PIIMPAPER01 PART ONE

A VISUALIZATION BASED TAXONOMY FOR INFORMATIVE REPRESENTATION: INTRODUCTION AND OVERVIEW

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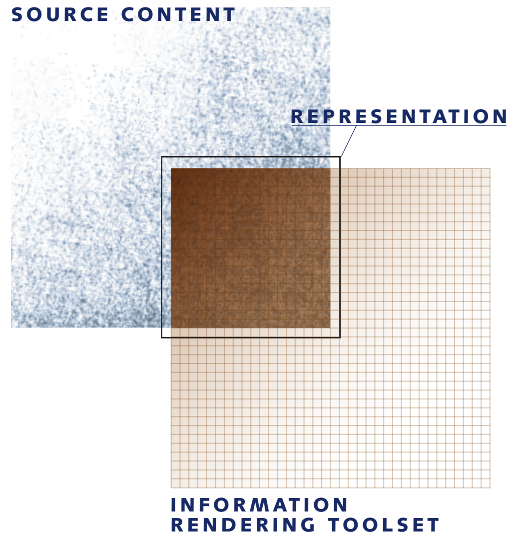
GENERAL INTRODUCTION: PIIM is the Parsons Institute for Information Mapping. PIIM is part of The New School, New York. One of PIIM's initiatives is to disseminate theory and method with the aim of building better *knowledge tools.* PIIM develops and utilizes theories derived from many design disciplines including: advertising, aesthetics, animation, architecture, audiovisualization, branding, communication, engineering, environmental design, exhibition design, game theory, graphic, GIS (Geographic Information Systems), human factors, illustration, information architecture, interaction, interface design, knowledge management, network theory, pattern recognition, pictography, process, semiotics, strategy, symbol, systems, transportation, typography, universality, and usability paradigms.

PIIM's goal is to develop methods (and help other entities utilize these methods) that allow one to derive useful understanding from information noise that is associated with any particular undertaking. Of special interest is deriving knowledge from massive, incomplete, or composite information sets, particularly if the information were to come from multiple fields and/or source types. We are also interested in the general dissemination of good information design practice; therefore, content from this document may be used in other publications provided the source is cited as described. (Please see end of paper for details on copyright and subsequent usage of text from this document.)

When creating knowledge tools, be they single documents or significant engineering undertakings, our ultimate aim is to build a framework of "informative context" concerning the available data. Despite the overwhelming percentage of scientific processing to achieve this, the final transference of insight occurs at the aesthetic level. If an effective visual context can be constructed, the user can build patterns of knowledge and make predictions. From these informative patterns, inferences concerning information that one does *not have* become possible. This permits "knowledge surfacing," whereby useful intelligence becomes apparent through an effective visual interface — and this is what we mean by information mapping. (Visit our website for more details on the concept of mapping information.)

TOPICAL INTRODUCTION: Today, a great deal of human activity falls outside of traditional human labor-intensive initiatives, such as agriculture, manufacturing, and mining. The effective control of these activities and other human-to-human, human-to-machine,



In the elemental and intrinsic sense, information cannot be seen: it needs to be made visible through a natural or creative artifice. Information only takes on a tangible form when rendered through a toolset.

If the resulting representation is visually informative, it will fall into four broad categories: pictorial, symbolic, quantitative, or relational.

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and human-to-nature activities involve the acquiring, discerning, and distributing of information. Knowledge workers (a term developed in 1959 by Peter Drucker), perform these new tasks, and they are at the center of an ever increasing percentage of the workforce.

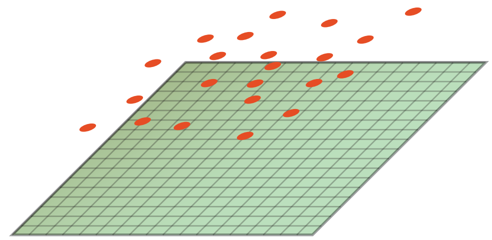
Knowledge workers need tools that allow them to properly access and navigate the information to which they must respond. The knowledge tools they use to do this are all around us: maps, charts, computer interfaces with their underlying applications, or simple documents. Knowledge workers use these tools to help themselves and others to analyze and make recommendations that inform the decision makers whose actions affect our society.

There is a problem. Organizations complain that workers are ill trained for the current information environment; workers argue that the tools are inadequete or ill concieved. PIIM *pursues seamless intelligence transfer through next-generation knowledge tools. This can be done by developing methods to improve the ability of knowledge tool builders to create such capability.*

In a general sense, design controls information; information controls energy; and energy controls action. The presentation of information is, therefore, critical, as its ultimate cause may generate significant and far-reaching outcomes. How the information is processed and manifested may range far across subjective and objective intent. This paper deals with an effort toward informing objectively through the understanding of basic visual categories.

Of particular interest to PIIM is the occurrence whereby so called "real images" become less informative than "conceptual images." In a sense, "cognitive accuracy" is the most important criterion when building informative displays, irrespective of whether the resulting images are static, interactive, or dynamic.

A VISUALIZATION-BASED TAXONOMY FOR INFORMATIVE REPRESENTATION (PART ONE, INTRODUCTION AND OVERVIEW): An early research project at PIIM involved the wholesale analysis of informative imagery. This proceeded from many former years of similar analysis and experience by the author. Thousands of images were reviewed with an aim at finding core, underlying principles relative to different kinds of principally objective (informative) representations. The goal was to find underlying similarities between source information, communicative intent, communica-



Every visualization has tangible elements arranged in some fashion. The underlying arrangement is what we call the basemap. The elements arranged according to the format of this underlying base map is what we call the superfice.

This relationship, between that which is visibly tangible (the superfice) and that which directly influences the order of the visible (the basemap), can be understood as two inseparable layers that together form a representational rendering.

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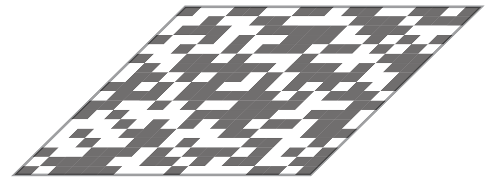
tive approach, and communicative outcomes; and then, to see if an exploitable language could be derived from such similarities. Dr. Arno Klein, now of Columbia University, contributed to this endeavor. This paper is partially derived from that research and presents a high level view of the entire taxonomic concept — additional papers will provide specific detail, from the utility of the taxonomy to the innovative coding method used to identify and classify any image for its inclusion into the taxonomy.

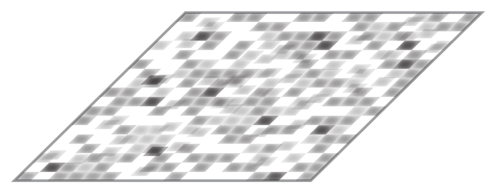
The shorthand name for this taxonomy is: VT-CAD ('Vee-Tee Cad'). It comes from an abbreviation of the full title as presented at a Washington DC academic symposium several years ago: A **V**isualization-Based Objective **T**axonomy for Informative Representation for the **C**lassification, **A**nalysis, and the **D**esign of Visualizations. For the rest of this paper the abbreviation VT-CAD will be used.

SOURCE CONTENT, INFORMATION RENDERING TOOLS, AND REPRESENTATIONS: In the elemental and intrinsic sense, information cannot be seen; it needs to be made visible through a natural or creative artifice. Information only takes on a tangible form when represented *through* something. For example, an idea or desire may be represented through speech; a story may be represented through text; and this text, in turn, portrayed through typography. Without some form of representation, the information cannot occupy space or time in the normal sense. Therefore, the very first step in making this raw information (what we'll call here *source content)* tangible is by driving it through a *rendering toolset.* (The toolset can be any capability, or combination of capabilities, that permit the source content to be rendered into a tangible representation.) Tangibility may involve any of the senses (sight, hearing, taste, touch, smell, or balance), but our concern with VT-CAD is visualization in the literal sense: the sense of seeing. Learning through visual means is the overwhelming source of knowledge transfer from people or things to human cognition.

At the primary level, therefore, our concern is that we have something before us that is *visually tangible,* further, that it was made visually tangible with the intent of informing. It is representative of some source content from which it was interpreted. For our purpose, a *representation* is, by definition, tangible at human scale — if, say, an image is captured from some otherwise invisible phenomena, that image must be modified into human perceptibility before it is classified for the VT-CAD. Other issues, such as



A structural representation of the basemap that supports pictorial high-constraint imagery: primarily those images that are ultimately generated through the capture of signals. Representations supported by this basemap are generally high definition pixel space in accurate arrangement and proportion.



A structural representation of the basemap that supports pictorial low-constraint imagery. This classification refers to real-type imagery that is usually generated through visual manipulation or designer intent — such as illustrations that are composed of low definition pixel spaces or non-pixel elements that are distorted, not in true proportion, or arranged in a customized manner.

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user-centric design and universal design in respect to particular visualizations, are handled in later papers.

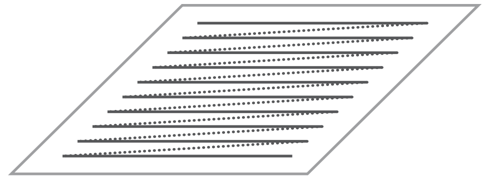
What the tangible form *looks like* is one concern; how an underlying grid, support, or matrix, seen or unseen, affects the quality of this tangible representation is another concern. Both concerns are grounded in a desire to determine how effective any particular visualization approach is in terms of the utility resulting from interpretating source content. This objective, to ultimately understand user value from any particular visualization, was a driving force in the development of VT-CAD.

Despite the great number of visualizations we have considered and the great number we have generated, we found a limited number of "pure visualizations." VT-CAD lists a total number of *eight* possible visual and non-visible "skin-sets" that singularly or in myriad multiple combinations, or distortions, make up all the objective visualization that we have come across. The VT-CAD exploits the nature of these possible layers to better understand ways to design future knowledge tools.

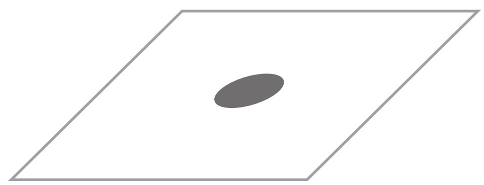
THE BASEMAP AND THE SUPERFICE: Every visualization has visibly tangible (light reflecting or light transmitting) elements arranged in some fashion. The underlying arrangement is what we call the *basemap*. How the elements are arranged according to this underlying base map is what we call the *superfice*. This relationship, between that which is visibly tangible (the superfice) and that which directly influences the order of the visible (the basemap), can be understood as two inseparable layers that form a representational rendering.

As stated, the superfice is always visible; by definition, it must be. The basemap is sometimes visible. The frequency for some kinds of basemaps to be made apparent, or not to be made apparent, depends on the purpose of the visualizations. Graphical visualizations, such as scatter plot graphs or timeline sequences, are usually displayed with the base map apparent. In other kinds of visualizations, pages of text for example, the grid may be very apparent, but it is not visible.

This distinction — and relationship — between the basemap and the superfice is a core feature of VT-CAD. The fundamental sixteen layers are first understood to be "inseparatedly divided" equally between basemaps and superfices. Therefore, there are eight possible basemap types and eight possible superfice types



A structural representation of the basemap that supports symbolic high-constraint imagery, whereby symbols are combined in relative position to convey meaning. An example of such imagery is a page of text — a narrative conveyed through a linear structure.



A structural representation of the basemap that supports symbolic low-constraint imagery. The classification that includes icons and stand-alone elements that have developed some degree of universality of meaning such as road sign symbols. Examples in this category are usually presented singularly.

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that attach to them. These eight can then be further simplified to four groups with two types in each group.

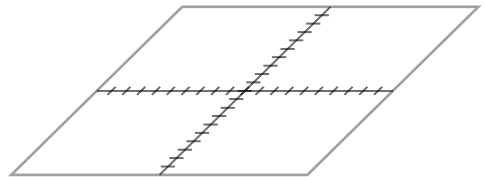
Perhaps the most important aspect of the classification system, at least from the perspective of generating new visualization toolsets that uncover knowledge from data, is that each of the visual pairs have a common usage. By exploiting this common usage, visual displays may be *advantageously typical* or *advantageously atypical in their design.*

THE FOUR PRINCIPLE VISUALIZATION CATEGORIES — EACH WITH THEIR TWO SUB-CATEGORIES: Despite the plethora of extant informative visual representations, only *four main categories* of graphic visual types, each with two distinctive sub-categories, were found. This results in the eight aforementioned pairs.

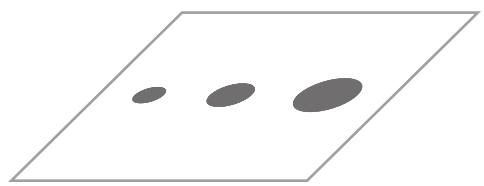
The greater percentage of informative visualizations are generally constructed from only one or two categories (as discussed below). Contemporary information graphics are generally constructed of more layers of information than in the past. This is probably due to technical advances and improved familiarization of the information users today. Regardless, in almost every case, one category of visualization still dominates.

It is difficult to not be highly influenced by the intent of the designer when investigating imagery, and in some instances, this was needed to make final, discrete decisions concerning the taxonomy of an image. However, we tried to investigate these images solely from the underlying structure and the visual results that the structure supported. We called this approach a "soft, top down approach." So, what were these main categories and how could all informative imagery boil down to just four such areas? Try as we might, even after reviewing thousands and thousands of images, we were able to include every visualization into the limited categories as follows:

The first type of visualizations were placed under the classification of **PICTORIAL IMAGERY.** Pictorial, or **REAL IMAGERY,** include all those representations that are associated, in a direct or abstracted way with the way humans see. This classification includes renderings of things in nature, or manmade things, particularly in some contextual framework. Macro- and micro-imaging also belong to this classification. Signal captured images, such as photography, and interpretive images, such as illustration, are pictorial images.



A structural representation of the basemap that supports quantitative high-constraint imagery. The category that organizes the superficial data through coordinate frameworks (such as a Cartesian grid) in which position of points or forms indicate specific value based on regionally determined values.



A structural representation of the basemap that supports quantitattive low-constraint imagery. The classification that includes icons and standalone elements that have developed into some degree of universality of meaning such as road sign symbols. Examples in this category are usually presented singularly.

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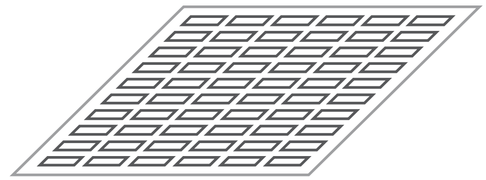
The second type of visualizations were placed under the classification of **SYMBOLIC IMAGERY.** This classification is language and icon based. It includes all examples composed of text, whether the text is composed of phenograms, ideograms, pictograms, or any combination. Symbols that identify an organization, such as a logo or symbols for road navigation, fall under this classification.

The third type of visualizations were placed under the classification of **QUANTITATIVE IMAGERY.** In these visualizations, quantitative methods were used to convey time, distance, or quantities. These visualizations were obviously common in scientific, financial, and statistical fields, but were found to be innovatively used in other fields as well.

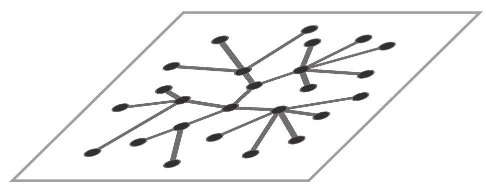
The fourth type of visualizations were placed under the classification of **RELATIONAL IMAGERY.** These kinds of images are increasingly more common today, as computing tools and the digital process are expedient in their generation: they include both tables and nodes and link type diagrams. Human social network diagrams fall under this classification, as do spreadsheets.

Of course, most informative representations utilize more than one of these categories of visualization simultaneously: even the simplest label on an image is a combination of pictorial and symbolic imagery. Some kinds of images can be very abstracted within their classification and have varying levels of *spatial constraint*. The taxonomy takes this into consideration; indeed, there emerged a very useful distinction between *high constraint* and *low constraint* examples in each classification. Again, despite the possibility for endless combinations or layering of imagery types, and despite abstraction and potential ambiguity at the low constraint aspects of the imagery, no image was found that could not be placed within the four categories and then further divided between high or low constraint sub-categories.

HIGH AND LOW SPATIAL CONSTRAINT CONSIDERATIONS: As stated, it was found that each classification had differing characteristics when displayed through high spatial constraint or low spatial constraint. This underlying constraint (or lack of constraint) can have a great influence on the type of resulting visualization, rendering two types of quite distinctive imagery within each category. The following descriptions provide some detail of how high or low constraint factors affect the visualization type and what a viewer actually "sees."



A structural representation of the basemap that supports relational high-constraint imagery. The category that supports proportionally consistent regions of segmented, interrelated units (such as tables composed of columns and rows; the traditional structural organization for database design).



A structural representation of the basemap that supports relational low-constraint imagery. The classification that includes link and node diagrams or a set of elements not constrained spatially but interconnected by visible references such as connecting lines.

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The most important aspect of the classification system, at least from the perspective of generating new visualization toolsets that uncover knowledge from data, is that each of the eight visual types has a distinct logic to its underlying support system. For example, real imagery is a matter of resolution, *i.e.*, the finer the smallest resolution element (*e.g.* pixel, or variable dot), the greater the opportunity to convey increased information. All other categories maintain grids or matrix types that are the truest identifiers to the category to which they belong. The basemap for each type of imagery is listed with its category as they are defined below.

PICTORIAL, HIGH CONSTRAINT IMAGERY:

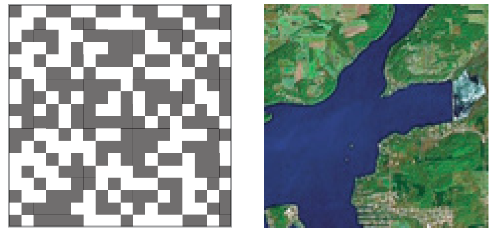
These are real images generated through the capturing of signals. The most apparent example is photography, which captures light and permits 2D (or 3D) renderings that represent light saturation within grains or pixels. Most of the imagery that falls under this category is related to geospatial representations that rely on the physical reality of space. The higher the resolution of this type of imagery, the smaller and more accurate the "pixel" size that makes up the image. BASEMAP: High definition pixel (or variable dot) space in true proportion.

PICTORIAL, LOW CONSTRAINT IMAGERY:

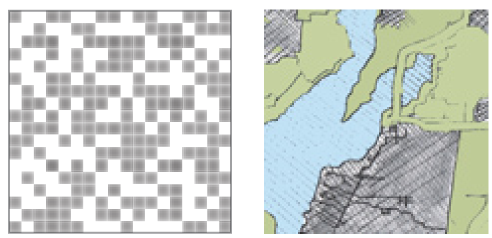
This classification refers to real-type imagery that is usually generated through visual manipulation or designer intent, such as illustration. A high definition image or a low-grade sketch both share the characteristic of being representations that appeal to natural human sensory capabilities. Even though a picture rendered simply as a sketch of something would hardly be considered accurately proportioned, it often implies such proportions. Human cognition fills in many gaps, from perceptual blind spots to conceptual assumptions based on familiarity. A pictorial, representational map-like rendering (*e.g.* cartogrammic image) may be of greater cognitive value in referencing the source content than an accurate geospatial (*e.g.* cartographic) rendering. Indeed, a highly distorted caricature may be more informative than a photograph, etc. BASEMAP: Low definition pixel space or non-pixel elements, distorted, not in true proportion, or arranged in a custom manner.

SYMBOLIC, HIGH CONSTRAINT IMAGERY:

Specific, visually rendered languages form this classification. This classification refers to symbols that belong to a greater set all of which are dependent upon the relative position of neighboring members to convey meaning. A page of printed text is the exem-



A pictorial, high-constraint image: Geospatial image captured by satellite camera from emitted signals (high accuracy image with pixels in uniform space relationships)



A pictorial, low-constraint image: Hand-drawn map emphasizing roadway (although far lower in accuracy than image above, supposedly portraying increased cognitive value for the intended user)

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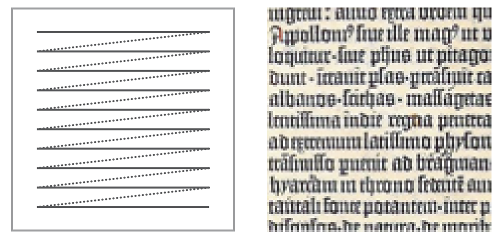
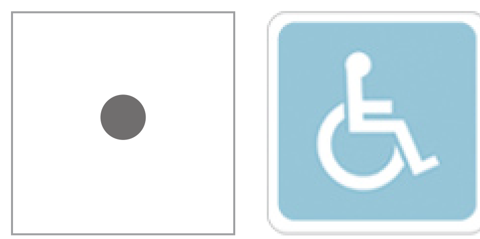
plar for this classification. Documented languages, from the Korean woodblock printings of the 8th Century through Gutenberg's achievement of the 15th Century to desktop documents generated *ad infinitum* today, are examples. Many contemporary subjective visual representations dispense with traditional sentence structure and utilize the mapping technique of "noun labeling." In some examples, called "word maps," the text becomes the spatial matrix, and here a combination of this classification as well as its low constraint companion are interposed. Our concern is the visual aspect; any sets of symbols that are not (on the whole) self-standing, but depend on their brethren for meaning are included. Some characters, such as many Chinese pictograms, convey meaning independently. There is a good argument that characters so displayed are en route to iconography. The classification generally considers languages to be building blocks. When the blocks are assembled, architecture results; when disassembled, they turn back to blocks and prepare for the next architectural challenge. Unlike physical things, these blocks strengthen with re-use, but they can only fleetingly carry meaning as single elements. BASEMAP: A line (usually broken into columns).



A symblic, high-constraint image:
Lines of typeset letterforms (letters must be organized into a linear matrix in order to convey meaning)

SYMBOLIC, LOW CONSTRAINT IMAGERY:

This classification includes icons and standalone elements that have developed universality of meaning. Road sign symbols are an example. Any information conveyed singularly through a cipher, symbol, or icon belong to this classification. Many designers have struggled through the task of placing numerous company logos or sponsors on the same document. Each logo was designed to stand alone, to be a representative voice of some company. They compete mercilessly together: as opposite an effect as when a well designed text font becomes uniformly blended. Icons and logos, even logotypes, are not team players, but they can be designed toward compatibility. There are occasions when they are both highly singular yet in appearance uniform, at least to human perception. Uniform Product Identification codes are an example of this condition. BASEMAP: A single dot.



A symblic, low-constraint image:
Iconographic symbol (meaning self-contained)

QUANTITATIVE, HIGH CONSTRAINT IMAGERY:

This category includes typical coordinate frameworks in which the position of points on that framework indicate their specific value. These representations are usually scientific in nature (suggestive of researched and objectively conveyed content). The intent from a strictly classification standard is that in a purely coordinate-based, data point-driven representation, text (or other) indi-

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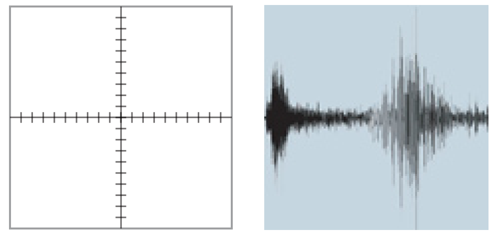
cations are usually required to identify the coordinate space; however, it is not necessary to include a legend to identify the points themselves. The points, therefore, have no intrinsic value, for it is their location that determines their value and meaning. BASEMAP: A Cartesian grid.

QUANTITATIVE, LOW CONSTRAINT IMAGERY:

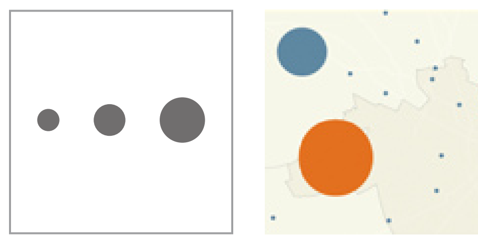
In this category, a device, which we refer to as a *glyph,* is defined as a symbol that communicates specific characteristics nonverbally, *i.e.,* symbolically. But, unlike a logo or a symbol, the value is temporary and specifically applied. For example, a dot of such and such a size may represent a population of x-value. If that dot is of a particular color it may represent a particular demographic, etc. A series of glyphs, supported by some legend, may also register to a mathematical or virtual space arrangement. Visual representations composed almost entirely of glyphs are not uncommon. Any amount of inherent quantitative or qualitative value may be loaded into these symbols (at the obvious cost of orientation and familiarization). Fortunately, the cost of becoming familiarized is not held too dear, as users commonly learn the aspects of a single glyphic element only to discard its specialist use on the very next document they view. Exceptions exist when continued usage, particularly within a specialist field, begins to establish symbolic meaning that transcends a particular representation, so that the elements have not only an intrinsic meaning but also a universal meaning that is carried from document to document. Once this occurs, their informational handling tends to differ as they become true symbols. BASEMAP: A series of variant dots.

RELATIONAL, HIGH CONSTRAINT IMAGERY:

This category refers to proportionally consistent regions of segmented, interrelated units (such as tables composed of columns and rows; the traditional structural organization for database design). The critical quality of this category is that the spatial aspects that separate entities in a diagram or image are based on a logic or algorithmic rendering. Distortions of true-space considerations are common, as in fractal imagery. Tree map images also belong to this category. Any field of interrelated space, no matter how distorted, provided there is an underpinning logic to that distortion, is included in this category. The images are always tabular in some fashion, but the table may be distorted beyond any recognizable tabular form. BASEMAP: Interrelated polygons.



A quantitative, high-constraint image:
Graphical display of intensity over time (level of intensity determined by position on graph)



A quantitative, low-constraint image:
Glyphic elements with assigned values (with temporary interrelated values, generally placed on non-quantitative basemaps)

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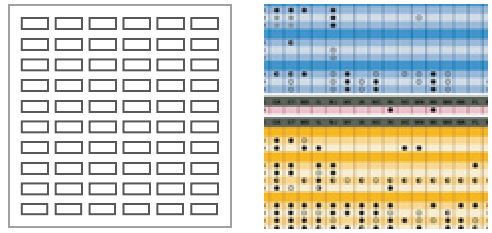
RELATIONAL, LOW CONSTRAINT IMAGERY:
This last category is most easily defined by link and node diagrams: the discrete elements in any image are not constrained spatially but are interconnected by visible references such as connecting lines. Network images are generally referenced to one another through non-real-space considerations.

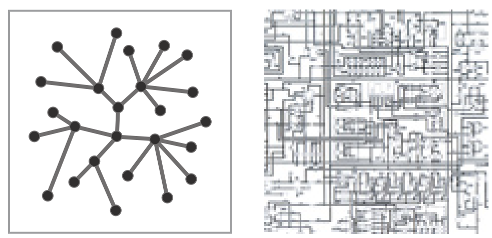
Of particular interest are those types of visualizations, such as flowcharts, that are not tabular but instead based on logical and organizational attributes attributes. Concern for accuracy in proportion is replaced with concern for fitting everything into the space allocated. A wiring diagram is a good example of how this "fitting concern" is handled. BASEMAP: A free floating point organized by artifice.

CLOSING NOTES: The intent of this PIIMPAPER was to present the bones and logic of VT-CAD. The reader should immediately benefit by considering optional structures for presenting the information with which they work. The very celebrated informative visualization by Charles Joseph Minard entitled *Napoleon's March into Moscow* is an example of how the use of an unexpected basemap (*i.e.*, category) can be used to such a powerful effect. During a presentation of this taxonomy, an attendee pointed out that our taxonomy was in error; Minard's depiction was time based, she stated, due to the obvious x-axis that defines the piece *(Quantitative, High Constraint Imagery)*. But Minard uses a very distorted map *(Pictorial, Low Constraint Imagery)* — one can even see the rivers crossing the x-axis — to define the bulk of the image. Minard's representation is one that Edward Tufte has made famous. In many ways, it violates core principals of typical legacy approach, but its uniqueness is an example where the unexpected deployment of atypical basemaps generates incredible insight into the information being conveyed.

Limited text from this PIIMPAPER may be used provided the following citation is directly referred to the text in question:
PIIMPAPER 01-01: *A Visualization Based Taxonomy for Informative Representation by William Bevington. http://piim.newschool.edu*



A relational, high-constraint image:
Tabular display of existing conditions within a matrix of possible fields (this image shows variants within the columns and rows through the use of glyphs)



A relational, low-constraint image:
A wiring diagram with nodes placed in artificial space (but showing true electrical interconnectivity)

PIIM

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There are three other associated papers that deal with VT-CAD, they are:

PIIM PAPER 01, PART TWO: Further defines VT-CAD, discusses aspects of extensive layering, and presents a comprehensive color-coded system to classify all images according to the taxonomy.

PIIM PAPER 01, PART THREE: Considers cases of highest obtainable precision in the category of real imagery as well as additional aspects of layering. Considers the interrelationship of representational accuracy vs. cognitive accuracy with a reorganization of the real imagery classification toward that end.

PIIM PAPER 01, PART FOUR: Presents deeper uses of the taxonomy in next generation information tools for knowledge workers and analysts, as well as how visualization is used in the different disciplines where "out-of-discipline" visualization may find benefits of cognitive gain.

PIIM PAPER 01, PART FIVE: Compares VT-CAD with other taxonomies that deals with other classification and design of informative visualizations.

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