SPATIAL COMPUTING 2020 VISIONING WORKSHOP

This document is a direct outcome of the CCC visioning workshop, From GPS and Virtual Globes to Spatial Computing-2020, held at the National Academies' Keck Center over Sept. 10th-11th, 2012 and was created in response to the need to assess interdisciplinary developments and research challenges across geography, computer science, cognitive science, environmental science, etc. The workshop sought to promote a unified agenda for spatial computing research and development across U.S. agencies, industries, and universities. The workshop program exhibited diversity across organizations (e.g., industry, academia, and government), disciplines (e.g., geography, computer science, cognitive science, environmental science, etc.), topics (e.g., science, service, system, and cross-cutting), and communities (e.g., ACM SIGSPATIAL, UCGIS, etc.).

The program consisted of opening remarks from the CCC and National Science Foundation during which spatial computing was defined, and community consensus and the challenges of diversity were articulated. There was a panel on disruptive technologies as well as a panel on national priorities chaired by White House Office of Science and Technology Policy (OSTP) Senior Advisor to the Director. The program featured breakout sessions grouped by spatial computing science, system, services, and crosscutting areas. The workshop concluded with a synthesis and reflection during which the success in bringing multiple disparate communities together was acknowledged and missing topics (e.g., national grid reference systems, measurement databases, etc.) were identified.

For more details, see the full report at **www.cra.org/ccc**

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Established in 2006 through a Cooperative Agreement between the National Science Foundation (NSF) and the Computing Research Association (CRA), the CCC serves as a catalyst and enabler for the computing research community. Its goals are to unite the community to contribute to shaping the future of the field; provide leadership for the community, encouraging revolutionary, high-impact research; encourage the alignment of computing research with pressing national priorities and national challenges (many of which cross disciplines); give voice to the community, communicating to a broad audience the many ways in which advances in computing will create a brighter future; and grow new leaders for the computing research community.

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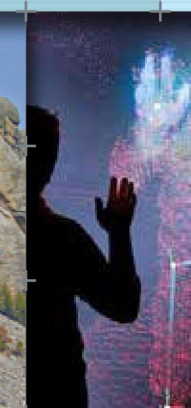
FROM GPS AND VIRTUAL GLOBES TO SPATIAL COMPUTING - 2020



EMERGING TRENDS

Everyone uses location-based services

The proliferation of web-based technologies, cell-phones, consumer GPS-devices, and location-based social media have facilitated the widespread use of location-based services. Internet services such as Google Earth and OpenStreetMap have brought GIS to the masses. With cell-phones and consumer GPS-devices, services such as Enhanced-911 (E-911) and navigation applications are consumed by billions of individuals. Facebook check-in and other location-based social media are also used by over a billion people around the world.

Everyone is a mapmaker and many more phenomena are observable

The fact that users with cell phones and access to the Internet now number in the billions is a new reality of the 21st century. Increasingly, the sources of geo-data are now smart-phone users who may passively or actively contribute geographic information. The immediate effect is wider coverage and an increased number of surveyors for all sorts of spatial data. Every phenomenon is becoming observable in the sense that the set of sensors are getting richer for 3D mapping and broader spectrums at finer resolutions are being captured. This affords the ability to observe more phenomena at higher levels of precision, but presents new challenges based on the increased data volume, variety, and veracity that are exceeding the capacity of current spatial computing technologies.

Every platform is location aware

Traditionally, spatial computing support was limited to application software layers (e.g., ESRI ArcGIS), web services (e.g., Google Maps, MapQuest), and database management (e.g., SQL3/OGIS). In recent years, spatial computing support is emerging at all levels of computer architecture such as HTML 5, social media check-ins, Internet Protocol Version 6 (IPv6), and open location services (OpenLS).

Expectations are rising and so are the risks

In recent years, spatial computing has fulfilled many societal needs. Localization services, navigation aids, and interactive maps have arguably exceeded users' expectations. Their intuitive basis and ease of use have earned these products a solid reputation. Consumers see the potential of spatial computing to reduce greenhouse gas emissions, strengthen cyber-security, improve consumer confidence and otherwise address many other societal problems. However, the very success of spatial computing technologies also raises red flags among users. Geo-privacy concerns must be addressed to avoid spooking citizens, exposing economic entities to liability, and lowering public trust.

PROMISING TECHNOLOGIES

1. Spatial Abilities Predict STEM Success

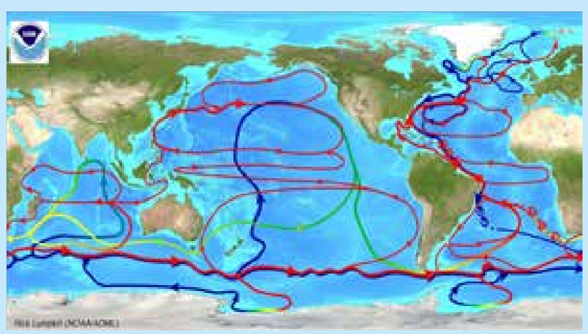
Spatial abilities include navigation, learning spatial layouts as well as mental rotation, transformation, scaling and deformation of objects across space-time, etc. Spatial skills strongly predict who will go into and succeed in science, technology, engineering, and math (STEM) fields. As it stands, the United States is facing challenges in educating and developing enough citizens who can perform jobs that demand skills in STEM domains. Improving spatial training at K-12 levels is likely to increase the number of students who excel in and pursue careers in STEM fields.

2. Emerging Spatial Big Data

Examples include trajectories of cell-phones and GPS devices, mobile check-in's, wide-area motion imagery, and location-based search information. Spatial big data has the potential of providing new understanding and spur innovation. A 2011 McKinsey Global Institute report estimated savings of $600 Billion annually by 2020 via reductions in idling and fuel used via smarter navigation. Location information from cellphones will allow urban informatics, allowing for real-time census information to be gathered for public health, safety and prosperity.

3. Augmented Reality Systems

Augmented reality (e.g., Google Glass) enriches our perception of the real world by overlaying spatially aligned media in real time. More specifically, it alters real-time images of the world by adding computer graphics and overlays to convey past, present or future information about a place. It already is used in a variety of places, such as heads-up displays in airplanes and has become popular with smartphone applications. Augmented reality will play a crucial role in assisted medicine, architecture, engineering, civil/urban planning, and intelligence amplification.



4. Time-Travel and Depth in Virtual Globes

Virtual globes such as Google Earth, Bing Maps, and NASA World Wind are being used to understand our changing planet in an enjoyable and interactive way. Time-travel and depth in virtual globes will provide the ability to visualize historical and future scenarios on a global scale for use cases such as visualizing changing arctic ice-sheets over recent decades as well as climate projects over upcoming centuries under alternative policy scenarios.

5. Spatial Predictive Analytics

Recent progress in spatial statistics and spatial data mining have the potential to improve accuracy and timeliness of prediction about the future path of hurricanes, spread of infectious diseases, and traffic congestion, which have confounded classical prediction methods. Spatial models can be invaluable when making spatio-temporal predictions about a broad area of issues including the location of probable tumor growth in a human body or the spread of cracks in aircraft wings or highway bridges.

6. Persistent Environmental Hazard Monitoring

Environmental influences on the air we breathe, the water we drink, the food we eat, can have significant impact on our health and safety. Spatial computing (e.g., volunteered geographic information, smart-phones and location-aware sensor networks) can greatly enhance spatial and temporal precision and accuracy of exposure data in sensitive environments such as schools, hospitals, fragile eco-systems, and vulnerable public gathering places.

7. Geo-collaborative Systems, Fleets and Crowds

Spatial Computing will take the Internet beyond cyberspace, enabling connections among fixed structures and moving objects such as cars, pedestrians, and bicycles, to help avoid collisions or coordinate movement. An example is the city of Los Angeles, CA, which recently interconnected all of its 4,500 traffic signals to improve traffic flow during rush hour through coordinated signals. Spatial computing enables smart-mobs (groups of people) to come together quickly for common causes yet are controlled by no one person. For example, drivers, smart cars, and infrastructure may cooperate in the future to reduce congestion, speed up evacuation, and enhance safety.

8. Localizing Cyber Entities

Location is fast becoming an essential part of Internet services, with HTML 5 and IPv6 providing native support for locating browsers and GPS-enabled phones locating people on the move. Location authentication in Internet entities may enhance cyber-security by helping verify the identity and location of message sources. For example, geo-targeted warnings for people in predicted tornado paths can help save lives by reducing false warnings. Location information for everything on the Internet has the potential to bring increased prosperity, security and privacy.

9. Moving Localization Indoors and Underground

Despite worldwide availability, GPS signals are largely unavailable indoors, where human beings spend 90% of the time. Location-based services, such as route navigation, are present in 10% of our lives but with emerging technologies such as indoor localization (already in major airports and hospitals), the new reality in the 21st century will see our spatial context being available close to 90% of our lives, leveraging localization indoors and underground (e.g., mines, tunnels) via cell-phone towers, Wi-Fi transmitters, and other indoor infrastructure.

10. Beyond Geo

Spatial computing ideas can transform information management in non-geographic spaces. For example, defect locations on silicon wafers may be modeled as statistical point processes to identify hotspots. Neuro-maps may organize patient data (e.g., MRI, CT) and intra-human body GPS may facilitate navigation along least-invasive route to reach and remove brain tumors. Astro-maps chart the stars and interplanetary GPS may improve space travel, whereas knowledge-maps plot our ideas and thoughts.