Visual Business Ecosystem Intelligence

Lessons from the Field

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With the emergence of new digital business data, opportunities exist to develop rich, interactive visual-analytics tools. Georgia Institute of Technology researchers have been developing and implementing visual business ecosystem intelligence tools in corporate settings. This article discusses the challenges they faced, the lessons learned, and opportunities for future research.

Visual business ecosystem intelligence is an important emerging capability for a range of corporate decision makers, including analysts, consultants, investors, and executives.[1] Firms are operating in increasingly complex and dynamic business environments. Disruptions and discontinuities can appear from potentially anywhere and have a profound negative impact. To survive, grow, and sustain a competitive edge in such environments, firms must have macroscopic tools that let them systemically monitor and assess business ecosystem activities.[2,3]

An interactive visual approach is particularly valuable because it moves beyond traditional static business reports and indicators to mapping, exploration, discovery, and sensemaking of complex business ecosystems. It lets decision makers digest the data, see patterns, spot trends, and identify outliers, and thereby improve comprehension, memory, and decision making.[4] It also makes business data more accessible and provides a method for improved communication. With an accelerating tsunami of digital business data—generated through enterprise applications and databases, search engines, news portals, corporate websites, patent repositories, online academic libraries, and social media—visual business ecosystem intelligence tools are moving from "nice to have" to "must have for survival."

However, designing and implementing effective tools requires careful consideration of the available business data, user requirements, and task contexts. Infusion in business practices necessitates continuous evaluation and fine-tuning. Although previous research has examined the challenges and opportunities of visualization in corporate settings,[5,6] researchers haven't focused on visual business ecosystem intelligence tools.

Building on earlier research,[1,7–10] this article reports on a series of practical experiences I, along with colleagues from the Georgia Institute of Technology, other universities, and industry partners, had in designing, developing, and deploying these tools. This article has three main goals. The first is to illustrate the growing essentiality of such tools in a variety of decision-making contexts. The second is to describe how we achieved actionable insights. The third is to recommend a process with which to pursue visual business ecosystem intelligence initiatives.

The Approach

Our tool development employs iterative, user-centered design[11] and is broadly organized into the following three phases.

The *envisioning* (predesign) phase consists of observational analyses of the as-is situation (users, tasks, and the decision environment), complemented by clarifying follow-up discussions with expert users. During this phase, we derive user profiles and design requirements. Because corporate users often

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aren't familiar with or clear about potential visualization alternatives, we create and discuss initial paper sketches. We also identify and acquire relevant data sources. If data is proprietary, we put into place appropriate confidentiality agreements.

In the *prototyping* (design) phase, we organize and potentially curate the relevant data. Next, we propose and develop interactive solutions and present them to expert users and other stakeholders. During this phase, many users begin to understand the value of interactive visualization tools and often request specific or additional data sources and functionalities.

During the *finalizing* (implementation) phase, we implement the tools into the work context.

Each phase can comprise multiple iterations; each iteration typically consists of analysis, design, and evaluation activities (observation, interviews, cognitive walk-throughs, and usability testing).

Three Scenarios

We developed tools for three scenarios: managing global supply chain risks, mapping competitive dynamics, and identifying venture capital networks.

Managing Global Supply Chain Risks

Supply chains are the lifeblood of today's global enterprises. Disruptions to them, caused by operational failures, natural disasters, or political unrest, can have significant negative, cascading, and unintended outcomes. Traditional supply chain practices focus primarily on dyadic risk management, rarely considering the complex interconnected and multidimensional nature of supply network risks beyond the first tier. This severely limits the enterprise's ability to more quickly identify the full spectrum of risks and develop appropriate mitigating strategies. Although it's well recognized that geospatial views of a supply chain are important, existing tools are limited. (A notable exception is SourceMap [www.sourcemap.com], which leverages social-data curation to map supply chains for purposes of social responsibility. However, it doesn't focus on visualizing risk data.)

We collaborated with a large aerospace defense manufacturer to develop a visual representation of risks and vulnerabilities in their increasingly complex global supply chain. Our central objectives were to enable supply chain managers to

- visually map, understand, and manage their extended enterprise;
- facilitate proactive risk identification; and
- ultimately provide greater supply chain transparency.

We first conducted an envisioning-phase study with three senior supply chain managers. These domain experts explained and demonstrated their work practices and data analysis problems. We asked clarifying questions where needed. To allow our experts to speak openly, given their work's classified nature, we put in place a nondisclosure agreement, and none of the sessions were recorded.

Next, we evaluated in depth the available supply chain data and metrics. Supply chains in the aerospace defense industry often consist of thousands of suppliers distributed globally and from multiple tiers. Most manufacturers in this industry tend to maintain a substantial inventory of key performance indicators (KPIs), including quality and delivery ratings and supplier risk profiles. Supply chain managers typically use these KPIs to assess their suppliers' operational and financial health and intervene when resolution is needed.

Our contextual inquiry of their work practices revealed three key challenges. First, although direct supply-chain-partner data was available, important subtier network data was sparse. Second, relevant data wasn't integrated or easily accessible and was commonly in table format. Systemic insights were thus difficult to achieve. Third, KPIs were generally presented without the broader context. Together, these challenges made subtier risk analysis a time- and resource-intensive task. Our domain experts articulated that they would greatly benefit from an interactive tool that could provide visibility into their supply network structure and KPIs.

On the basis of this envisioning-phase study, we derived a task list and a set of design requirements. We designed a paper mockup and discussed it with our domain experts. This step enabled user buy-in.

Next, in the prototyping phase, we built a prototype visualization, iteratively validating and fine-tuning our design.

The core visualization included a network-based representation of the global supply chain (see Figures 1 and 2). Nodes represented firms and facilities; edges represented relationships between them, depicting the bidirectional flow of tangible and intangible resources. The nodes' size and color depicted the relative importance (based on structural betweenness centrality) and risk level. We chose a five-level diverging color scheme commonly used to depict increasing risk. The edge thickness corresponded to the level of resource flow, thus indicating dependence. Users could toggle between a force-directed layout, to emphasize the centrality of firms in the supply chain, and a concentric layout, to emphasize the ego perspective of subtier suppliers.

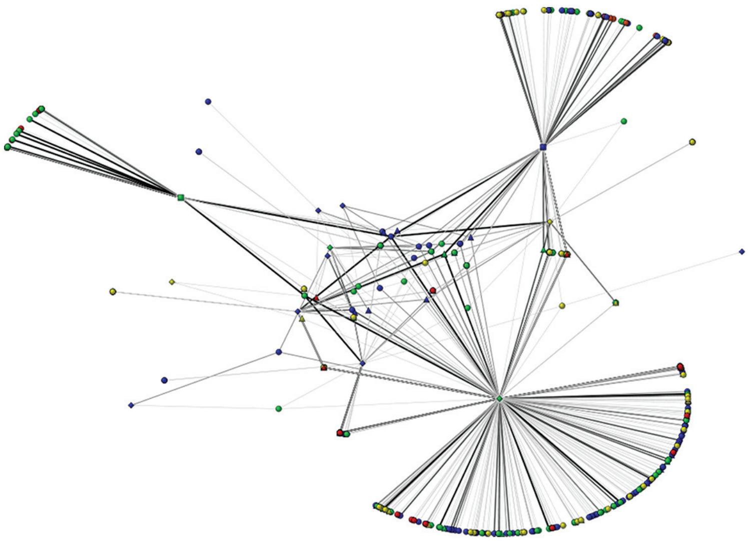

Figure 1. A risk-encoded, force-directed network of a supply chain provides insight into complex interdependencies and enables identification of shared and questionable suppliers. Some shared suppliers in the visualization's center have high risk (indicated by red nodes); the visualization directs decision makers to focus on those for further analysis.

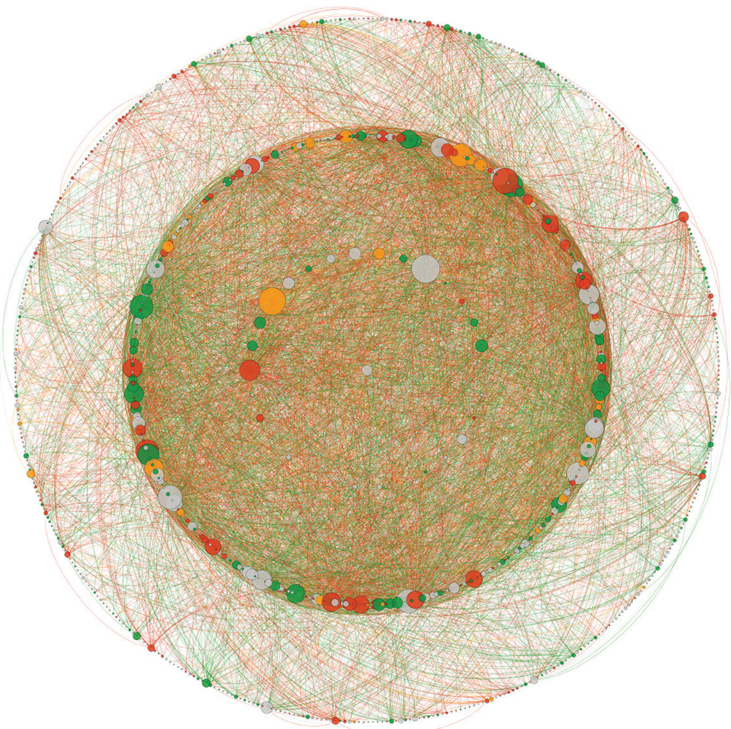

Figure 2. A risk-encoded, concentric layout of a supply chain reveals multitier risk distribution and subtier supplier importance. There are some important first-tier suppliers (encoded by size) with medium (orange), high (red), and unknown (gray) risk.

Postdesign, we conducted a qualitative user study with five supply chain managers. They discussed the benefits and drawbacks of using our tool with real supply chain structure and risk data. We found that they could gain several important actionable insights, including

- rapid identification of high-risk sole-supplier dependence (that is, supply chain breaking points),
- systemic identification of supply bottleneck patterns, and
- tier-wise distribution of supply chain risks.

Our tool's development and subsequent use also led to the formation of a supply chain risk group in our client organization that incorporated our visualization approach into their daily work.

Mapping Competitive Dynamics

Rapid technological advances, changing societal preferences, and shifting economic and regulatory conditions require firms to continuously seek ways to improve existing value propositions and provide new ones to grow and survive. So, an important aspect of business strategy formulation is to scan the competitive environment for opportunities and threats. However, converging ecosystems (the confluence of multiple market segments) make a systemic understanding of competitive dynamics increasingly challenging as firms from potentially distant market segments enter the ecosystem and existing relationships are transformed.

Compared to using perceptual measures, a quantitative visual approach provides a more objective foundation, which is critical for managerial sensemaking and decision making. It also enables comparative analysis of patterns within and across industries as well as a way to answer foundational business ecosystem strategy and policy questions.

In collaboration with business innovation executives and analysts at a leading semiconductor company, we explored how to measure and visually depict the evolution of competitive dynamics of the converging information and communications technology (ICT) ecosystem.[10] Traditional ecosystem analyses use financial data but fail to capture the nature and content of interfirm activities. Instead, and on the basis of analyst feedback, we used the Thomson Reuters SDC Platinum database. This database contains detailed information on interfirm relationships (strategic, R&D, sales and marketing, supply and manufacturing, and licensing and distribution), curated from US Securities Exchange Commission filings, trade publications, wire services, and news sources, across more than 50 market segments from 1990 to 2012. We further organized the market segments into five broad categories based on analyst conventions. The long time range let us account for multiple industry life cycles. The large number of market segments let us examine ecosystem convergence with significant granularity. Our final dataset included 20,232 firms and 20,870 relationships.

Our envisioning phase continued with the specification of relevant competitive dynamic metrics. Grounded in prior research and through iterative discussions with market analysts, we identified three prevalent dimensions of competitive ecosystem dynamics:

- *Coopetition* refers to cooperation between competing firms, possibly leading to win–win conditions.
- *Convergence* refers to the blurring of industry boundaries.
- *Complexity* refers to the information-theoretic structural entropy of the ecosystem.

Both coopetition and convergence are prevalent in the ICT ecosystem as firms continuously search for new ways to create and deliver value.[12] Because none of the three dimensions exist directly, we developed graph and information-theoretic proxy metrics. We verified and validated the metrics through multiple rounds of expert review.

In the protoyping phase, we developed sketches, discussed them with executives, and developed three interactive visualizations corresponding to each metric. Given that relationships (between firms and segments) are key to competitive dynamics in business ecosystems, we used both node–link (see Figures 3 and 4) and matrix (see Figure 5) representations. Throughout the visualizations, we applied consistent node color schemes depicting the five market segments. A key objective of the executives was to map the ecosystem complexity transformation path. So, we integrated a scatterplot with heat map colorization (see Figure 6).

The metrics and visualizations were well received by analysts and executives. They thought that the visualization of the ecosystem complexity transformation path was particularly useful. For instance, using it, they identified that some market segments were more peripheral (for example, media companies) or more tightly interconnected (for example, hardware vendors and software providers), explaining the observed codependence. The visualizations also revealed counterintuitive results, such as the flattening of ecosystem complexity in the early 2000s, which suggested a shift from value creation to value extraction.

Although an ecosystemic view was the initial goal, subsequent discussions about the visualizations revealed that a firm-specific focus, such as the temporal comparison of firm-level strategies and ecosystem positioning, would be highly valuable. We plan to pursue that next.

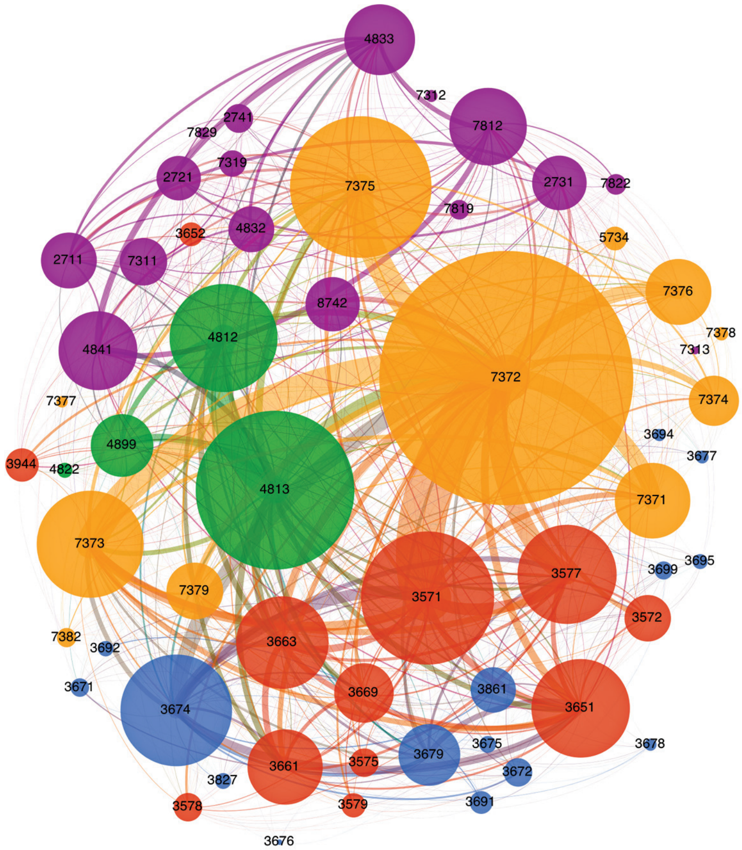

Figure 3. A force-directed network visualization of ecosystem convergence. Nodes depict market segments; edges depict interfirm relationships between market segments. Node and edge sizes are proportional to the number of firms in the market segment and the total number of relationships, respectively. Software segments (orange) play a central role and have strong ties with hardware equipment (red) and service providers (green). Media and content providers (purple) play only a peripheral role.

Identifying Venture Capital Networks

Venture capital financing is an important catalyst for business ecosystems' emergence, growth, and evolution. Venture capitalists (VCs) operate in an information-rich but highly uncertain environment. They cope with this by pursuing startup investment opportunities jointly. The resulting syndicate network lets them reduce and share risks, find and evaluate potential target companies, share expertise, and generate deal flows.[13]

But what syndicate network structural characteristics do successful VCs have, and how does this network change by funding round? The use of quantitative approaches, including data mining and pattern recognition, to scout better deals and entrepreneurs is gaining traction in the VC community. Nevertheless, visual-analytics tools that map and help explore the venture-capital-financing landscape are still limited.

We collaborated with a serial entrepreneur turned VC to visually map the syndicate network structure of the converging technology ecosystem.

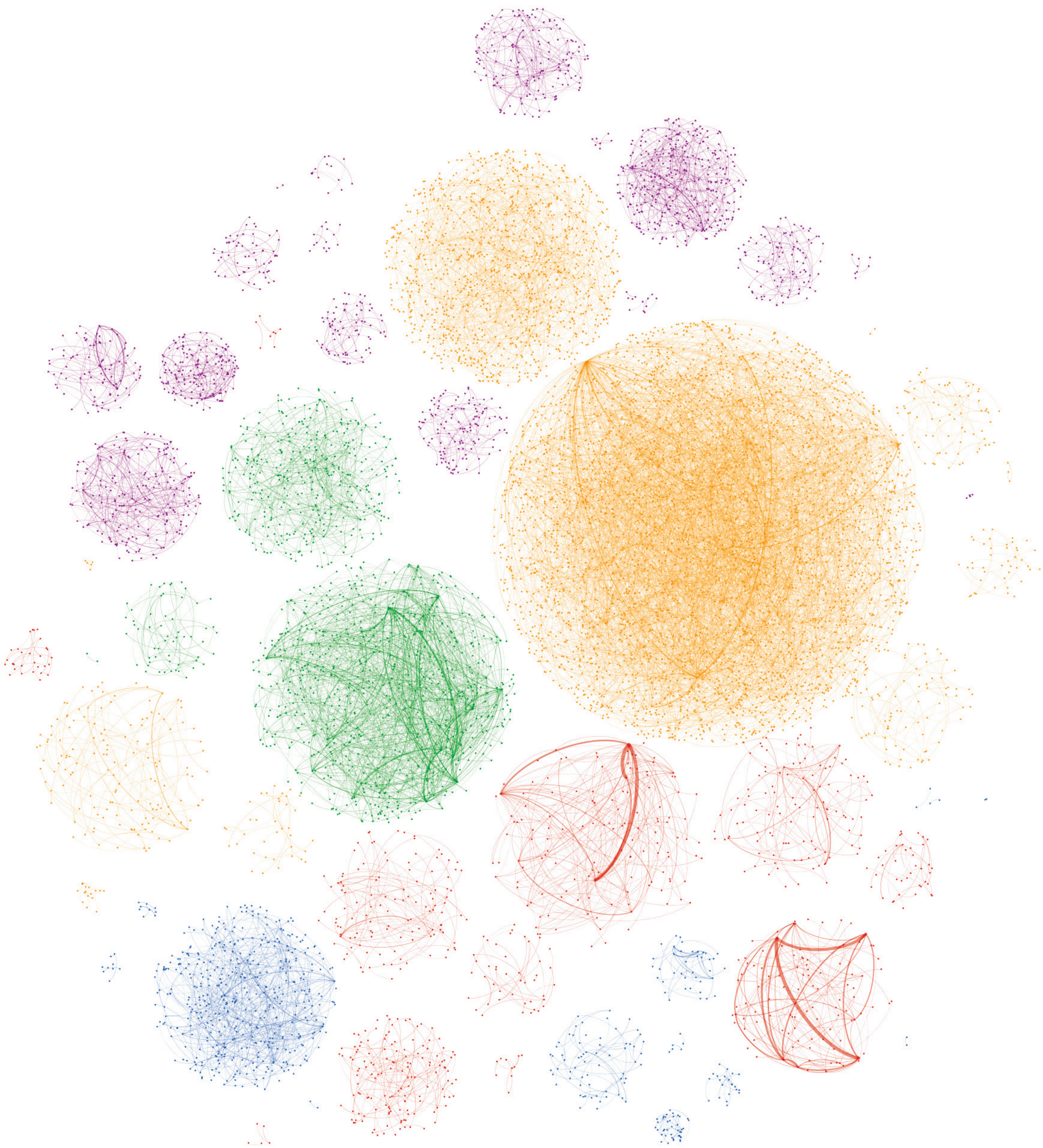

Figure 4. Ecosystem coopetition refers to the collaboration level in each market segment. We used the same layout as for ecosystem convergence to position market segments and visualized the firms and relationships in them.

The objectives were to understand what investment strategies VCs pursue and identify how the structure differs across the early and late financing stages.

Our earlier discussions with several senior VCs revealed that accurate, comprehensive data on VC financing is scarce and often limited to specific market segments. Most VCs maintain their own proprietary datasets. Although some commercial databases exist (for example, Thomson Reuters' VentureXpert), they're costly and cumbersome to work with. More recently, however, open data sources have emerged. Perhaps the most prominent is CrunchBase (www.crunchbase.com), a socially curated venture-capital-financing website containing data on firms, investors, and funding rounds.

When we commenced this project, an API to download data wasn't available. Our initial task therefore involved the tedious step of scraping and preparing data for visualization. We found that although the data was rich, it contained missing elements, including funding rounds, dates, and market segment information. Our final curated dataset included more than 71,000 funding rounds for more than 62,000 companies by 8,049 funding entities (41 percent business angels and 59 percent venture capital firms) from 2007 to 2012.

Our envisioning-phase discussions revealed that VCs prefer summary visualizations first and then details on demand. So, we sketched a design that would depict the evolution of overall venture-capital-financing investments (total and average) and a categorization by market segment. We proposed several designs but ultimately settled on an integrated line and bar chart (see Figure 7).

Next, we developed a venture-capital-financing syndicate network visualization using a concentric layout (see Figure 8). We differentiated investor types by color (angels in red, VCs in turquoise) and used that color scheme throughout all other visualizations. The visualization was searchable, zoomable, and filterable by investor type, market segment, and funding round. A temporal slider let analysts examine the network over time. Hovering over nodes provided additional details.

From our contextual inquiry, we learned that VCs often coinvest in multiple ecosystem segments. To depict the coinvestment pattern in different market segments, we used a matrix differentiated by investor type (see Figure 9). The darker the cell, the greater the coinvestment level was. Analysts commented that this representation let them confirm their perception that VCs coinvested in closely related segments (for example, software and the Web), whereas angels' investment strategies were a bit more exploratory.

Finally, we used multidimensional scaling to visualize how investors' portfolios differed. On the basis of previous research, we used a modified Blau index to calculate an investor's portfolio diversity. Our visualizations (see Figures 10 and 11) revealed that VCs tended to be fairly similar, with the most successful ones being more centrally located. Superangels, however, were clearly differentiated from the pack, leading to an important aha moment.

During the finalizing phase, an initial postdesign survey with a group of VCs indicated that our visualizations provided helpful insights into the syndicate network's macroscopic structure. The VCs particularly liked that our visualizations were built on open data. They also commented that the segment coinvestment and angel–VC similarity visualizations were particularly useful. These views let them understand startup investment strategies and identify potential syndicate partners.

Lessons Learned

The lessons we learned fall broadly into the categories of data, users, design and implementation, and evaluation.

Data

Corporate data is often distributed across different groups in the firm. Relevant secondary data from external sources might also be available. We found that decision makers often prefer visualizations driven by both proprietary and open data to gain comprehensive, complementary, and comparative insight. Careful curation of relevant data, which involves identification, extraction, organization, integration, and verification, is thus critical for successful use of visual business ecosystem intelligence tools.

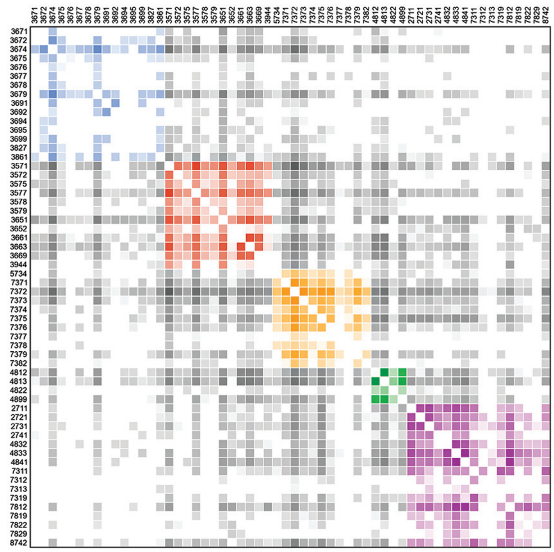

Figure 5. A market-segment ordered matrix of ecosystem coopetition. Colored blocks represent the extent of coopetition in a market segment. Gray cells indicate collaboration with other market segments. The hardware component segment (blue) is sparsely interconnected, suggesting low levels of coopetition.

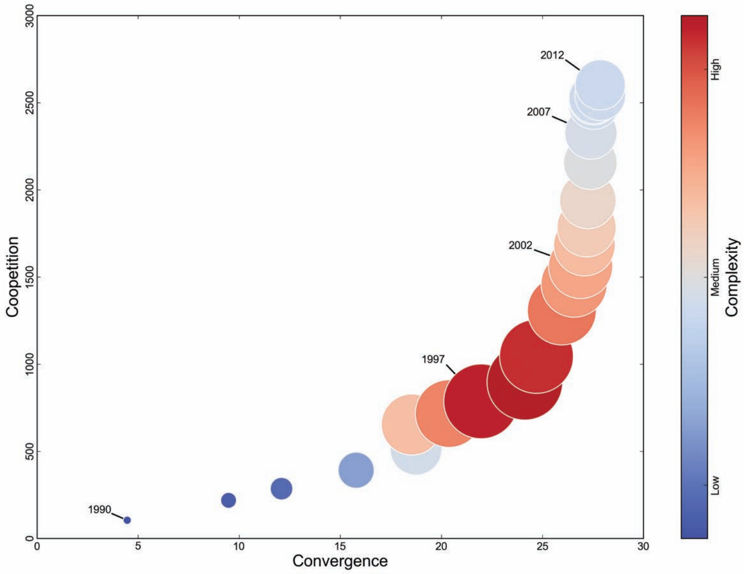

Figure 6. An ecosystem transformation path visualization, framed in terms of convergence, coopetition, and complexity, reveals a business ecosystem's competitive trajectory. The ecosystem was shaped early on by increasing convergence and more recently by increasing coopetition, suggesting a shift from value creation to value capture.

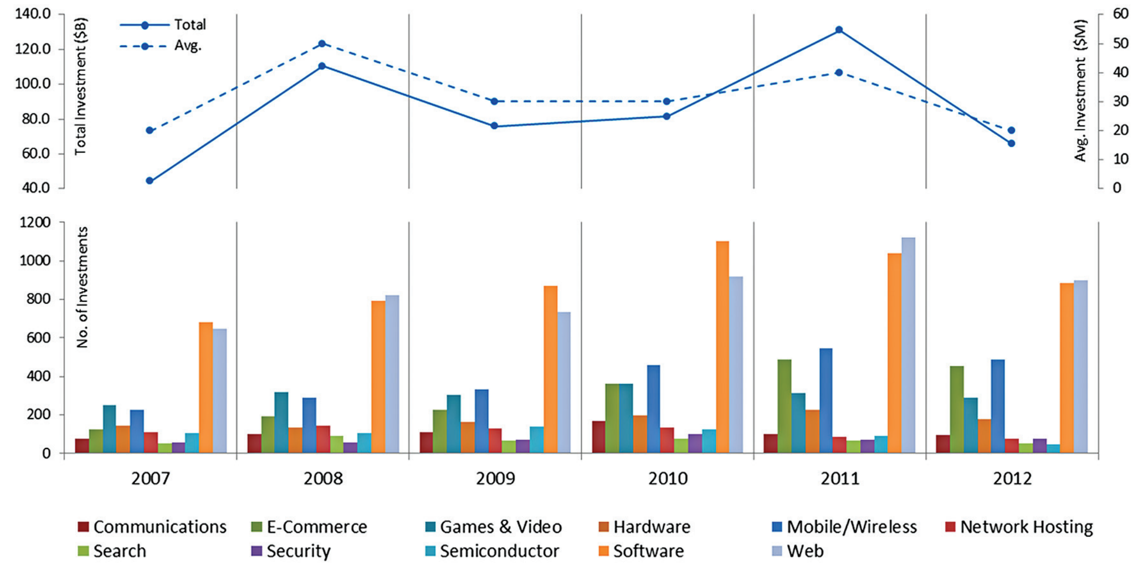

Figure 7. The evolution of venture-capital-financing characteristics by information-and-communications-technology ecosystem segment. The figure identifies a disproportionate level of investments in hardware and the Web compared to semiconductors and security.

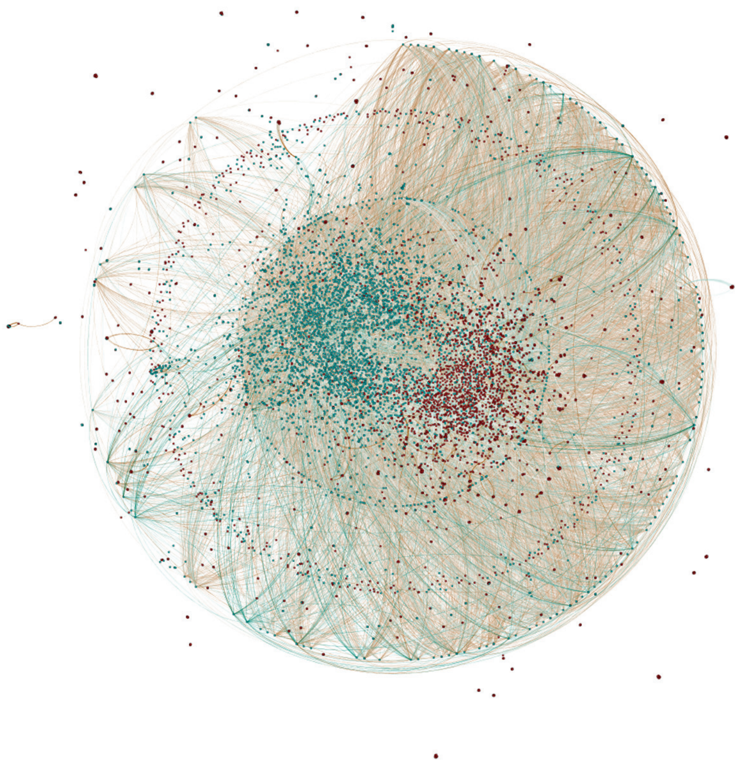

Figure 8. A venture-capital-financing syndicate network with angels in red and venture capitalists (VCs) in turquoise. The edge color indicates the portfolio similarity between two investors.

Business ecosystem analysis requires an explicit specification of system boundaries. In some cases, they're predefined—for example, by geographic location, market segment, supply chain, or relationship type. In industry analyses, however, it's unclear which market segments to include or exclude. In such contexts, we found it particularly valuable to use a seed-snowball approach, in which we selected an initial list of core firms, including all related firms (within *k* steps). Without a specification, any entities are fair game, and ecosystem data can quickly get unmanageable.

Corporate decision makers like metrics. Unfortunately, ecosystem-level measures are rare and must be developed from the underlying business data. We found that iterative development, verification, and validation of metrics grounded in established prior research or disciplines resonates with executives. For instance, we used strategy research and graph theory to develop relevant ecosystem metrics.

Most firms have confidentiality guidelines and information restriction policies that protect sensitive technical or commercial information from being disclosed to others. Any information collected during tool development is therefore subject to these requirements. Such policies might also restrict accessibility and use of the visualization tool and publication of results. We found that a confidentiality agreement let us exchange information more freely and build trust with our expert participants by ensuring that information was handled appropriately.

Users

Developing these tools requires an understanding of users' visual literacy. Most corporate decision makers are comfortable with traditional computer-aided support tools such as pivot tables and spreadsheets. In our studies, visual literacy varied substantially, with many users comfortable with network visualizations but fewer users comfortable with matrix

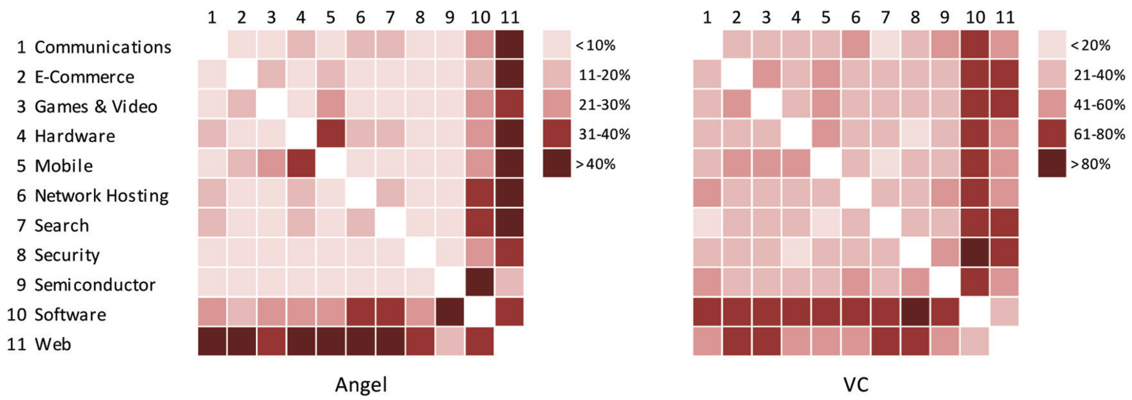

Figure 9. Comparing ecosystem segment coinvestment between angels and VCs. This representation let the analysts confirm their perception that VCs coinvested in closely related segments (for example, software and the Web), whereas angels' investment strategies were a bit more exploratory.

visualizations. As visual business ecosystem intelligence becomes more mainstream, it's important to consider what type of user and associated learning curve will be involved. The key tradeoff is the time and effort to develop tools that are useful, intuitive, and simple versus those that are more advanced with greater functionality and capabilities.

Overcoming technology inertia is a significant challenge. Corporate decision makers are often attached to existing tools and reluctant to learn a new system despite its potential value. We found that through discussions, participatory design, and prototypes we could reduce reluctance in adopting and using new tools. Once users were comfortable with a tool, they requested additional data and tool functionalities.

Design and Implementation

There are a wide range of ecosystem analysis tasks. Contextual inquiry and iterative design are critical to understanding tasks and workflow and developing effective visual support, respectively. We found that visualization sketches helped accelerate the design process. Prototypes let us evaluate the task–visualization fit and improve and finetune the tools.

We also observed that corporate decision makers preferred hybrid and linked visualizations instead of being locked into one type of view. This let them explore the data more freely, use the representation they were most comfortable with, and compare and contrast complementary perspectives on the same type of data.

The assimilation of these tools requires a project champion and top management support. Commitment is critical to drive consensus and oversee the implementation life cycle. In the three cases we report here, we worked with corporate decision makers who were committed to developing new tools for ecosystem analyses.

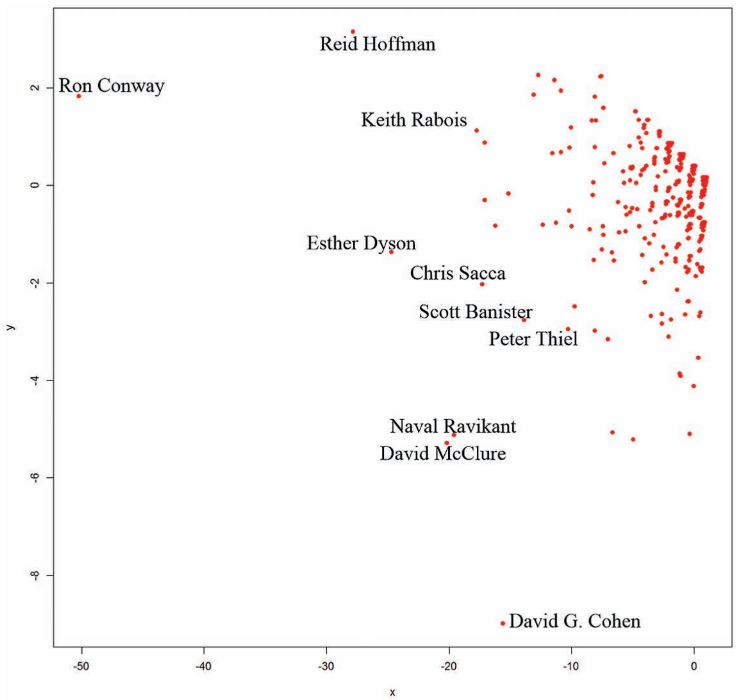

Figure 10. A multidimensional-scaling visualization of angels. Our visual-analytics approach identified superangels (labeled) as outliers.

Evaluation

We conducted evaluation and usability studies with both our direct collaborators and external users. This provided important feedback on tool usability and usefulness, reduced our collaborators' time commitment, and potentially let us understand relevant functionalities we hadn't initially considered. We conducted evaluations throughout the prototyping and finalizing phases, enabling us to accelerate the entire process.

Although our tools have been deployed in practice, we don't have extensive longitudinal data yet. Such a study should provide further insight.

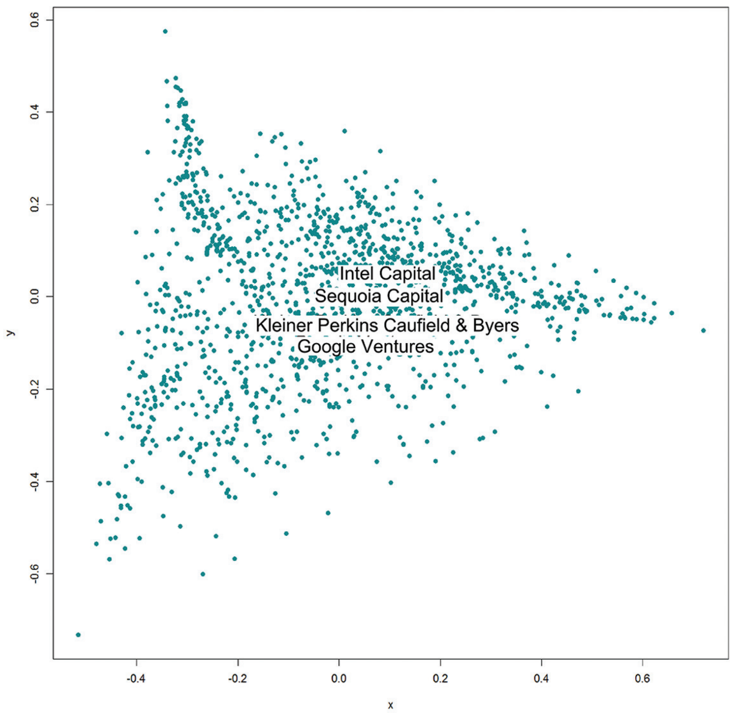

Figure 11. A multidimensional-scaling visualization of VC firms. Highly active VCs (labeled) are more centrally located.

By presenting our experiences here, I hope to advance the understanding of visual business ecosystem intelligence tools and help others who are considering developing them.

Interesting future research includes the integration of predictive and prescriptive analytic capabilities, as well as the development of tools for collaborative and distributed-intelligence environments.

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