How Does the Design Community Think About Design?

Design is a term that brings many people together. Collectively, we distinguish ourselves from others by the fact that we are *designers* and members of a *design community*. But, *design* is also a term that pushes people apart. The *design* that some value in the new fashions in the boutiques in Milan is not seen by everyone as *design*. While some are impressed with the *design* of a new telephone, not everyone sees this as *design.* As a community, we believe design is important. But, as a community, we do not have a common definition of what it is. Many views of *design* have been proposed. Several *classifications* of design have been proposed. In this paper, we also seek to classify views on design. Unlike earlier efforts, however, we want to find the classification that the global community of designers uses. To this end, we examine the patterns of citations to key authors' works (Author Co-citation Analysis) to uncover this classification and identify seven key author clusters representing identifiable theory groups or schools of thought/practice in design.

Keywords
Theories of design, design taxonomy

INTRODUCTION

In *The Sciences of the Artificial*, Simon [24, p. 111] argues that design is "the core of all professional training; it is the principal mark that distinguishes the professions from the sciences". In Simon's terms, "everyone designs who devises courses of action aimed at changing existing situations into preferred ones".

Design is a term that brings many people together. Conferences, publications, and professional societies are formed to support the *design community*. Collectively, we distinguish ourselves from others by the fact that we are *designers*.

Design is a term that pushes people apart. The *design* that some value in the new fashions in the boutiques in Milan is not seen by everyone as *design*. While some are impressed with the *design* of a new telephone, not everyone sees this as *design*. While we might collectively agree that *interface design* is different from *interaction design* is different from *user experience design*, we will not agree on which is the *real* design task.

Design unites us, but *design* divides us. As a community, we believe it is important. But, as a community, we do not have a common definition of what it is. Many views of *design* have been proposed. Several *classifications* of design have been proposed. In this paper, we review some of these views and some of these classifications.

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Our goal in this paper is to discover how the various views of *design* are related and to use this as a basis for building an overarching theory of design. Unlike earlier efforts to classify design approaches, which are based primarily on the analysis of one or a few people, we want to find the classification that the global community of designers uses. To this end, we analyze the citations in the design literature over a ten-year period in a database of over ten million documents and employ bibliographic co-citation analysis to uncover the classification scheme implicitly used by these authors.

We begin by providing a brief history of *design*. Then, we summarize views of design and look at previous categorizations of design. Next, we use co-citation analysis to present a classification of design, based on the collective wisdom of the global design community. Finally, we outline next steps.

A BRIEF HISTORY OF *DESIGN*

Design, from a historical perspective, has been around for millennia. As Mayall [15] notes in *Principles of Design*, design, viewed as the creation of artifacts that are used to achieve some goal, traces back to the development of stone tools. Formal descriptions of design methods, theories of design, and categorizations of design have existed for only a few decades. Most members of the design community would view current design as much more *complex* than the design of stone tools. But, what has changed about the nature of design over this time?

Mayall [15] notes that early design was driven by the belief that *new* is *better* and that *technology* is *good*. The designer was unaware of for whom the products were intended and did not question the effects those products might have on individuals or society.

Up until about the 1950's a rational step-by-step approach to design served adequately for those artifacts being created. Technical knowledge about the properties of materials were well known and the step-by-step traditional rational approach for solving problems in a coherent manner was adequate. Research and scientific knowledge was familiar with the composition of materials and designers could adequately predict the outcomes for their artifacts given that no other known variables or principles of design were violated.

Around the 1950's, things begin to change. As technological growth accelerated, the focus came around to the objective of "serving the convenience of man in industry as well as elsewhere" [15, p. 11]. The demands of the salesman encouraged a new definition of design for products, which brought the focus back to the effects of the artifact on people and society, as well on the artifact itself.

Around the 1960's, new technologies and new uses for systems had reached the point where a step-by-step approach to design was no longer feasible. Architect Christopher Alexander [1] acknowledges in *Notes on the Synthesis of Form*, that many design problems are reaching "insoluble levels of complexity". Problems that used to be somewhat simple in nature had somewhat simple solutions, but as technology, materials and social structures changed, and changed more and more rapidly, so did the nature and complexity of the design problem. Soon the traditional rational methods used in design started to become inadequate to address the increasing complexity facing designers. This brought about a discussion in the literature and a call for change in the traditional approaches to design problems, an understanding of the nature of the rising complexity in problems facing designers, as well as a need to develop new methods to help handle the enormous number of variables in the emerging design problems. Among those calling for change in the traditional approaches were Cross [7], Jones [13], Mayall [15], Rittel [20], and Simon [23]. As well as the recognition in different fields of the inadequacies of the purely rational approach to design, there was also discussion of the inadequacies of current professional education and the need for a change in the current academic curriculum (Schön [21]; Simon [23]).

Most of the literature which emerged from the recognition of this gap in traditional design methods tends to fall along the lines of individual disciplines. Christopher Alexander [1] writes about design in architecture, Nigel Cross [7] writes about design in engineering. Horst Rittel [20] approaches design problems from the point of view of urban planning. Pelle Ehn [9] approaches design with a focus on the user in cooperative design methods, while Rasmussen et al [19] and Vicente [28] focus on sociotechnical man-machine systems (e.g., nuclear power plants). Herbert Simon, in *The Sciences of the Artificial* [24], approaches design from the perspective of economics but his discussion of design is not field specific and is applicable across different domains.

VIEWS OF DESIGN

A Sampling of Definitions

There is no single, universally accepted, concise definition of design. In the table below, we present a sampling of definitions of design proposed by various authors and discuss these further below. While we have not attempted to provide an exhaustive list, we have attempted to include a diverse set of authors whose works are frequently cited.

The theoretical discussion in *The Sciences of the Artificial* [24] is, in many respects, an encompassing view of design. *The*

Herbert A. Simon	...devising courses of action aimed at changing existing situations into preferred ones
J. Christopher Jones	...initiating change in man-made things
Christopher Alexander	...the process of inventing physical things which display new physical order, organization, form, in response to function
Horst Rittel	...structuring argumentation to solve "wicked" problems
Donald Schön	...a reflective conversation with the materials of a design situation
Pelle Ehn	...a democratic and participatory process
Jens Rasmussen/ Kim Vicente	...creating complex sociotechnical systems that help workers adapt to the changing and uncertain demands of their job

Sciences of the Artificial is one of the most highly cited resources in the modern design literature. In his conclusion, Simon notes that in large part, "the proper study of mankind is the science of design, not only as the professional component of a technical education, but as a core discipline for every liberally educated person" [24, p. 138].

In Simon's discussion, design is concerned with the construction of artifacts and artifacts are any systems produced by people to help them meet their goals. This discussion of artificial things lays the foundation for the rest of the text and Simon's argument that design, creating a current situation into a preferred one, is at the "core of all professional training and the principal mark that distinguishes the professions from the sciences" [24, p. 111].

Simon approaches this exploration of artificial science and design with the background of an economist. He argues against the once widely accepted view of a *rational decision maker* and proposes that instead of looking for optimal solutions, humans are actually bounded by their cognitive capabilities and other constraints. Referring to these constraints as bounded rationality, Simon argues that given all the alternative possibilities, decision-makers set feasible goals and use decision methods that look for good, or satisfactory solutions, instead of optimal ones as rationality suggests. Simon refers to this as *satisficing*.

In *Cognitive Work Analysis* Kim Vicente [28] approaches the design of work support systems from the Scandinavian perspective using 30 years of Jen Rasmussen's research. The social concerns associated with the Union movement of the 1970's, "safety, productivity, and worker health", are an important component to this approach. This book is a discussion of the design of work support systems that match workers' performance criteria and leave them space to learn and develop their expertise [28, p. xi].

Cognitive Work Analysis is primarily concerned with task analysis and advocates a holistic approach to design. The design of information systems should be based on an explicit analysis of work and used as a means to "derive implications for design" [28, p. 13]. The analysis of the work domain is only valuable to the extent to which it gives designers the insight for the creation of tools that help workers adapt to unexpected situations as well as the changing demands of their jobs and the job environment.

Cognitive Work Analysis is described as a *formative* model for design. This approach describes the requirements that must be satisfied so that a system could behave in a new desired way, identifying requirements, both technological and organizational, that need to be satisfied if a device is going to support work effectively [28, p. 110]. This is contrasted to a *descriptive* model, which focuses on simply portraying work, and a *normative* model, which expresses how a system should behave. An important goal of the formative approach is to "design a future work practice rather than to design the details of the device" [28, p. 112].

Christopher Alexander in *Notes on the Synthesis of Form* [1] shares with Simon, Rasmussen and Vicente a focus on the environment. He addresses the problem of design complexity by focusing upon the problem in its potential environment of use. In the first chapter Alexander defines the ultimate object of design as being form. This idea is based on the fact that every design problem begins with an effort to achieve fitness between two entities, the form in question and its context [1, p. 15]. The form is the solution to the problem and the context is what defines the problem. He further clarifies this by discussing that design isn't form alone, but the ensemble of form and its context, a necessary property of this being "good fit".

Alexander argues that we don't recognize good fit, but rather, we recognize what doesn't fit. Alexander illustrates this point by noting that it is almost impossible to name the characteristics of a house that fits into its context and very simple to name the specific aspects of a house which do not. The task of design, according to Alexander, is "not to create form which meets certain conditions, but to create such an order in the ensemble that all the variables take the value zero"; each variable need only be specific enough and clearly enough defined so that any actual design can be classified unambiguously as a fit(0) or misfit(1) [1, p. 27].

Alexander also discusses the important underlying structural correspondence between a *pattern* and the process of designing a physical form that answers a given problem. The process that Alexander proposes consists of identifying the patterns in the problem and then decomposing those pieces and units of the problem. Alexander concludes that every aspect of a form can be understood as a structure of its components. He sees each component with a dual nature, first as a unit and second as a pattern. "Its nature as a unit makes it distinct from its surroundings, while its nature as a pattern specifies the arrangement of its own component units. It is the height of the designer's task to make every diagram both a pattern and a unit. By doing so, the composition of the diagrams will lead to a physical object whose structural hierarchy is the exact counterpart of the functional hierarchy established during the analysis of the problem; as the program clarifies the component sources of the form's structure, so its realization in parallel will begin to define the form's physical components and their hierarchical organization." [1, p. 131]. By looking at the problem in its context and then breaking the problem components into smaller components Alexander later goes on to identify and create a pattern language for architecture. (see Alexander [2]).

Horst Rittel, in a manner similar to Simon's focus on *artificial* science, notes that design problems are different from problems in the natural sciences. Problems in natural science are what he refers to as "tame or benign" because the end mission is clear. Problems along this line have a finishing point, there are criteria where one can tell when a solution has been found. This is unlike what Rittel refers to as *wicked problems*, which do not have those two clarifying traits.

There are some distinguishing criteria for wicked problems which set them apart from other kinds of problems. Rittel states that the information needed to "understand the problem depends upon one's idea for solving it". In other words, "the process of formulating the problem and of conceiving a solution (or re-solution) are identical, since every specification of the problem is a specification of the direction in which a treatment is considered." Traditional rational models for solving design problems do not work and Rittel believes that the approach to take with wicked problems should be based on a model of planning as an *argumentative* process, the process being one where the "image of the problem and the solution emerge gradually… as a product of unremitting judgment which has also been subjected to critical argument" [20, p. 138].

Like Simon's *The Sciences of the Artificial*, Donald Schön's [21] *The Reflective Practitioner* is at a theoretical level. Unlike Simon, however, Schön discusses several distinct domains of application. *The Reflective Practitioner* is not a design text in the sense that it describes a particular view of design. Rather, it presents a theory of how professionals learn. We include this text in the present study because it is highly cited by writers in the design community.

The Reflective Practitioner is based upon Schön's conviction that universities are not devoted to "the production and distribution of fundamental knowledge in general, but in a particular epistemology that fosters selective inattention to practical competence and professional artistry" (preface). This claim forms the foundation for his discussion of how professionals think in action when situations arise that are a surprise or do not fit a known model or method for finding a solution. The everyday work of a professional is in the "tacit knowing-in-action" [21] (pg. 49). It is how we do things somewhat automatically without consciously thinking about them. Schön distinguishes *reflection-in-action* as an aspect of professional practice that comes about when a practitioner encounters an unexpected, surprising or unknown situation for which their knowledge base has no frame in which to set the problem. As the practitioner is trying to make sense of this situation that he has not encountered previously, and which no model fits, there is a reflection that takes place upon the "understandings, which have been implicit in his action". This is an artful manner of inquiry by which practitioners sometimes deal with uncertainty. Schön calls a pattern of reflection-in-action, "a reflective conversation with the situation" (Schön [21, p. 268].

Schön touches upon reflection-in-action as a very elemental part of the design process. The reflective conversation takes place when the designer reflects-in-action on the "construction of the problem, their strategies of action or the model of the phenomena which were implicit in his moves" [21, p. 79]. Design and teaching reflection-in-action is discussed in more detail in *Educating the Reflective Practitioner* [22].

In *Work-oriented Design of Computer Artifacts*, Pelle Ehn [9] notes that the design of systems to function in complex situations, such as large technology-oriented companies or interdisciplinary design domains, requires a deep understanding not only of the application domain, but also of the practice of the people who will use the systems. Designers do not start with this understanding, but must work to attain it. A central theme of Ehn's approach to design is that the users and developers must work closely together. Ehn's approach is sometimes called the *Scandinavian approach to design,* or *participatory design*, as well as *work-oriented design*. Communication among all those involved in a design effort is facilitated by a *language of doing* that helps to overcome the lack of a common vocabulary among users and designers.

Taxonomies of Design

As noted earlier, the natural division of design problems along different disciplines, and the very apparent dissimilarities of the end products each field works with, would then make it easy to break down the literature in terms of the different disciplines: engineering, architecture, urban planning, information systems, sociotechnical systems, etc. Certainly, designing a house is nothing like designing a nuclear power plant, nor is designing an information system anything like planning a city or designing a servo system for controlling a conveyor motor via a delaying mechanism (Glegg [10]). But, in a larger sense, isn't *design* still *design* regardless of the domain of application?

In *Design Methods*, Jones [13] reviews ancient and modern design methods from craft evolution and design-by-drawing to the logical, scientific and creative techniques. By describing the different methods and discussing their nature and then subsequently classifying them, Jones attempts to make it easier for designers and planners to find a method that might suit a particular design activity.

He divides the emerging design methods into three perspectives. The first is that of creativity, or the black box, which implies that the valuable part of the design process goes on inside the designer's head and partially out of reach of the designer's conscious control. The next view is the rational view or the glass box. These "glass box" methods are based on *rational* assumptions. The process is assumed to be completely explicable and the designer has full knowledge of what they are doing and why they are doing it. The last method outlined by Jones, is that of the designer as a "self-organizing system". The self-organizing system carries out the search for a suitable design while also controlling and evaluating the patterns of the search [13, p. 55]. This model of self-plus-situation enables each member of a design team to understand the degree to which the search actions do or do not produce an acceptable balance between variables.

Similar taxonomies have been proposed by Dym [8] and Candy & Edmonds [4] [5]. In summarizing work in engineering design, Dym [8] classifies design problems as "creative," "variant," or "routine." *Creative design* involves the creation of a new product or invention and is initially characterized by a lack of domain knowledge. *Variant design* typically involves revisions of an existing design. While the designer typically has the requisite domain knowledge, there is challenge in how to fit the modified components into the overall design. *Routine design* typically involves a problem in which the designer has all the knowledge needed to solve that problem.

Candy and Edmonds [4] [5] propose a model for understanding how designers work. This model is based on observations of designers in a variety of domains. This process model describes design activities as involving (1) *Exploration and Evaluation,* (2) *Generation and Invention,* and (3) consideration of *Constraints and Requirements.* These three phases parallel the taxonomies of Jones and Dym.

These taxonomies have a great deal of intuitive appeal, and we expect most members of the design community would agree that these taxonomies *make sense*. While these taxonomies give us ways to think about design, they stop short of describing how one design method might relate to another or how one method might be better suited than another for a given problem.

We argue that the most significant shortcoming of such taxonomies is that they represent the thoughts of a few people. They do not capture the collective wisdom of the larger design community. How we might do this is the topic of the next section.

COLLECTIVE CATEGORIZATION OF DESIGN

Bibliometrics is the quantitative study of literatures as they are represented in bibliographies, such as the reference lists of journal articles (White and McCain, [31]). In scholarly communication the references cited in the bibliography allow readers to locate the source of the materials and it is assumed that these cited works have a subject or other connection with the citing article. Citation counting is a well-known method for identifying influential older works and their authors. We can also use some of the standard tools of multivariate analysis — cluster analysis and multidimensional scaling — to identify citation patterns in large bodies of literature and to visualize the underlying intellectual or subject structure of a discipline or subject (White and McCain [31]).

AUTHOR CO-CITATION ANALYSIS

In the 1970s, Henry Small and Belver Griffith introduced the notion of [document] co-citation analysis—the study of changing patterns of co-occurrence of highly cited documents in reference lists—as a way to visualize structure and change in scientific fields (Small [25], Small & Griffith [27]). Documents frequently co-cited have a subject relationship; clusters of co-cited documents represent research specialties. Author co-citation analysis (ACA) is a related approach that focuses on cited authors' *oeuvres* rather than individual cited documents (White [30], [32]; McCain [16], [17]). Cited authors' names, like cited documents, stand as concept symbols—representatives of key ideas (Small [26]). The frequent co-citation of two authors names may be evidence of the similarity of their work, or of citing authors' recognition of their opposing views on a topic of joint interest.

For our particular interest in design methodologies across different disciplines, author co-citation analysis is a tool that allows us to visualize the interconnectedness of authors writing about design across many different fields such as engineering, architecture, urban planning and information systems, as recognized by hundreds if not thousands of commentators. Instead of reading the source literature for descriptive insights, ACA allows the unseen structures embedded in the literature to rise to the surface.

In the following sections we briefly describe the data gathering and analysis methods used in the present research. For an in-depth discussion of methodology and background in ACA, please see McCain [16].

ESTABLISHING A SET OF AUTHORS

The first step in ACA is to establish a set of authors to be searched as *cited references* in the Institute for Scientific Information databases. The authors can be chosen for a variety of different reasons, but the ultimate goal is to develop a list that is varied and representative of the breadth of the domain of interest. For this study, the list was compiled through discussion with a domain expert and by looking at published literature on design methodologies in different disciplines. We began with 10-15 well-known names such as Herbert Simon, Christopher Alexander, Nigel Cross, Jens Rasmussen, and Don Norman. The initial list of authors expanded to include 54 authors from Software Engineering, Urban Planning, Architecture, Engineering, User Interface Design, and Cooperative Design as well as other subject areas. This list was not meant to be comprehensive, but to reflect those authors we thought were representative of the design community in different disciplines. We validated this list by presenting it to other frequently cited writers on design who provided confirmation that the collection of names was representative of different views in the design literature. Twenty authors were eliminated in preliminary analyses. These included authors with low citation and co-citation counts and a set of authors representing Software Engineering design methodologies. In the last instance, the SE authors were found to be essentially unconnected with the remainder of the author set; their presence added little to the analysis (McCain [16]).

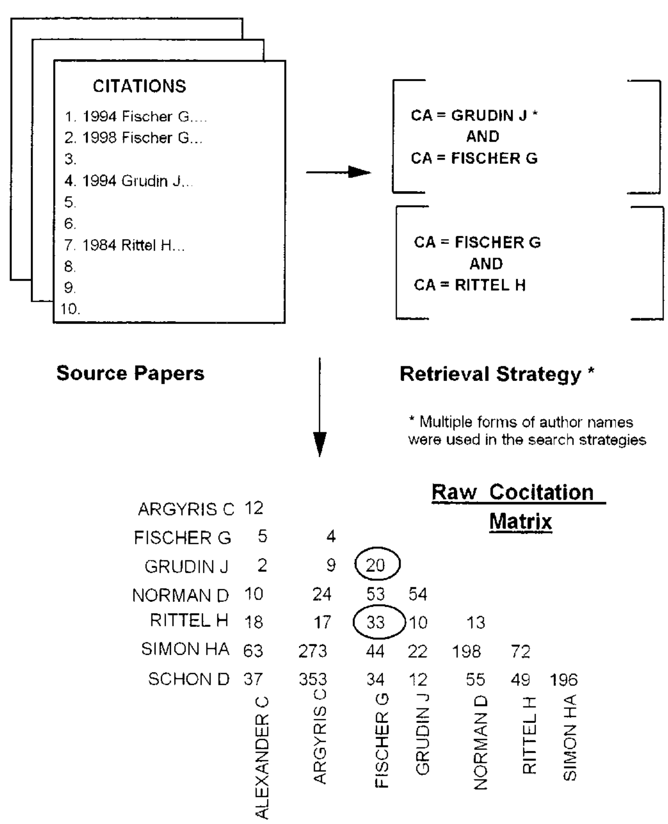

Figure 1: A portion of the matrix of raw cocitation counts.

CO-CITATION ANALYSIS

The raw co-citation counts for the remaining 34 names were retrieved from the citation databases published by the Institute for Scientific Information and accessed via the Dialog service for the years 1990 – 2000; this portion of the database includes in excess of 10 million source articles and 230 million cited references [29]. We searched across all three ISI databases, SciSearch , Social SciSearch, and Arts & HumanitiesSearch, eliminated duplicate sources, and compiled the co-citation counts for each unique pair of authors' names as a square matrix (Figure 1). The numbers in the off-diagonal cells are counts of all papers retrieved by entering each individual pair of author names regardless of how many different works are cited in the bibliographies. A typical search statement would be:

SELECT CA=SIMON HA AND CA=ALEXANDER C

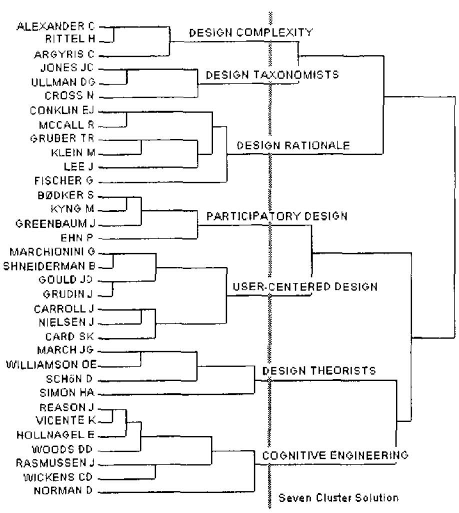

Figure 2: Cluster Analysis of 34 authors in design theory 1990 – 2000.

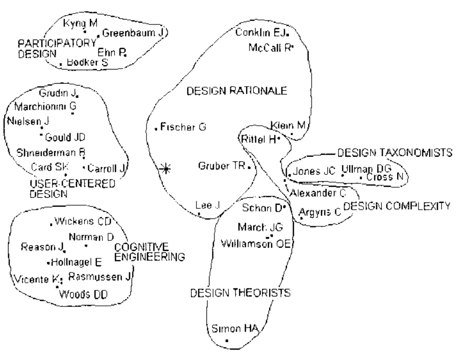

Figure 3: Author Co-citation Map.

This statement retrieves all journal articles citing at least one work by Simon and one work by Alexander. (Note: All counts refer to first or sole-authored cited works—cited co-authors are not accessible in these databases).

DATA ANALYSES

We inserted the mean off-diagonal value for each author pair into the diagonal cells of the co-citation matrix [33] and then converted the raw co-citation counts to a matrix of Pearson correlation coefficients (Pearson's r). Converting to correlations helps to focus on the similarity of co-citation patterns of two authors and eliminates much of the effect of differences in overall citation visibility (two authors with very different citation rates but similar patterns would have a high correlation and be linked in the analyses). The raw co-citation matrix is thus converted to a "proximity matrix" of inter-author similarities.

In a proximity matrix containing similarity measures, the higher the value of the cell representing the intersection of Author A and Author B, the closer (more similar) the authors are (as opposed to a matrix of airline distances, in which a larger number would represent a greater distance).

We used several complementary multivariate analyses to examine the co-citation patterns in the correlation matrix, two of which we report here:

- cluster analysis (SPSS procedure CLUSTER, complete linkage method) identifies clusters of authors with similar co-citation patterns;
- Multidimensional scaling (SPSS procedure ALSCAL, non-metric method) produces a two-dimensional visualization of the similarities between data as a whole.

DISCUSSION

Figure 2 shows the results of the hierarchical cluster analysis as a dendrogram. All hierarchical agglomerative cluster analyses begin with a set of individual objects and, step by step, join objects and clusters until a single cluster is achieved. The dendrogram shows the cluster structure, beginning with 34 individual authors on the left and ending with a single cluster on the right. Two authors are joined, an author is added to a cluster, or two clusters are merged, based on the distance criterion. The horizontal distance traveled between mergings is evidence of the integration or isolation of the authors or clusters. Authors clustered together generally have an identifiable link based on the subject matter of their writings, their geographic or institutional affiliation, school of thought, or other intellectual connection. Inspection suggests that a seven-cluster solution is a good representation of the cocited author structure of this data set ([16] for discussion).

Figure 3 shows these results as a two-dimensional MDS map, enhanced by the clusters identified in Figure 2. Multidimensional scaling attempts to represent the entire data matrix as a two-dimensional (or higher) display. Points, representing authors, are positioned so as to approximate their similarities in the original matrix. Authors with many links to others tend to be placed near the center of the map—the compass rose. Authors with fewer links can be found closer to the periphery and authors with links to others are generally placed close together (within the limits of the dimensional solution chosen). Closely positioned authors in different clusters have important "secondary" links and may be considered boundary spanners. The overall arrangement of author clusters along axes can point to trends in scholarly activity, strong contrasts in theoretical position or other domain-specific themes.

This analysis is based on an analysis of all papers in the Institute for Scientific Information databases that cite the authors used in this analysis and that were published in the years 1990-2000. Over ten million source documents are contained in these databases. Aggregating across this data, we catch the collective wisdom of authors in the design community during this decade.

What do the figures above tell us? Collectively, the design community sees seven clusters of authors and, correspondingly, seven clusters of ideas within the global topic of design. Before describing these clusters, however, we want to point out some interesting aspects of the map above.

There is no central focus that holds the design community together. The compass rose in Figure 3 is at the *center* of the design community. An author here would share similarities with many other authors in this analysis. This author would be the *center* of the design community. But, no author appears here. The authors who are closest to this *center* are Carroll, Fischer, Gruber, and Lee. But, their grouping with this *center* is not as tight as the groupings in the rest of Figure 3. From this, we conclude that design is not one community with diverse interests, but several sub-communities grouped under a common theme. Still, the authors named above are the closest the design community has to representing a common focus.

Some views of design focus strongly on people, others do not. The right half of Figure 3 seems different than the left half. On the left half, we have clusters for *participatory design, user-centered design,* and *cognitive engineering.* On the right half, we have clusters for *design complexity, design taxonomists, design rationale,* and *design theorists.* The relationships among authors on the left (*people*) side of the map are very close, compared to their relations with authors on the right, which focus more on the philosophy of design.

Some views of design build theory, some want to build successful systems. Moving from the bottom of Figure 3 to the top, there seems to be a shift away from using existing theory toward building useful, successful systems. The bottom-most point in this figure is represented by Simon. His writings on design are arguably the most theoretical and the farthest removed from application of all those in this analysis set. Also near the bottom is the *cognitive engineering* cluster, a cluster largely focused on applying cognitive theory to system development and enriching cognitive theory as a result of that application. Toward the top of Figure 3 is the *participatory design* cluster. Motivated by a belief, which many in the design community hold, that design should be a participatory and democratic process, this cluster is driven more by the pragmatic concerns of building successful systems than by existing theories. This is not to say, of course, that their results will not influence theory, only that their actions are not motivated by theory. Similarly, the top portion of the *design rationale* cluster contains authors who are working on building successful design rationale systems.

The seven clusters. In the paragraphs below, we comment on the clusters represented in Figures 2 and 3. In addition to briefly describing the clusters, we also comment on the relations between clusters.

Participatory design. The cluster in the upper left of Figure 3 includes Kyng, Greenbaum, Ehn, and Bødker. This cluster is the strongest advocate for involving users in the design process. *Cooperative design* and *participatory design* emphasize the need for designers and users to work actively together. In addition to the focus on participation, this cluster sees *design in use, system tailoring,* and *work-oriented design* as essential. Work environments are not static and systems must be designed to accommodate change. As Figure 3 indicates, Grudin, although more tightly grouped in another cluster, also gravitates toward this focus on people.

User-centered design. The middle cluster on the left side of Figure 3 includes Grudin, Marchioni, Nielsen, Gould, Shneiderman, Carroll, and Card. These authors have all argued for a shift in perspective on the part of designers. For example, Grudin [12] argues that the goal of user interface consistency directs attention away form the users and their tasks; Gould and Lewis [11] encourage designers to shift away from traditional methods and focus on empirical measurement, iterative design, and an early focus on users. The work by Card and his colleagues on GOMS [6] calls for a focus on the cognitive properties of users of systems. What holds this cluster together is a balanced focus on users and their tasks. While the cluster above focuses primarily on people and the one below focuses primarily on their work environment, this cluster balances between the two.

Cognitive engineering. The bottom cluster on the left side of Figure 3 includes Wickens, Norman, Reason, Hollnagel, Rasmussen, Vicente, and Woods. What brings this cluster together is a strong focus on the cognitive properties and on how these properties determine how people interact with systems in some environment. Norman's *Design of Everyday Things* [18] and Vicente's *Cognitive Work Analysis* [28] are good examples of this focus.

Design rationale. The top-most cluster on the right side of Figure 3 includes Conklin, McCall, Fischer, Klein, Gruber, and Lee. It is important to note that Rittel, who is included in a separate cluster, is also close to the center of this cluster. Rittel viewed design as a *process of argumentation* and the authors in this cluster all focus on the communication that supports design. Many of the representative works in this cluster focus on *design rationale*, a concept that was initiated by Rittel's work on IBIS [14]. Other works, such as Fischer's *Domain-oriented design environments* focus on overcoming the *symmetry of ignorance* problem that Rittel [20] sees as preventing communication between designers and users. The groupings in this cluster are not as tight as in other clusters, reflecting the many views that exist within the *design rationale* sub-community.

Design complexity. This cluster, that includes Rittel, Alexander and Argyris, locks together the remaining three clusters on the right side of Figure 3. Argyris' *action science* [3] Alexander's *patterns* [2], and Rittel's *argumentation* [20] are all ways to help designers to manage the complexity of a design problem. The three remaining clusters on the right side see complexity as a significant problem and look to this cluster for ways to reduce it.

Design taxonomists. The cluster containing Jones, Ullman, and Cross has in common the collection of different views into a single source. These authors are cited not only for their own ideas but also for their collections of the ideas of others. We find it interesting that this cluster links more closely with the clusters on the right of Figure 3 than with those on the left. Perhaps it is more appropriate for taxonomists to deal with the *theoretical* right hand side of Figure 3 than with the *people* oriented left hand side.

Design theorists The cluster containing Schön, Simon, March and Williamson seems to have in common that these authors approach design and designers from a theoretical level and do not deal extensively with concrete applications of those theories. This cluster is closely associated with the *theoretical* right hand side of Figure 3, but, as a whole, is reasonably close to the center of the map in Figure 3.

SUMMARY AND NEXT STEPS

As we stated in the introduction, our goal is to have an overarching theory of design. We are not there yet, but we have made significant progress. We know that when members of the design community write about design, they, collectively, see seven major topics in design. There are distinct sub-communities rather than a single community with diverse interests. Analysis of these writings over the 1990-2000 time frame shows seven sub-communities within the global design community. To be sure, people talk with those in other sub-communities, but affinity is stronger within these sub-communities than to a central *design community.* Conferences, journals, and textbooks should show balance across these sub-communities.

There are other things that we would like to know, but currently do not.

How, for example, do the various theories of design relate to a given problem? It is likely that one method would work better for some problems than for others. We do not yet have a taxonomy of design problems that points to design methods. We plan to begin this by applying the analysis described in this paper to the literature that describes applications of methods to problems.

How does the view that we present based on 1990-2000 writings match that of previous decades? We expect that it does not and would like to trace the evolution of design topics by applying this analysis to earlier decades.

Who have we left out of this analysis? As we noted earlier, software design was excluded from this analysis because it was weakly linked to literature used here. In effect, software design has its own design literature. Since our analysis was based on published literature, we have omitted any design community that does not rely on an archival published literature. We would like to hear from any such community and jointly decide how to include them in a future analysis.

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