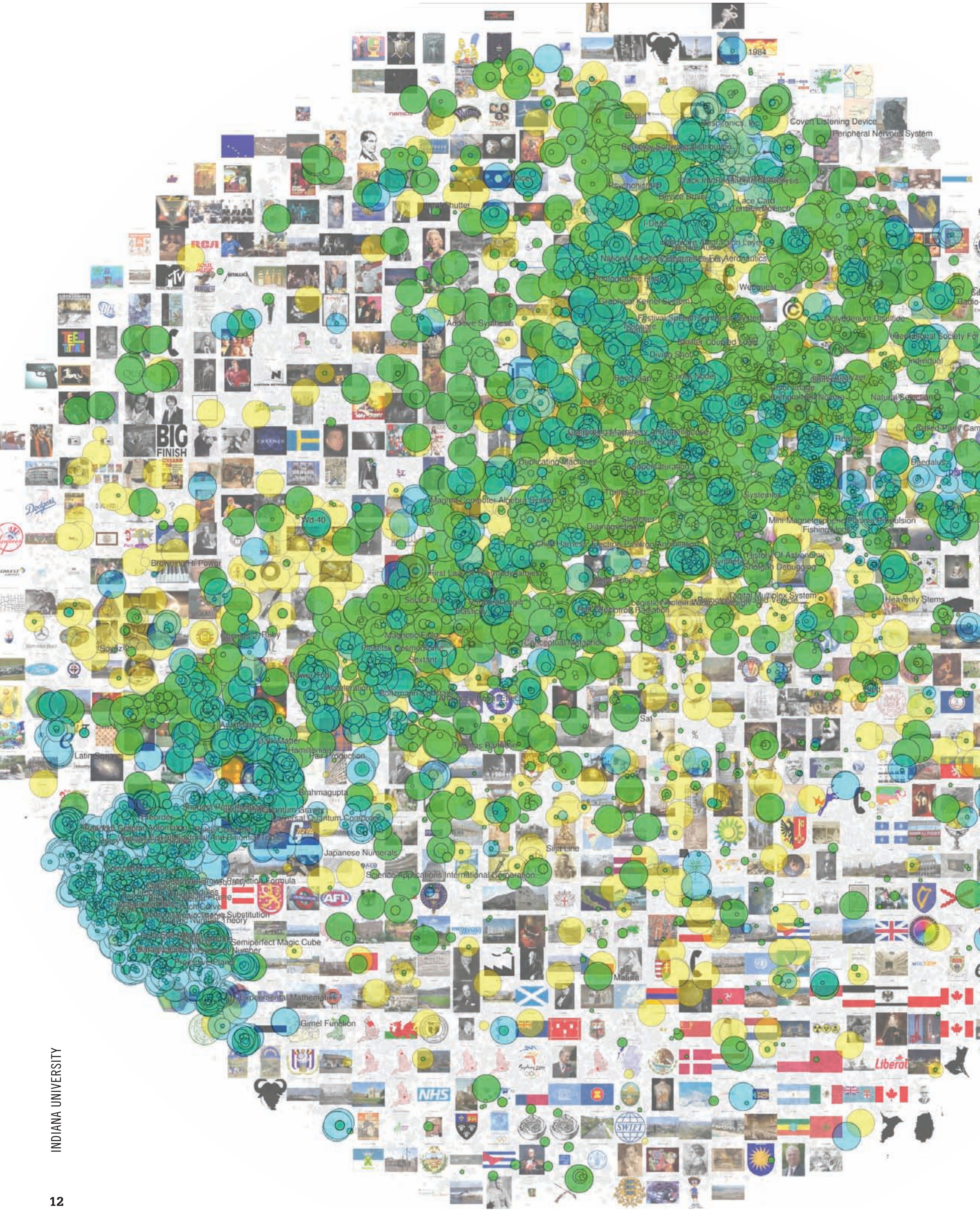
Covert Listening Device
Peripheral Nervous System
Respironics, Inc.
Psychohistory
Device Driver
Lace Card
I-Deas
Hardware Abstraction Layer
National Advisory Committee For Aeronautics
Photographic Plate
Webquest
Graphical Kernel System
Festival Speech Synthesis System
Additive Synthesis
Molybdenum Disulfide
Emitter Coupled Logic
Diving Shot
Individual
Natural Selection
Called Party Camp
Duplicating Machines
Supersaturation
Daedalus
Turing Test
Systemics
Macsyma Computer Algebra System
Diamagnetism
Mini Magnetospheric Plasma Propulsion
Fishing Lures
Wd-40
Chip Harness
Electron Positron Annihilation
Browning Hi-Power
History Of Astronomy
Shotgun Debugging
First Law Of Thermodynamics
Digital Multiplex System
Heavenly Stems
Solar Flare
Temporal Logic
Plasticity
Magnetic Field
Conceptual Metaphor
Sextant
Power Tool
Acceleration
Sat
Dark Matter
Hamiltonian
Pair Production
Thomas Pynchon
Latin Square
Brahmagupta
Quantum Gravity
Universal Quantum Computer
Japanese Numerals
Science Applications International Corporation
Silja Line
Prediction Formula
Substitution
Algebraic Number Theory
Semiperfect Magic Cube
Experimental Mathematics
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MTV
TEEN TITANS
Dodgers
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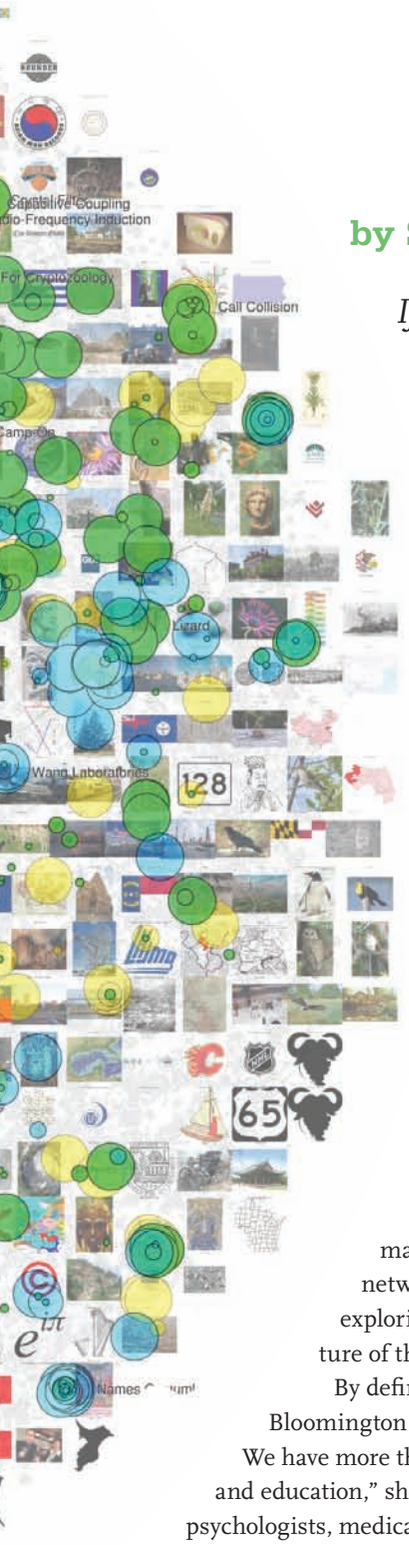
NHS
SWIFT
Liberal

Mapping the Future of Knowledge



by Steve Kaelble

If knowledge is power, the human race must be on the verge of blowing a fuse. Every day, thousands upon thousands of pages of research are thrown into the hopper of collective knowledge. Immeasurable stores of medical data are created, and air traffic data and phone call data and financial data and countless other types of information.

Sure, the vastness of what we don't know is astonishing—but so is the immensity of what we do know. How can we possibly make sense of all this knowledge?

These are the kinds of questions that fuel the work of Katy Börner, the Victor H. Yngve associate professor of information science at Indiana University Bloomington. Börner and her research team are involved in a wide array of pursuits related to networks of knowledge and information—in essence, using science to learn more about science itself. Börner is founding director of IU's Cyberinfrastructure for Network Science Center, and she directs the Information Visualization Laboratory at the IU School of Library and Information Science. She's also adjunct associate professor in informatics, a faculty member in cognitive science, and a research affiliate with IU's Biocomplexity Institute and Complex Systems Group.

Network science—the core of Börner's work—is about gaining an understanding of both human and natural networks. These are networks in the very broadest sense of the word, from computer networks to social networks to ecological networks. Network science is about developing algorithms and exploring common principles that dictate how such networks function and how function affects the structure of these networks.

By definition, it's a highly interdisciplinary pursuit, which is one reason Börner loves working on the IU Bloomington campus. "I'm very impressed by the diversity and quality of the network science researchers at IUB. We have more than 25 faculty members in more than 10 departments who are engaged in network science research and education," she says. "This makes Indiana University a unique place." The field attracts the interest of physicists, psychologists, medical researchers, economists, library science experts, bioinformatics specialists, and computer scientists of all stripes, to name a few.

[LEFT] This visualization explores the activity of science, math, and technology related artcles in the English-language Wikipedia (http://en.wikipedia.org). The central image shows 659,388 articles (circles). Overlaid is a 37 x 37 grid of relevant half-inch sized images. Blue, green, and yellow circles represent the 3,599 math-, 6,474 science-, and 3,164 technology-related articles respectively.

Map #165, Mapping Science exhibit, http://scimaps.org

MAKING KNOWLEDGE MAPS

When it comes to getting a handle on the world's ever-exploding body of knowledge, it helps to have a map, and Börner is a widely recognized expert in what's known as "mapping knowledge domains"—creating graphical depictions of the networks of scientific knowledge, or as she puts it, "mapping the structure and dynamics of science."

Why is this important? An explanation can be found in a chapter on "Visualizing Knowledge Domains" that Börner co-wrote in 2003. Sorting through mountains of scientific literature is "time-consuming, difficult to repeat, and subjective. The task is enormous in its complexity," wrote Börner and her co-authors. "Sifting through recently published documents to find ones that will later be recognized as important is labor-intensive."

Using the latest technologies and newest theoretical approaches, Börner and her colleagues take a "big picture" approach to visualizing knowledge, aiming to make the task of research more efficient and effective.

"This field is aimed at easing information access, making evident the structure of knowledge, and allowing seekers of knowledge to succeed in their endeavors," she and Richard Shiffrin wrote a few years ago in the *Proceedings of the National Academy of Sciences*. (Shiffrin is Luther Dana Waterman Professor of psychological and brain sciences at IU Bloomington.)

At the center of Börner's inquiries is the Cyberinfrastructure for Network Science Center. Housed within the School of Library and Information Science, the center has eight rooms in the Wells Library, occupied by six staff members plus many graduate students and visiting faculty. It is abuzz with network science activity, from studies of Wikipedia to creation of a huge scholarly database to development of navigational tools for scientists. IU created the center in 2005, Börner says, because "there is a large pool of network science research which needed a home, and there was a need to have a shared infrastructure."

One prominent product of the center's efforts is the Network Workbench, a project led by Börner (working with colleauges Albert-Laszlo Barabasi, Santiago Schnell, Alessandro Vespignani, Stanley Wasserman, Eric Wernert, and system architect Micah Linnemeier) that is funded by the National Science Foundation. (Börner is a frequent recipient of NSF funding, as well support from the National Institutes of Health and the James S. McDonnell Foundation.)

The NWB is a computing environment that enables large-scale network analysis, modeling, and visualization that advances the work of researchers in fields such as biomedicine, physics, and the social sciences. "It's a very easy-to-use tool for different areas of network science," says Börner.

Users can download the NWB and use it to access a variety of major network datasets or upload networks of their own for examination. It allows researchers access to more than 100 validated algorithms for network analysis, modeling and visualization, which speed the study of unwieldy sets of data.

What can one accomplish using the Network Workbench and other tools of network science? Consider the field of epidemiology. There's been a lot of talk about avian flu, and what might happen should this potentially devastating bug find an efficient way to infect humans. If that happens, it will be critically important to figure out where the flu is most likely to spread, so that resources to fight it can be properly directed.

Network science allows epidemiologists to dig into the huge databases that track air travel, crunch the data with global census information and existing disease patterns, and generate sophisticated models of what might happen, when and where.

That's the concept behind EpiC, short for Epidemics Cyberinfrastructure, a project co-led by Börner, Steven J. Sherman in IU's Department of Psychological and Brain Sciences, and Alessandro Vespignani, of IU's School of Informatics. Started in 2007 with $1.2 million in National Institutes of Health funding, the project's goal is to make it easy for the world's epidemiologists to share and reuse datasets and algorithms relating to epidemics. (For more on EpiC, see story Page 16).

Börner and former Ph.D. student Ketan Mane have also employed network science to examine a large dataset of leukemia patients. Their question was, why do some patients do well following chemotherapy while others don't? Sophisticated analysis of the data uncovered patterns in the levels of follow-up the patients received, and the ways that family backgrounds and activities related to the attention given to matters such as medication regimes. This kind of knowledge, Börner says, "has an impact on how you educate patients and monitor them. Visualizations of complex data can have an affect on whether parents return from the hospital with their child or without."

JESUS, HITLER, AND BRITNEY SPEARS

Börner has been at the forefront of a massive computational social science project focusing on the knowledge contained in the online resource Wikipedia. IU visualization expert Bruce W. Herr II, data-mining guru Todd Holloway, graphic designer Elisha F. Hardy, and others loaded huge dumps of Wikipedia content into their network science tools, tracked how the articles linked to one another, and gauged which topics generate the most interest in terms of the frequency of updates.

The result: a complex mosaic of Wikipedia images, arranged by their linkages, with dots indicating the hottest topics. According to studies by Börner and her colleagues, the most actively updated topics were Jesus and Adolf Hitler. A poster the researchers created includes comments such as these remarks from New York visual artist Daniel Zeller: "The mosaic stunningly illustrates the broad spectrum of what I would call the diffuse focus of the masses. Its value is in its all-encompassing overview, and that it allows one to explore and compare this focus. ... My faith in humankind would be restored to someday see that Albert Einstein and Muhammad generated more interest than Britney Spears."

This kind of graphical representation of knowledge is the

focus of the Information Visualization Laboratory (IVL) within the School of Library and Information Science. The IVL is a network in and of itself, comprising researchers and students and specialists in everything from graphic design to computer programming to database administration. Among its contributions is the Information Visualization Cyberinfrastructure (IVC), a project initially supported in part through Börner's fellowship from IU's Pervasive Technologies Laboratory (now the Pervasive Technologies Institute). IVC is a Web resource that offers a comprehensive set of software packages related to data mining and information visualization. The project bundles software into learning modules and offers access to computing resources and a large repository of data.

Börner's team has also developed the Cyberinfrastructure Shell, described on its Web site as "an open source, community-driven platform for the integration and utilization of datasets, algorithms, tools, and computing resources." CIShell extends the Open Services Gateway Initiative industry standard and is at the core of NWB, EpiC, and IVC. Börner says CIShell "enables non-computer scientists to plug-and-play datasets and algorithms as easily as we share images and videos using Flickr and YouTube."

Photo courtesy of Indiana University

Katy Börner

TEACH A PERSON TO FISH, AND ...

With the right kinds of network science tools in hand, huge stores of information no longer seem so daunting. So Börner's Cyberinfrastructure for Network Science Center set out to establish its own clearinghouse of scholarly knowledge. The Scholarly Database (SDB) project, led by Senior Systems Analyst Nianli Ma, amasses more than 18 million publications, patents, and grants, many of which include full text, making it unique in size and scope. The tools of network science allow efficient search and perusal of the SDB in ways that visualize connections emerging across different disciplines.

The center also adds to the knowledge and understanding of network science through its talk series that takes place every Monday evening at the Wells Library. All faculty and students with an interest in network analysis, modeling, visualization, and complex systems research are invited. Organized by Börner since 2004, the series features IU researchers as well as experts from other institutions, such as Purdue University horticulture and landscape architecture professor David Salt who discussed how network science aids in "mapping connections between the genome, ionome [all the minerals and trace elements in an organism], and the physical landscape." An expert from Budapest, George Kampis, recently discussed the analysis of complex ecological networks, such as food webs and RNA structures.

The work of Börner and her network science colleagues at IU and elsewhere is diverse and complex. Because it touches so many disciplines, it promises to have implications too broad to predict. It's all about creating a scholarly marketplace where researchers can effectively interact, share expertise and tools, and be inspired by one another's work, Börner says.

"We aim to give our clients—governments, researchers, companies— a fishing rod rather than a fish. Ideally, the tools, tutorials, and hands-on expertise we provide empower them to make sense of their ever increasing mounts of data."

Network science promises to have an impact on how diseases and wars are fought, how governments deal with economic calamities and other massive problems, how humans relate to one another on a global scale. These are issues for which the knowledge and solutions may already exist, but buried in a mountain of knowledge, information, and data.

"No human being can process all that," Börner observes. The ultimate aim, she says, is: "How do we create better tools to make sense of what we already know?"

Steve Kaelble is a freelance writer and publication manager at Community Health Network in Indianapolis.

MORE INFORMATION

Börner Home Page, Center, Lab
http://ella.slis.indiana.edu/~katy/
http://cns.slis.indiana.edu/
http://iv.slis.indiana.edu/

Cyberinfrastructure Design
http://cishell.org/
http://ivl.slis.indiana.edu/
http://nwb.slis.indiana.edu/
http://epic.slis.indiana.edu/

Mapping Science Exhibit
http://scimaps.org/
http://scimaps.org/maps/wikipedia/

Talk Series on Networks and Complex Systems
http://vw.slis.indiana.edu/netscitalks/