative geographers will be able to construct powerful models for predicting and mapping future population health outcomes, as well as diagnostic tools for identifying the location and timing of exposure events.

3.4   Exposure

Exposure studies provide important insights into how and why people present certain diseases. Of particular relevance is the notion of the "exposome," defined as the totality of an individual's exposure over the life course [3,7]. Different exposures are of relevance to different health outcomes, and studies in life course epidemiology will provide fertile ground for advancing our understanding of exposure geography. Further work to document spatiotemporal footprints of people with regard to both activities and environments is needed so we can free ourselves from excessive reliance on place of residence (as a proxy

for exposure) and build personal maps of exposure over varying time scales. Biological markers of exposure can thereby help to validate human exposure to a hazardous substance. The resulting lifelines and spatiotemporal patterns of people will serve as a basis for investigating various factors responsible for diseases. Challenges for such analyses include data integration from a semantic and statistical point-of-view and dealing with data inaccuracies and uncertainty. To tackle the semantic issues, a group of participants started planning for a community effort to generate shared vocabularies for annotating and discovering exposure data.

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