Research Contribution Types in Human-Computer Interaction

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Research in *Human-Computer Interaction (HCI)* contains both technological and human-behavioral concerns. As a result, the contributions made in HCI research tend to be familiar to either engineering or the social sciences. The research types covered here are *empirical*, *artifact*, *methodological*, *theoretical*, *dataset*, *survey*, and *opinion*. Of course, many articles make more than one type of contribution. The goal of this document is to give students insight into the contribution types found in HCI papers, and to provide examples for further reading. I do not claim that the examples chosen are the "best of each type;" rather, they are examples with which I am familiar and papers that I appreciate.

1. Empirical

Description. Empirical research contributions consist of new findings based on systematically observed data. Empirical contributions may be quantitative or qualitative (or mixed), and usually follow from scientific studies of various kinds (*e.g.*, laboratory, field, ethnographic, *etc.*). In HCI, the purpose of empirical contributions is, by providing new data, to reveal formerly unknown insights about human behavior and its relationship to technology. Empirical research methods commonly used in HCI include formal experiments, field experiments, field studies, interviews, focus groups, surveys, usability tests, case studies, diary studies, ethnography, contextual inquiry, experience sampling, and automated data collection (*e.g.*, sensing, logging).

How this work is evaluated. Empirical contributions are considered trustworthy when the methods that produce them are executed with rigor and precision. "The devil is in the details" in empirical work. Identifiable confounds and biases must be avoided in studies of all types. If methods are sound and findings important, empirical contributions will be judged favorably.

Examples.

Bragdon, A., Nelson, E., Li, Y. and Hinckley, K. (2011). Experimental analysis of touch-screen gesture designs in mobile environments. *Proceedings of the ACM Conference in Human Factors in Computing Systems (CHI '11)*. Vancouver, British Columbia (May 7-12, 2011). New York: ACM Press, 403-412.

Burke, M., Kraut, R. and Williams, D. (2010). Social use of computer-mediated communication by adults on the autism spectrum. *Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW '10)*. Savannah, Georgia (February 6-10, 2010). New York: ACM Press, 425-434.

Casiez, G., Vogel, D., Balakrishnan, R. and Cockburn, A. (2008). The impact of control-display gain on user performance in pointing tasks. *Human-Computer Interaction 23* (3), 215-250.

Chilana, P.K., Wobbrock, J.O. and Ko, A.J. (2010). Understanding usability practices in complex domains. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '10)*. Atlanta, Georgia (April 10-15, 2010). New York: ACM Press, 2337-2346.

Clarkson, E., Clawson, J., Lyons, K. and Starner, T. (2005). An empirical study of typing rates on mini-QWERTY keyboards. *Extended Abstracts of the ACM Conference on Human Factors in Computing Systems (CHI '05)*. Portland, Oregon (April 2-7, 2005). New York: ACM Press, 1288-1291.

Czerwinski, M., Horvitz, E. and Wilhite, S. (2004). A diary study of task switching and interruptions. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '04)*. Vienna, Austria (April 24-29, 2004). New York: ACM Press, 175-182.

Dawe, M. (2006). Desperately seeking simplicity: How young adults with cognitive disabilities and their families adopt assistive technologies. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '06)*. Montréal, Québec (April 22-27, 2006). New York: ACM Press, 1143-1152.

Findlater, L., Wobbrock, J.O. and Wigdor, D. (2011). Typing on flat glass: Examining ten-finger expert typing patterns on touch surfaces. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11)*. Vancouver, British Columbia (May 7-12, 2011). New York: ACM Press, 2453-2462.

Grudin, J.T. (1984). Error patterns in skilled and novice transcription typing. In *Cognitive Aspects of Skilled Typewriting*, W. E. Cooper (ed.). New York: Springer-Verlag, 121-143.

Hwang, F., Keates, S., Langdon, P. and Clarkson, P.J. (2004). Mouse movements of motion-impaired users: A submovement analysis. *Proceedings of the ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '04)*. Atlanta, Georgia (October 18-20, 2004). New York: ACM Press, 102-109.

Kurtenbach, G. and Buxton, W. (1994). User learning and performance with marking menus. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '94)*. Boston, Massachusetts (April 24-28, 1994). New York: ACM Press, 258-264.

Lee, S. and Zhai, S. (2009). The performance of touch screen soft buttons. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '09)*. Boston, (April 4-9, 2009). New York: ACM Press, 309-318.

Patel, K., Fogarty, J., Landay, J.A. and Harrison, B. (2008). Examining difficulties software developers encounter in the adoption of statistical machine learning. *Proceedings of the 23rd AAAI Conference on Artificial Intelligence (AAAI '08)*. Chicago, Illinois (July 13-17, 2008). Menlo Park, California: AAAI Press, 1563-1566.

Poltrock, S.E. and Grudin, J. (1994) Organizational obstacles to interface design and development: Two participant-observer studies. *ACM Transactions on Computer-Human Interaction 1* (1), 52-80.

Shinohara, K. and Wobbrock, J.O. (2011). In the shadow of misperception: Assistive technology use and social interactions. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11)*. Vancouver, British Columbia (May 9-12, 2011). New York: ACM Press, 705-714.

Wobbrock, J.O. and Gajos, K.Z. (2007). A comparison of area pointing and goal crossing for people with and without motor impairments. *Proceedings of the ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '07)*. Tempe, Arizona (October 15-17, 2007). New York: ACM Press, 3-10.

2. Artifact

Description. Artifacts in HCI are inventions, including new systems, architectures, tools, techniques, or designs that reveal new opportunities, enable new outcomes, facilitate new insights or explorations, or impel us to consider new possible futures. Artifact contributions are, by definition, dependent upon never-before-seen inventions that are instantiated as prototypes, sketches, mockups, or other portrayals, and are often at least somewhat functional. Novel systems, architectures, and tools provide new knowledge by showing *how* to accomplish new things formerly impossible, or how to accomplish formerly possible things more easily (*e.g.*, Dixon, Gajos, Greenberg, Myers, Patel, Wobbrock). Novel techniques provide new *ways* of interacting with a range of technologies, striving to be reusable across many platforms or situations. (*e.g.*, Baudisch, Grossman, Kristensson). Novel designs may be prototypes, sketches, mockups, or other portrayals whose purpose is to exhibit new possible futures (*e.g.*, Kane, Schwesig, Wigdor).

How this work is evaluated. Artifact contributions are often accompanied by empirical evaluations but they do not necessarily need to be. New systems, architectures, and tools are often best evaluated in a principled, holistic fashion on the basis of what they make possible, how they do so, and what new possibilities they open. Techniques, on the other hand, are almost always evaluated formally and quantitatively, as human performance with techniques is central to understanding techniques' merits. New designs, in general, are evaluated according to the bold and compelling vision they propel, and how richly painted is the possible future created by the design. Designs that are deeply implemented also may be considered systems and may be evaluated accordingly.

Examples.

Baudisch, P., Sinclair, M. and Wilson, A. (2006). Soap: A pointing device that works in mid-air. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '06)*. Montreux, Switzerland (October 15-18, 2006). New York: ACM Press, 43-46.

Dixon, M. and Fogarty, J.A. (2010). Prefab: Implementing advanced behaviors using pixel-based reverse engineering of interface structure. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '10)*. Atlanta, Georgia (April 10-15, 2010). New York: ACM Press, 1525-1534.

Gajos, K.Z., Weld, D.S. and Wobbrock, J.O. (2010). Automatically generating personalized user interfaces with SUPPLE. *Artificial Intelligence 174* (12-13), 910-950.

Greenberg, S. and Fitchett, C. (2001). Phidgets: Easy development of physical interfaces through physical widgets. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '01)*. Orlando, Florida (November 11-14, 2001). New York: ACM Press, 209-218.

Grossman, T. and Balakrishnan, R. (2005). The Bubble Cursor: Enhancing target acquisition by dynamic resizing of the cursor's activation area. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '05)*. Portland, Oregon (April 2-7, 2005). New York: ACM Press, 281-290.

Kane, S.K., Avrahami, D., Wobbrock, J.O., Harrison, B., Rea, A., Philipose, M. and LaMarca, A. (2009). Bonfire: A nomadic system for hybrid laptop-tabletop interaction. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '09)*. Victoria, British Columbia (October 4-7, 2009). New York: ACM Press, 129-138.

Kristensson, P.-O. and Zhai, S. (2004). SHARK^2: A large vocabulary shorthand writing system for pen-based computers. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '04)*. Santa Fe, New Mexico (October 24-27, 2004). New York: ACM Press, 43-52.

Myers, B.A., McDaniel, R.G., Miller, R.C., Ferrency, A.S., Faulring, A., Kyle, B.D., Mickish, A., Klimovitski, A. and Doane, P. (1997). The Amulet environment: New models for effective user interface software development. *IEEE Transactions on Software Engineering 23* (6), 347-365.

Patel, S.N., Gupta, S. and Reynolds, M.S. (2010). The design and evaluation of an end-user-deployable, whole house, contactless power consumption sensor. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '10).* Atlanta, Georgia (April 10-15, 2010).New York: ACM Press, 2471-2480.

Schwesig, C., Poupyrev, I. and Mori, E. (2004). Gummi: A bendable computer. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '04)*. Vienna, Austria (April 24-29, 2004). New York: ACM Press, 263-270.

Wigdor, D., Forlines, C., Baudisch, P., Barnwell, J. and Shen, C. (2007). LucidTouch: A see-through mobile device. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '07)*. Newport, Rhode Island (October 7-10, 2007). New York: ACM Press, 269-278.

Wobbrock, J.O., Wilson, A.D. and Li, Y. (2007). Gestures without libraries, toolkits or training: A $1 recognizer for user interface prototypes. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '07)*. Newport, Rhode Island (October 7-10, 2007). New York: ACM Press, 159-168.

3. Methodological

Description. Methodological research contributions add or refine the methods by which researchers or practitioners carry out their work in HCI. Research methods enable scientists to make new discoveries, while practitioner methods enable designers and developers to apply their craft to greater effect. While entirely new methods of either sort are infrequently proposed, method variations are regularly proposed.

How this work is evaluated. Methodological contributions are evaluated on the basis of the novelty and utility of the new or improved method. Demonstrating the utility of a method usually requires an empirical validation of some kind. Such a validation may be formal in nature (*e.g.,* an experiment in which one of two groups uses the new method, while the other group uses a *de facto* method), or a case study (*e.g.,* where the method is applied in a particular setting and outcomes are analyzed and reported). The goal of validating a methodological contribution is to convince readers that the new method or method variation is useful, valid, and reliable for its intended purpose. As the method is to be used by others, it should be described well enough to be employed by experienced researchers or practitioners.

Examples.

Blomberg, J., Giacomi, J., Mosher, A. and Swenton-Wall, P. (1993). Ethnographic field methods and their relation to design. In *Participatory Design: Principles and Practices*, D. Schuler and A. Namioka (eds.). Hillsdale, New Jersey: Lawrence Erlbaum, 123-155.

Consolvo, S. and Walker, M. (2003). Using the Experience Sampling method to evaluate ubicomp applications. *IEEE Pervasive Computing 2* (2), 24-31.

Holtzblatt, K. and Jones, S. (1993). Contextual Inquiry: A participatory technique for system design. In *Participatory Design: Principles and Practices*, D. Schuler and A. Namioka (eds.). Hillsdale, New Jersey: Lawrence Erlbaum, 177-210.

Kjeldskov, J. and Stage, J. (2004). New techniques for usability evaluation of mobile systems. *International Journal of Human-Computer Studies 60* (5-6), 599-620.

Guiard, Y. (2009). The problem of consistency in the design of Fitts' law experiments: Consider either target distance and width or movement form and scale. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '09).* Boston, Massachusetts (April 04-09, 2009). New York: ACM Press, 1809-1818.

Palen, L. and Salzman, M. (2002). Voice-mail diary studies for naturalistic data capture under mobile conditions. *Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW '02)*. New Orleans, Louisiana (November 16-20, 2002). New York: ACM Press, 87-95.

Price, K.J. and Sears, A. (2009). The development and evaluation of performance-based functional assessment: A methodology for the measurement of physical capabilities. *ACM Transactions on Accessible Computing 2* (2), 10:1-10:31.

Soukoreff, R.W. and MacKenzie, I.S. (2003). Metrics for text entry research: An evaluation of MSD and KSPC, and a new unified error metric. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '03)*. Ft. Lauderdale, Florida (April 5-10, 2003). New York: ACM Press, 113-120.

Soukoreff, R.W. and MacKenzie, I.S. (2004). Towards a standard for pointing device evaluation, perspectives on 27 years of Fitts' law research in HCI. *International Journal of Human-Computer Studies 61* (6), 751-789.

Wobbrock, J.O., Aung, H.H., Rothrock, B. and Myers, B.A. (2005). Maximizing the guessability of symbolic input. *Extended Abstracts of the ACM Conference on Human Factors in Computing Systems (CHI '05)*. Portland, Oregon (April 2-7, 2005). New York: ACM Press, 1869-1872.

Wobbrock, J.O., Findlater, L., Gergle, D. and Higgins, J.J. (2011). The Aligned Rank Transform for nonparametric factorial analyses using only ANOVA procedures. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11)*. Vancouver, British Columbia (May 7-12, 2011). New York: ACM Press, 143-146.

4. Theoretical

Description. Theoretical contributions consist of new models, principles, concepts, or frameworks, or important variations on those that already exist. These may be quantitative or qualitative in nature, but are always structured so as to be useful in the pursuit of future knowledge. Theories are built over time, and in some fields (*e.g.*, psychology), after repeated and rigorous validation, may attain the status of "laws." Theories are both descriptive and predictive in nature; that is, they reveal the essential features of *what is* while accounting for as-yet unobserved outcomes. Theoretical contributions significantly advance our understanding by providing inherently reusable constructs and "ways of thinking" about problems.

How this work is evaluated. Theoretical contributions must be validated for their novelty, importance, descriptive power, and predictive power. A theory that accounts well for observed data from a particular situation but has no ability to transfer to any new situation is inherently limited in its usefulness. (The theory may be said to be "over-fit" to the observed data.) Conversely, a theory that is so broad it can "predict anything" probably does not contain any real descriptive power. (It lacks specifics and is "under-fit.") For these and other reasons, theory validation is almost always accompanied by empirical observation.

Examples.

Bellotti, V., Back, M., Edwards, W.K., Grinter, R.E., Henderson, A. and Lopes, C. (2002). Making sense of sensing systems: Five questions for designers and researchers. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '02)*. Minneapolis, Minnesota. New York: ACM Press, 415-422.

Buxton, W. (1990). A three-state model of graphical input. *Proceedings of the IFIP TC13 Third Int'l Conference on Human-Computer Interaction (INTERACT '90)*. Cambridge, England (August 27-31, 1990). Amsterdam, The Netherlands: North-Holland, 449-456.

Cao, X. and Zhai, S. (2007). Modeling human performance of pen stroke gestures. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '07)*. San Jose, California (April 28-May 3, 2007). New York: ACM Press, 1495-1504.

Card, S.K., Mackinlay, J.D. and Robertson, G. (1990). The design space of input devices. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '90)*. Seattle, Washington (April 1-5, 1990). New York: ACM Press, 117-124.

Guiard, Y. (1987). Asymmetric division of labor in human skilled bimanual action: The kinematic chain as a model. *Journal of Motor Behavior 19* (4), 486-517.

MacKenzie, I.S. (1992). Fitts' law as a research and design tool in human-computer interaction. *Human-Computer Interaction 7* (1), 91-139.

Schön, D.A. (1992). Designing as reflective conversation with the materials of a design situation. *Knowledge-Based Systems 5* (1), 3-14.

Wobbrock, J.O., Cutrell, E., Harada, S. and MacKenzie, I.S. (2008). An error model for pointing based on Fitts' law. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '08)*. Florence, Italy (April 5-10, 2008). New York: ACM Press, 1613-1622.

Zhai, S., Kong, J. and Ren, X. (2004). Speed-accuracy tradeoff in Fitts' law tasks—on the equivalency of actual and nominal pointing precision. *International Journal of Human-Computer Studies 61* (6), 823-856.

5. Dataset

Description. Datasets are infrequent contributions in HCI, but they do occur. A dataset contribution provides a new and useful corpus, often accompanied by an analysis of its

characteristics, for the benefit of the research community. Datasets enable evaluations against shared benchmarks by new algorithms or systems. Dataset contributions are common in the pattern matching, operating system, and database communities, among others.

How this work is evaluated. A dataset contribution is judged favorably the extent to which it supplies the research community with a much-needed corpus against which to test future innovations. Also, datasets should be accompanied by explanations of how and where the data was gathered, why it is adequately representative, and common procedures to employ with it. Often, datasets are published with new tools that instantly give researchers greater facility with the data.

Examples.

Hse, H. and Newton, A.R. (2003). *Sketched Symbol Recognition using Zernike Moments*. Technical Memorandum UCB/ERL M03/49, Electronics Research Lab, Department of EECS, University of California, Berkeley.

MacKenzie, I.S. and Soukoreff, R.W. (2003). Phrase sets for evaluating text entry techniques. *Extended Abstracts of the ACM Conference on Human Factors in Computing Systems (CHI '03)*. Ft. Lauderdale, Florida (April 5-10, 2003). New York: ACM Press, 754-755.

Myers, B. *et al.* (1997). Using benchmarks to teach and evaluate user interface tools. Available at http://www.cs.cmu.edu/~amulet/papers/benchmarks.pdf

Plaisant,C., Fekete, J.-D. and Grinstein, G. (2008). Promoting insight-based evaluation of visualizations: From contest to benchmark repository. *IEEE Transactions on Visualization and Computer Graphics 14* (1), 120-134.

Willems, D., Niels, R., Gerven, M. van & Vuurpijl, L. (2009). Iconic and multi-stroke gesture recognition. *Pattern Recognition 42* (12), 3303-3312.

6. Survey

Description. Survey contributions are attempts to review and synthesize work done in a research field with the goal of exposing trends, themes, and gaps in the literature. Survey contributions take a step back, organizing the literature of a field and reflecting on what it means. Often, survey contributions are conducted after a field has reached a level of maturity. It is not uncommon for surveys to be over fifty pages in length, with references numbering in the hundreds.

How this work is evaluated. To be effective, survey contributions must not be mere catalogs of prior work. Rather, they must review and synthesize this work, extracting emergent themes or trends, and identifying gaps where new opportunities lie. Surveys are judged on their completeness, thoroughness, organization and of material, the depth of their synthesis, maturity of their perspective, and fairness with which other authors' work is characterized. Surveys are also judged favorably the extent to which they uncover promising new areas for future work.

Examples.

Balakrishnan, R. (2004). "Beating" Fitts' law: Virtual enhancements for pointing facilitation. *International Journal of Human-Computer Studies 61* (6), 857-874.

Holden, M.K. (2005). Virtual Environments for Motor Rehabilitation: Review. *CyberPsychology and Behavior 8* (3), 187-211.

Johnson, G., Gross, M.D., Hong, J. and Do, E.Y.-L. (2009). Computational support for sketching in design: A review. *Foundations and Trends in Human-Computer Interaction 2* (1), 1-93.

MacKenzie, I.S. and Soukoreff, R.W. (2002). Text entry for mobile computing: Models and methods, theory and practice. *Human-Computer Interaction 17* (2), 147-198.

Plamondon, R. and Srihari, S.N. (2000). On-line and off-line handwriting recognition: A comprehensive survey. *IEEE Transactions on Pattern Analysis and Machine Intelligence 22* (1), 63-84.

Sawilowsky, S.S. (1990). Nonparametric tests of interaction in experimental design. *Review of Educational Research 60* (1), 91-126.

Shaer, O. and Hornecker, E. (2009). Tangible user interfaces: Past, present and future directions. *Foundations and Trends in Human-Computer Interaction 3* (1-2), 1-137.

Welford, A.T. (1960). The measurement of sensory-motor performance: Survey and reappraisal of twelve years' progress. *Ergonomics 3* (3), 189-230.

7. Opinion

Description. Papers making opinion contributions seek to change the minds of readers through persuasion. Although the term "opinion" might suggest a less-than-scientific effort, in fact, opinion contributions, to be persuasive, often draw upon any or all of the above contribution types to advance their case. Opinion contributions are such not because they lack any empirical or theoretical basis, but because of their goal, which is to *persuade* rather than simply to *inform*. Along with persuasion, the goal of opinion contributions is to impel discussion, reflection, and even dissention or a change in course for the field.

How this work is evaluated. Opinion contributions are evaluated on the credibility and use of their supporting evidence, on the fair consideration of alternate perspectives, and on the strength of their articulated persuasion. Essentially, opinion contributions must center on topics of vital interest to an academic community, and should therefore have broad appeal.

Examples.

Bannon, L. (2011). Reimagining HCI: Toward a more human-centered perspective. *interactions 18* (4), 50-57.

Dourish, P. (2006). Implications for design. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '06)*. Montréal, Québec (April 22-27, 2006). New York: ACM Press, 541-550.

Greenberg, S. and Buxton, B. (2008). Usability evaluation considered harmful (some of the time). *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '08)*. Florence, Italy (April 5-10, 2008). New York: ACM Press, 111-120.

Harper, S. (2007). Is there design for all? *Universal Access in the Information Society 6* (1), 111-113.

Newell, A. and Card, S.K. (1985). The prospects for psychological science in human-computer interaction. *Human-Computer Interaction 1* (3), 209-242.

Norman, D.A. (1999). Affordance, conventions, and design. *interactions 6* (3), 38-43.

Norman, D.A. (2006). Logic versus usage: The case for activity-centered design. *interactions 13* (6), 45, 63.

Olsen, D. (2007). Evaluating user interface systems research. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '07)*. Newport, Rhode Island (October 7-10, 2007). New York: ACM Press, 251-258.

Shneiderman, B. (2000). Universal usability. *Communications of the ACM 43* (5), 84-91.