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IT 103-001

4/30/12

Recent Developments in Information Technology Applied to Neuroscience

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-Liz Elkind

INTRODUCTION

Information-technology innovations in the last decade have had a tremendous effect on the health care industry, particularly in the field of neuroscience. The developments of digital modeling and data imaging are further advanced by the recent growth of open-source software and cloud computing, leading to long-term ripple effects in the areas of neurological research, diagnostics, and treatment. Research is able to go more precisely in-depth, and diagnosing and treating a patient are done less invasively and with greater accuracy and effectiveness as neuroscience is digitized.

BACKGROUND INFORMATION AND RECENT DEVELOPMENTS

Scientists have been working to more accurately observe brain tissue at the cellular level (neuron imaging and analysis, now the study of connectomics) for over a century. What was originally achieved through the use of chemicals to stain neurons, with inconsistent and inexact results, has been vastly improved with modern technology ("Mapping Brain Circuits," 2009). One current method is to use fiber optics, in which "data travels at the speed of light" (Steinberg, 183) and is communicated as accurately as it is quickly (ibid). Applying this medium to neuroscience, scientists can use light to trigger a chain reaction of neurons, effectively illuminating a direct line of communication within a neuronal circuit ("Mapping Brain Circuits," 2009).

Meanwhile, data are analyzed and used more in-depth and efficiently through modeling. As stated in Introduction to Computer Information Systems, "Model-based [decision support systems] depend upon the manipulation of a model or queries that define assumptions about the problem domain [i.e., specific, relevant data being analyzed] under consideration. Models incorporate data and parameters provided by decision-makers to aid in analyzing a situation" (510).

Theoretical modeling can also be done with other methods such as compartmental modeling – using single electrical circuits to represent neurons, since their behavior is analogous. This is less convenient and more time-consuming than virtual modeling, though ("Computational Neuroscience," 2008).

Three-dimensional modeling – creating spatially accurate digital images representing a scanned object – has, in turn, become an infinitely useful tool. This digitalization of data allows for accurate, minimally invasive study and examination of the brain.

Higher-resolution digital imaging has also enabled significant advances in brain mapping and identifying neural circuitry. By combining these visual techniques with gene-targeting technology and fluorescent, colored proteins, scientists have created brilliant, detailed images known as "brainbows:" color-coded photographs of "structures and connections in the brain" (Frankel, 2008).

Modeling software and the tools to develop and share (and neuron-simulating platforms to further use) it – "to share neuroimaging results and enable meta-analysis of studies of human brain function and structure" (http://brainmap.org/, 2003-2011) – have become widely available online by using Java (to operate programs across different operating systems) and XML (to share data across different systems) languages and a mix of tools to store, analyze, and organize data (http://www.brainmap.org/, 2003-2011; Howell; UCL, 2012; Perlewitz).

These are just a few instances of open-source software being used in the field of neuroscience to make neuron modeling and data analysis available to a wider range of scientists (and students).

This is also part of a larger movement toward sharing software, services, and information, also known as infrastructure convergence – in effect, cloud computing, enabled by increasingly high-bandwidth (i.e., faster and more powerful) Internet connections.

Cloud computing includes Software as a Service (SaaS), Infrastructure as a Service (IaaS), and Platform as a Service (PaaS). The service being provided is utility computing, through which users can bypass traditional hardware. “Open-source software is critical to the growth of both software-as-a-service and cloud computing, and cloud-based computing in turn is making it easier for open source vendors to lower costs” (Brodkin, 2008).

This self-perpetuating convergence of infrastructure means a greater capacity to immediately share, access, analyze, store, and manage greater amounts of data from different locations. It is “easier and more affordable to share research data, tools, and computing power….falling prices make it more affordable to link scientific communities with…high-performance computing and to connect distributed databases and other resources…that can be accessed in real-time through a simple and user-friendly interface” (Ellisman, 2007).

POTENTIAL BENEFITS

The benefits of digitizing neuroscience include an increased quality of patient care, as doctors are better able to diagnose and treat all manner of disorders, illness, and trauma in patients’ brains with greater effectiveness and less risk.

Neuroscientists are able to conduct research and development more cost-effectively and in-depth. As an example, there is the potential to learn more about genetic disorders, such as Tay-Sachs disease, addiction, bipolarism, and Huntington’s disease, and verify the extent to which genetics and brain development play a role. If specific genes that cause, or give a predisposition to, various disorders and diseases can be identified and isolated, that could lead to previously unknown treatments, even cures (NIH, 2011; NIH, 2012).

There is a sociopolitical impact, as well: as our knowledge of the brain increases, we have a more nuanced and accurate understanding of the ways in which behavior correlates with brain development and health. This, in turn, could positively – assuming that more information results in positive change – influence social policy and mores, even our educational and justice systems (Finneran, 2012; Dawson, Ashman, & Carver, 2000).

Additionally, "leading [information systems (IS)] researchers are convinced that the neurobiological measurement, such as fMRI, EEG, and PET, has the potentials to shed light on innovative IS theories and next generation information systems (Dimoka et al., 2011; Riedl et al., 2010; Loos et al., 2010)" ("WITS 2011"). In other words, as computers and information systems and technology influence neuroscience, neuroscience may, in turn, improve understanding of computers and information systems and technology.

LEGAL, ETHICAL, SECURITY-RELATED, AND SOCIOPOLITICAL CONCERNS

A number of ethical issues could arise within these new developments applied to neuroscience.

At the current stage of brain mapping tools, experiments are mainly being conducted on non-human mammals – a potential animal rights issue ("Mapping Brain Circuits," 2009). An issue with a wider range and impact might be regarding military-funded neuroscientific research and developments. The technology the government could have at its disposal includes an effective lie detector test through functional magnetic resonance imaging, or fMRI, and the ability to target and influence a person's hormones.

"‘People have begun to speculate on these issues, but right now it's really unclear,’ says [Professor Hank Greely, Director of Stanford's Center for Law and the Biosciences]. ‘Alternatively, some have argued that we'll need something new—that the existing Bill of Rights doesn't protect mental privacy adequately enough in the face of these emerging technologies.’” (Ghorayshi, 2012)

Privacy – of data as well as identity – is also a concern with regard to cloud computing. There is less of a guarantee of privacy by nature of using a cloud, and in one example, “system administrators are custodians of a huge quantity of [aggregated] data” (Ryan, 2011).

Brain mapping could lead to an incredible wealth of new information – which could have an incredible impact on society, though not necessarily in a positive way.

There already has, for some time, been an ongoing debate as to what, or who, has the most influence over our thoughts, actions, and behavior (Schwartz, 2012). As mentioned in the previous section, a definitive conclusion would almost certainly bring drastic, unforseeable sociopolitical change.

CONCLUSION

Knowledge of the human brain has vastly increased with the development of computers and information technology. Scientists are making inroads toward brain mapping, and research capabilities are expanding with the practice of cloud computing. Health and science, as industries and fields of research, are rapidly developing, occasionally intersecting, and influencing one another. As scientists continue finding new ways of analyzing neural function, there will continue to be an untold impact on health and, quite possibly, on policy, communication, and our understanding of ourselves.

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