

Understanding Interfirm Relationships in Business Ecosystems with Interactive Visualization

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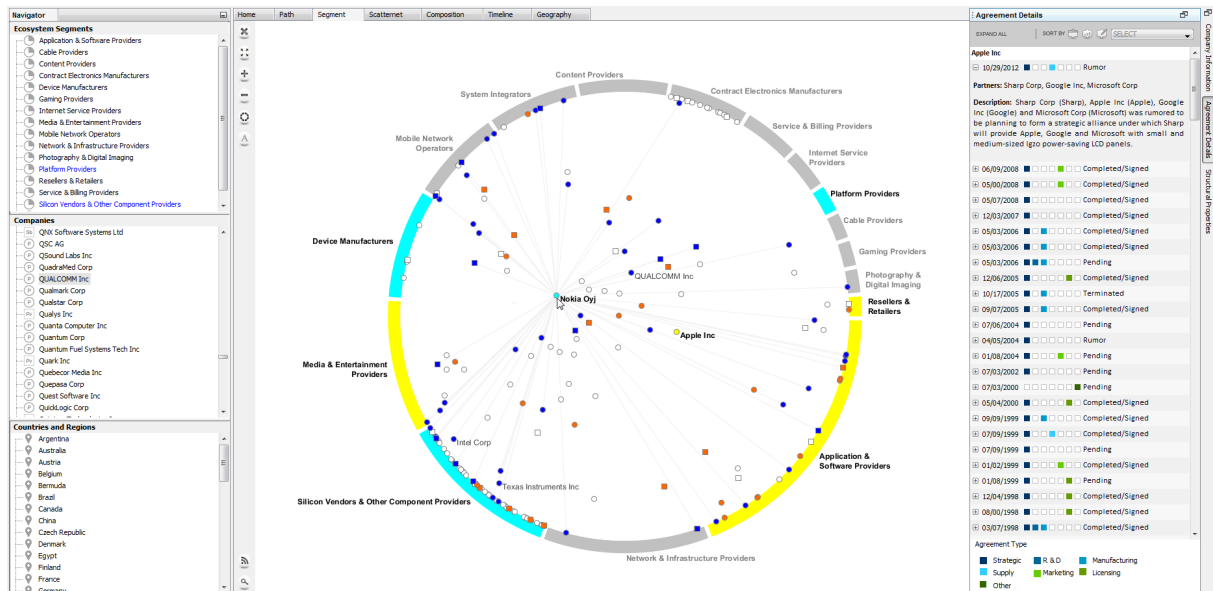


Fig. 1. The dotlink360 user interface including the navigator panel (left), the central visualization window, and the details panel (right). This image shows the Segment view with Apple selected so it and its market segments are colored yellow, while its partners are colored orange. The mouse cursor is over Nokia so it and its segments are colored light blue, with its partners dark blue. Company positions are determined by their segment memberships.

Abstract—Business ecosystems are characterized by large, complex, and global networks of firms, often from many different market segments, all collaborating, partnering, and competing to create and deliver new products and services. Given the rapidly increasing scale, complexity, and rate of change of business ecosystems, as well as economic and competitive pressures, analysts are faced with the formidable task of quickly understanding the fundamental characteristics of these interfirm networks. Existing tools, however, are predominantly query- or list-centric with limited interactive, exploratory capabilities. Guided by a field study of corporate analysts, we have designed and implemented dotlink360, an interactive visualization system that provides capabilities to gain systemic insight into the compositional, temporal, and connective characteristics of business ecosystems. dotlink360 consists of novel, multiple connected views enabling the analyst to explore, discover, and understand interfirm networks for a focal firm, specific market segments or countries, and the entire business ecosystem. System evaluation by a small group of prototypical users shows supporting evidence of the benefits of our approach. This design study contributes to the relatively unexplored, but promising area of exploratory information visualization in market research and business strategy.

Index Terms—Business ecosystems, market research, strategic analysis, design study, interaction, network visualization

1 INTRODUCTION

Business ecosystems are characterized by large, complex, and global networks of firms, from many different market segments, all collaborating, partnering, and competing to ultimately create and deliver products and services to end customers [9]. Appropriate levels of competitive insight in business ecosystems are thus very difficult to achieve

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and generally limited to a firm’s immediate market boundaries. This, however, has significant business implications as firms may underestimate serious competitive threats and disruptive firm activities resulting in a loss of strategic competitive advantage or market share [5]. Driven by these economic pressures and an increasingly complex global business environment, business ecosystem intelligence systems are now moving from “nice-to-have” to “must have for survival”.

Business ecosystem intelligence is an important capability for a wide range of corporate decision makers, including analysts, consultants, investors, and executives [25]. Market analysts, for instance, seek to understand competitive trends, strategies, threats and opportunities. Executives seek to identify potential strategic collaborators and customers and determine innovation white spaces. Venture capitalists would like to identify promising investment opportunities and determine how they fit in the overall business landscape. For readability, these types of users are referred to as “analysts” from here on.

The fundamental challenge is that these types of analysts have access to and must digest far more data than they have time for, and the

amount of potentially relevant ecosystem data keeps increasing [34]. Existing tools in this area predominantly create list-based reports or static snapshots of interfirm activities with little flexibility, thus providing a highly myopic view of business ecosystems.

To address this problem, we have designed and developed dotlink360, an interactive visualization tool that supports the analysis of interfirm relationships in business ecosystems. We utilize information visualization because it capably supports the open-ended exploration and flexible questions that analysts generate. Furthermore, visualization is an effective way to portray the complex interfirm networks that characterize business ecosystems. Our research began with a field study of analysts and we established a set of design requirements based on our findings. An initial version of dotlink360 [8] met many of the design goals, but user testing revealed a number of problems in its interface and visualizations. Thus, we performed a significant redesign of the system. Following [41] we report on our development process and the new system in this design study.

dotlink360 is the first system to provide a connected set of views that give insights into the compositional, temporal, and connective nature of large-scale complex business ecosystems. The system, whose interface is shown in Figure 1, provides a flexible, interactive way for analysts to explore interfirm networks and relational content of individual companies, ecosystem segments, and countries. Common partners and ecosystem segment membership can be visually identified, agreement portfolios can be compared, and networks can be mapped by salient ecosystem metrics. We also provide the ability to *broadcast* relevant companies from one view to another, facilitating rapid multi-view comparisons and insights.

2 DATA AND FOCUS DOMAIN

Our system draws on the industry’s two foremost data sources for the analysis of interfirm relationship structure and performance: Thomson Reuters SDC Platinum and Capital IQ Compustat.

The Thomson Reuters SDC Platinum database (henceforth SDC) is the most prominent, comprehensive, and accurate commercial database used in the analysis of global interfirm relationships across multiple sectors [39]. It is widely used by researchers and practitioners alike in the fields of strategy, finance, and policy (e.g., [24, 38, 40]). SDC contains detailed information on nearly 700,000 global alliances, agreements, and joint-ventures across over 1,000 industry segments from 1985 to the present. The underlying data is curated from SEC filings, trade publications, wires and news sources, validated by an extensive, expert staff, and updated monthly. The nature of each relationship is described by several elements, including important relationship dates (announced, signed, terminated, extended), relationship type (e.g., strategic, marketing, research & development, licensing, marketing), firms’ primary and secondary market segment (based on Standard Industry Classification Codes), contact information, ticker symbol, and a textual synopsis of the relationship content and terms. SDC does have some limitations. It is accessed and explored using a query-based approach. Results are presented through list-based reports with each row depicting a single relationship. This output format makes systemic understanding of interfirm structure and evolution challenging at any level of analysis (i.e. firm, segment, country, etc.).

Capital IQ Compustat (henceforth Compustat) is a comprehensive and widely used database of financial information of active and inactive publicly listed companies in the world. Compustat is primarily used by institutional investors, bankers, advisors, analysts, and asset/portfolio managers. For each publicly traded firm from SDC, we obtained relevant quarterly financial and accounting data.

We selected perhaps the most dynamic and rapidly evolving industry today, the mobile ecosystem [7], as our initial focus domain. Driven by the convergence of enabling technologies, devices, and applications, the complexity of the mobile ecosystem is increasing multifold as new actors emerge, new interfirm relations form, and the traditional distribution of power shifts. Mobile network operators are worried about becoming “dumb pipes” and consequently are searching for new business models. Platform providers are in a fierce battle for dominance. Device manufacturers are rapidly launching innova-

tive smartphones. New apps – ranging from productivity to games to wellness – are emerging on a daily basis. Participant firms in the mobile ecosystem come from a variety of ecosystem segments. Potentially disruptive innovations can thus appear from a plethora of areas. Analysts are in need of effective ecosystem intelligence tools that help them navigate and make sense of the diverse activities shaping this highly complex and global business environment.

The dataset for the mobile ecosystem we use in dotlink360 draws from SDC and Compustat. An all-inclusive dataset of this ecosystem would contain more than 40,000 companies across 16 segments. As our focus was on the most relevant companies in the ecosystem, we narrowed our focus to the largest firms and their relationships across these segments. These firms were identified by a set of experts as well as drawn from practitioner mentions in press releases. We dropped companies not having a connection with this set from this version of our system. Thus, the final dataset for dotlink360 contained 2,809 companies (58% publicly listed, 34% U.S. based) and 17,025 agreements (80% strategic, 15% R&D, 14% Manufacturing, 3% Supply, 21% Marketing, 14% Licensing) from 1990-2012. For each of the publicly listed companies (1,620), we retrieved financial and accounting information from Compustat. This includes measures such as capital expenditures, cost of goods sold, earnings, earnings per share, market capitalization, low/high 52-week stock price, price/earnings ratio, return on assets, research and development expenditures, and selling, general, and administrative expenses. As the two datasets used separate company identifiers, in several instances we had to manually fix company name inconsistencies. We also truncated some company extensions (e.g., Corporation to Corp, Incorporated to Inc, etc.) and generated company aliases to ensure readability of labels in the views.

More abstractly, our ecosystem dataset is a network, with nodes and edges representing companies and agreements respectively. The network is also multivariate as nodes (companies) have many attributes and edges (agreements) have multiple types. Furthermore, the network is time-varying as agreements occur at specific points in time.

3 RELATED WORK

While there is a growing recognition of the potential value of visualization in the business, strategy and innovation communities [15, 31, 49], there is a dearth of tools that interactively visualize interfirm networks and business ecosystems. Most visualizations are static depictions of organizational networks (at the inter-personal, -firm, -region, or country level) using (social) network analysis software such as Pajek [2], UCINET [4], or Gephi [11]. Examples include analyses of biotechnology [37], software [26], manufacturing [33], and mobile telecommunications [7, 10]. These visualizations, however, merely complement the corresponding statistical analyses of organizational networks and primarily provide network, matrix, or multi-dimensional scaling views, offering limited user interactivity and flexibility to depict more complex relationships. Data cannot be automatically refreshed and must be manually modified every time a new visualization is requested.

Existing business visualization tools primarily focus on specific business issues or contexts, such as business processes [43], knowledge management [13] and discovery [16], technological intelligence and forecasting [50], portfolio management [17], finance and stock markets [18, 45, 51], or patent analysis [27, 28]. Most of these business visualization tools, however, simply act as measurement dashboards and not as exploratory systems. Notable exceptions include Wright’s suite of 3D visualizations for business applications [48], such as management decision support, reporting, and risk management in domains such as banking, retail, and manufacturing; the Bloom Project [23], which uses Prefuse-Flare to depict relationships between organizations in complex networks; and Quid [19], which uses Gephi to visualize technology areas. However, our system differs from these tools in several ways. Wright’s 3D visualizations focus primarily on portfolio, financial, and transactional data and not on entity network relationships. While Bloom and Quid provide network visualizations, they only utilize a single view and do not consider ecosystem data on market segments and countries. Our system in contrast allows interactive exploration of these ecosystem data using multiple views.

4 DESIGN REQUIREMENTS

In order to better understand the requirements and desirability of an analysis tool for the mobile industry ecosystem, we conducted an in-depth field study, consisting of a web-based survey and interviews with 24 senior industry individuals. Participants included eight technology market analysts, fourteen executives (e.g., CXOs, VPs, and Directors) from technology and consulting companies, and two technology venture capitalists. All participants held strategic decision making roles in their respective organizations and had significant media, IT, or telecom work experience (>10+ years). Cumulatively, this group of experts provided a significant level of depth and breadth of knowledge to inform the design of a business ecosystem analysis and visualization system. The results of this field study led to the identification of a number of core design requirements that have driven our research.

Both top-down and bottom-up examination of an ecosystem are critical. 21 of the experts emphasized the ability to examine business ecosystems from a company, market segment, or country perspective. One expert commented that *"it is helpful to have a birds-eye view of the ecosystem, but at the same time [the system] should be able to allow users to drill down into individual companies and segments."* Providing flexible navigation between higher-level ecosystem overviews and individual company details became a key objective for us.

Understanding interfirm connectivity, composition, and temporality is vital. All of the experts stressed the importance of interfirm relationships, the portfolio of interfirm agreements, and the longitudinal evolution of agreements in ecosystems. It became clear that presenting these relationships, their compositions, and their temporal characteristics would be vital.

Comparative perspectives drive insights. 22 of the experts commented that they preferred multiple, complementary perspectives on the agreement data that allow them to quickly compare and contrast different aspects of the company agreements. One expert, for instance, stressed that *"... [she] wanted to see the same data from multiple angles."* We thus believed that it would be important to communicate multiple perspectives to the analysts.

Communicate agreement summaries first, then details as desired. A majority of the experts emphasized that structural patterns between firms are more important than details of the agreements in the early phases of ecosystem investigation as it allows them to examine high-level strategic behavior before understanding specifics of the relationships. As one expert highlighted, *"show me the most essential things first, and if I want more, it should be available on click."*

Provide a familiar metaphor while supporting direct and prompt interaction, not complex queries and commands. Analysts are not necessarily computer experts and they do not want an overly complex analysis tool. While some complexity is inevitable because of the size and variety of data involved, the system still should be relatively easy to learn and use. All of the experts advocated a simple user interface with familiar functionalities (e.g., scrollable lists, drag-and-drop, right-click for menus) found in common software packages.

Beyond these domain-specific design requirements, we determined that common network-related analysis tasks such as those identified in the taxonomy [30] and exemplified in systems such as Vizster [21], SocialAction [36], and MatrixExplorer [22] should be supported. Furthermore, adopting the "Search, Show Context, Expand on Demand" design model [44] seemed appropriate for the system.

5 SYSTEM

Based on our user and task analysis, we developed a visualization system to communicate interfirm relationship information to analysts. The initial version of the system provided multiple visualizations, and potential analysts felt that it provided many useful representations of the data [8]. However, they also identified a number of usability and organizational issues with the system, and had difficulty using the force-directed network visualizations it provided. Thus, we decided to redesign the system incorporating the knowledge we gained building and evaluating the first version. We carried only one of the initial system's five visualizations forward (the Periscope view which we now call the Segment view) and created a new, simpler interaction model.

The new dotlink360 system interface (see Figure 1) is divided into three sections. The center and largest region contains the six main visualizations (called "views") provided by the system. Each view resides in a separate panel that is selected via the tabs at the top. On the left of the interface is a "navigator" panel with scrolling lists containing the ecosystem segments, companies, and countries, respectively. An analyst drags items from these lists into a center visualization in order to view the items in that context. Finally, the right region of the interface is a "details" panel where detailed information about companies and relationships in the center view is shown.

We decided to use multiple visualizations within the system due to the variety and amount of data about each company and its relationships, as well as the different perspectives that an analyst might explore. The central region is the focus for the analyst and receives the majority of attention and interaction. We believed that the tab metaphor would be familiar and easy to navigate for the prospective analyst population. We made the design decision of including an explicit details region to the right rather than overloading the central visual representations due to the volume of data to communicate. This right region can be expanded and hidden on demand.

In dotlink360, we also made an explicit design decision to focus more on individual companies rather than present visualizations of the complete ecosystem. Our earlier interviews with analysts revealed that they usually explored specific companies in detail rather than broadly browsing all companies. Furthermore, we believed that visualizations attempting to show all the companies and their interfirm relationships within this dataset would be exceedingly dense and complex, and difficult to draw much information from.

The general workflow of the interface is from left-to-right. The analyst pulls companies, segments, and countries from the navigator panel into the center and then interacts with the view, occasionally displaying further details to the right as desired.

The six views in the center region provide the foundation for interactive exploration in dotlink360. The views communicate three primary perspectives about companies in the mobile ecosystem: *compositional* (1 view), *temporal* (1 view), and *connective/structural* (4 views). Across all the views, a number of interactive operations are present, available through a command bar at the left edge of the center region. For example, commands for clearing the view and searching for a company are present. Additionally, we provide a "Broadcast" command that allows all the companies in one view to be sent to one or all of the other views, either as replacements or additions.

Other interactive operations are persistent throughout the views, such as mouse hover that presents quick details via tooltip, and a right mouse button click that displays more commands for the selected company, including showing more details in the right interface region.

The right details region contains panels for company information, agreement details, and network structural properties (Figure 2). The company information panel shows a company's address, market segments, and key competitors, among other information. The agreement details panel lists all of a company's agreements and their characteristics or those between two companies. The structural properties panel provides many metrics about the company including counts and status of different agreement types, agreement metrics such as a portfolio diversity index, and structural properties such as the company's betweenness centrality and clustering coefficient in the ecosystem.

The subsections below describe the three visualization perspectives and the six constituent views in more detail. To help explain each, we use a running example of an analyst interested in learning more about Hewlett-Packard's (HP) interfirm relationships.

5.1 Compositional Perspective

The Composition view provides a perspective on how different agreement types contribute to the agreement portfolio of an entity (company, market segment, or country). This view helps analysts perform part-to-whole analysis of an entity's agreements and a comparative analysis of the agreement portfolios of multiple entities.

Similar to the parallel bargram motif [47], the view (shown in Figure 3) displays two horizontal bars for each entity being displayed.

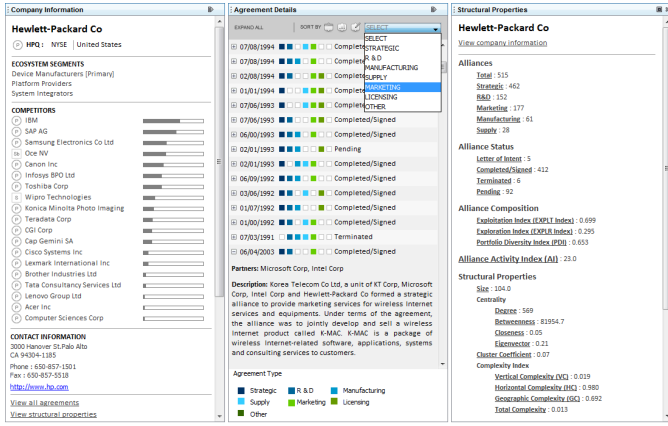


Fig. 2. The three details panels that can be shown in the right UI region.

The top bar represents the complete agreement portfolio of an entity and consists of color-coded horizontal regions. Each bar segment represents a different agreement type (e.g., strategic, R&D, licensing, etc.) and its length is proportional to the number of agreements of that type. Note that an agreement can be of multiple types thus the numbers in the top bar often sum to a total larger than shown in the lower bar. Multiple entities can be displayed in the view and they are positioned into different sections (companies, market segments, and countries) as the analyst drags them into the view. The length of every entity's top bar is the same, so it only represents proportions of agreement types. The lower gray bar for each entity represents its total agreement count and its length is scaled to reflect that number. Figure 3 shows HP's agreement portfolio as well as the portfolio of Samsung, a key partner and competitor; the agreement portfolio of one of the market segments both operate in; and the agreement portfolio of South Korea, where Samsung is headquartered.

We considered multiple representations for the Composition view (pie charts, vertically stacked bars, etc.) but ultimately decided on this horizontal composite bar strategy. We believed that this representation depicts the part-whole ratio well, would be familiar to the system's potential analysts, and would easily facilitate comparison between multiple companies, segments, and countries. Its horizontal orientation also allows text labels to be easily read. Because the number of agreements for a particular entity can vary from just a few to thousands, we decided to use the single gray lower bar to represent the total count (scaled using a square root function) and the longer colored bar of a consistent larger size to show relative agreement type proportions.

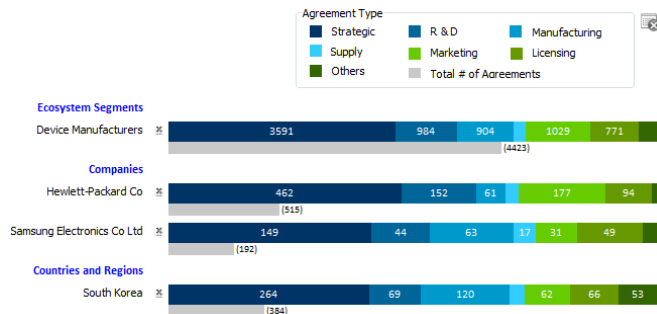


Fig. 3. The Composition View shows the agreement portfolios of companies, market segments, and countries. The top bar for each encodes proportion of agreement types, while the bottom depicts total count.

5.2 Temporal Perspective

The Timeline view (Figure 4) provides a temporal perspective on the trend in agreements formed by a particular entity such as an individ-

ual company, an ecosystem segment, or a country. This view helps analysts to understand how that entity's participation in agreements of different types has changed over time.

We decided to employ a traditional time-series style visualization with time progressing along the x-axis. This type of representation is common in many time-oriented visualizations [6] and we felt it would be familiar to analysts. We considered using a control slider to animate through periods in time, but showing an entity's complete history of agreements seemed better for comparison and trend-spotting.

Specifically, the Timeline view presents both a line chart and a bar chart as shown in Figure 4. The lower bar chart displays the yearly distribution of different agreement types for the selected entity. Each agreement type is represented by a colored bar whose length is proportional to the number of agreements of that type formed in that year. (Recall that agreements can be of multiple types.) Clicking on a year label expands it to show the monthly breakdown for that year. The upper line chart represents the total agreement count in each year for the selected entity. When the entity is a company, the line chart also plots the average number of agreements in the company's primary market segment and the average across all segments using two red triangles.

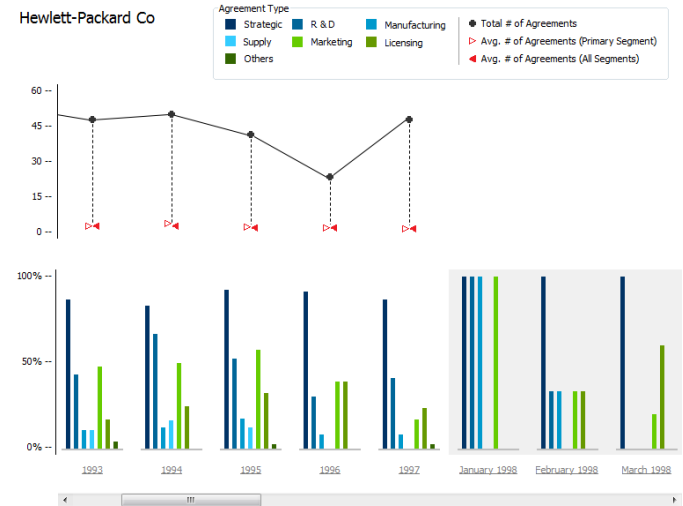


Fig. 4. The Timeline View shows total agreement count relative to primary segment and overall ecosystem (top) and a yearly/monthly breakdown by agreement type (bottom).

5.3 Connectivity Perspective

A final key perspective of interfirm agreements is to show the set of connections between companies. We ultimately decided to use four different views to represent this perspective. Each one emphasizes a different accompanying attribute of the dataset. All four views (Path, Segment, ScatterNet, and Geography) utilize a node-link network visualization where companies are the nodes and a link is drawn between two nodes if those companies have an agreement. Each visualization then positions the company nodes according to its theme or individual perspective, as discussed below. Node-link representations are pervasive and many widely-used software systems such as Gephi [11] and NodeXL [20] have further popularized their application.

We considered other network representation techniques such as a matrix-view or a connection list but ultimately decided on a node-link representation for multiple reasons. First, we knew that the node-link representation was well-known by potential users of the system. This familiarity should lead to more rapid learning and understanding of the visual metaphor and interface. Second, we believed that other design choices we were making would offset some of the well-known negative aspects of node-link diagrams. In particular, we decided not to render the entire set of companies and resulting massive network,

which would only lead to the classic “hairball” visualization problem. Instead, we use an approach where an analyst starts with a company of focus and then expands connections from there. This style of beginning network exploration from a focus then growing out based on interest has been illustrated in systems such as Vizster [21] and [44].

Additionally, we decided not to use a “traditional” graph drawing algorithm such as force-directed placement to position companies in our visualization. An earlier version of dolink360 [8] did just that but analysts did not like the instability of the layouts – small changes in the companies shown sometimes caused big changes in the positioning. Further, analysts inferred information from company positions even though those positions really did not signify much beyond network connections. Instead of that approach, we now provide either a simpler node positioning strategy (Path) or we position company nodes based on other important data relating to the company (Segment, ScatterNet, Geography), following an attribute-based layout strategy [46, 42].

Within all four connectivity views, visual characteristics of the nodes, commands for rendering the network, and interactive operations on the nodes are consistent. For instance, public companies are shown as small circular icons and non-public (private, non-profit, and subsidiary) companies as small square icons. When a company is dragged into a visualization, it becomes selected and its node turns yellow. A single mouse-click also selects a company node and turns it yellow. Visible companies holding an agreement with a selected company are colored orange and their two nodes are connected with a faint gray line. For interactive exploration without an explicit selection, simply mousing over a company highlights it in light blue and all its agreement partners in dark blue. The nodes revert to their prior color when the mouse cursor moves off the node. When the analyst double-clicks on a company’s node, all of its agreement partners are added to the view. Thus, the analyst can progressively add more and more companies as desired.

We considered different alternatives for companies and connections but ultimately settled on the design described above. We did not want to introduce too many node shapes and, based on user feedback, used two icons to represent public and private companies. We decided to use node color to represent the state and context of interactive mouse selections rather than company attributes. Similarly, we did not vary the size of the nodes. Instead, we use node positioning on the right-side panel to communicate other company data and attributes. We felt that this provides a “cleaner” visual representation of the network that would be easier to read and understand. Similarly, we considered altering line thickness and color for representing agreement (edge) attributes, but because attributes such as agreement type and number have so many potential values, we felt that such a mapping would lead to a confusing rainbow of varying edges throughout. Ultimately, many design iterations led to faint gray edges that communicate company agreements when needed, but do not distract as a whole.

The left command bar on the four connectivity views includes icons for commands to zoom and re-center the view, turn edge lines on/off, and turn node labels (company names) on/off. These commands give the analyst more control over the view and help provide more detail or simplify the representation, as desired. When one company is selected, a right mouse button click on a second company displays the details menu that includes a command for showing all agreement details between those two companies (displayed in the right region). Agreement details are drawn in a compressed list where each agreement can be expanded to see a text summary of it. Agreement type (strategic, R&D, manufacturing, supply, marketing, licensing, etc.) is color coded. The agreement list can be sorted by date, type, status, or strength.

5.3.1 Path

The Path view (Figure 5) enables visual exploration of the network defined by companies and agreements. It is the topology-focused connectivity view, emphasizing companies and their groups of partners, as well as shared agreements across companies. The node-link network visualization in this view provides a few simple layout heuristics and techniques. Companies are dragged in and positioned by the analyst. Expanding a company (via double-click) to show its agreements

draws its partners in a circular “galaxy” around it. Any company can be dragged to a new position as desired.

An important concept in this view is that of “leader” and “follower” companies. Leader status is not an intrinsic ecosystem attribute; instead, it is a means of helping analysts focus on companies of interest. Any company explicitly added to the Path view, whether by dragging from the left panel or by broadcast from another view, is considered a leader. In addition, expanding a company via double-click makes it a leader and adds its missing partners to the view. Those added partners are considered followers in the view. When the analyst uses the mouse to drag a leader company, its connected partners move with it. Two “clean-up” node repositioning layout algorithms are also provided in the view, positioning leader nodes in a grid or around a circle, as illustrated below.

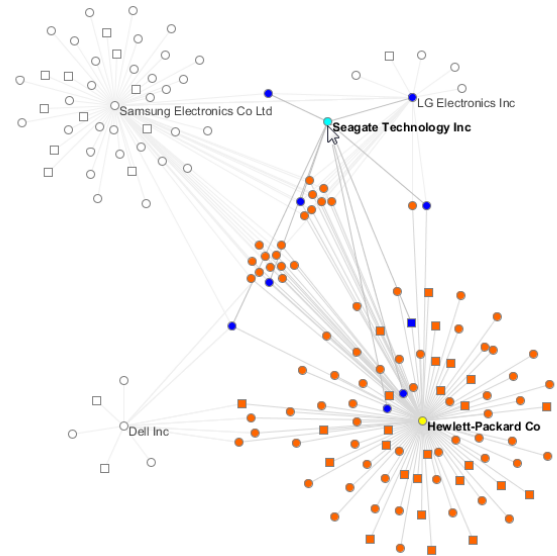


Fig. 5. The Path View emphasizes company agreements and overlaps between companies. Here, HP is selected (yellow) and its partners are in orange. The mouse cursor is over Seagate so it is light blue and its partners in dark blue.

Suppose that HP is added to the Path view by dragging, making it a leader. Double-clicking on HP’s node adds its partners as followers, arranged in concentric circles around the leader. Samsung Electronics is one of HP’s most similar competitors, and is also among its partners. Double-clicking on the node for Samsung makes this company a leader, and adds its missing partners to the view. (Note that some of their partners also may be partners with HP and thus were already in the view.) We also double-click on Dell and LG to bring their partners into the view. After just a few company expansions like this, the view may become a tangle of nodes and edges and be difficult to interpret. Thus, the system provides grid and circular layout algorithms to reorganize the view. In these algorithms, leader companies are placed into a grid or around a circle, respectively, and all follower (partner) companies have their positions determined by the leaders to which they connect (average of the positions plus a little jitter). Figure 5 shows the grid layout applied to the present example. We hover over Seagate Technology and notice that while not directly connected to HP, it shares some common partners.

5.3.2 Segment

The Segment view (Figure 6) depicts the position of companies relative to their market segments. Using this view, the analyst can quickly identify a company’s “niche” within the ecosystem and discover possibilities of cross-segment convergence. The view lays the different market segments out as slices around the circumference of a circle. It then positions companies inside the circle relative to the segment(s) that the companies reside in and it shows agreements between companies

through the familiar network edges. This type of circle-relative layout of nodes has been suggested in earlier systems such as VisAware [32] and StarGate [35]. We felt that it would effectively convey both segment membership and company agreement links.

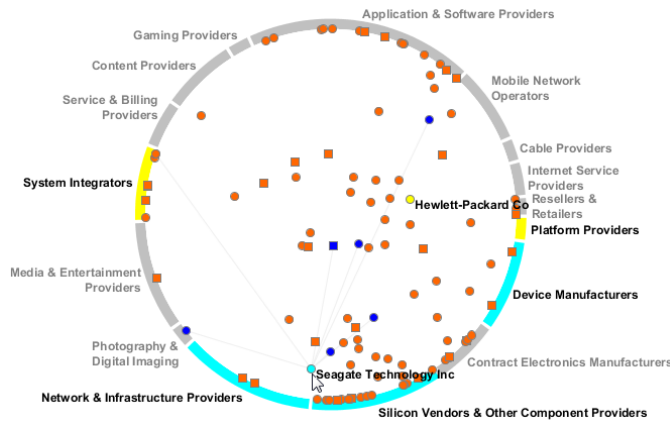


Fig. 6. The Segment View showing HP, Seagate and its partners and emphasizing Seagate's market segments and partner companies.

In this view, the size of each segment arc is proportional to the number of companies in that segment across the entire ecosystem. Three different orderings of the segment arcs around the circle are available: by value chain, by existing versus emerging segments, and by segment size. As mentioned above, companies dropped into the view are represented by nodes placed at the centroid of their market segments. Companies residing in only one segment are drawn in a band along the segment in order to differentiate them from each other. Hovering the mouse over a company highlights its segments, and hovering over a segment highlights all of the companies in the view resident in that segment. Figure 6 illustrates HP, Seagate and their partners. It shows that Seagate participates in three market segments in the value chain and has agreements with companies across a range of segments. This view is applicable to set-valued categorical attribute data and would be appropriate for similar data from other domains.

5.3.3 ScatterNet

Because the dataset contains such a wide variety of metrics and information about each company in the ecosystem, we felt that dotlink360 should provide one view of the company-to-company agreement information in the context of those metrics. The ScatterNet view (Figure 7) provides this perspective and is essentially a node-link diagram embedded in a scatterplot. Rather than have company (node) positions determined via a graph layout algorithm, their x and y positions in the view are determined by the company's values along the two ecosystem attributes assigned to the two axes. Available ecosystem attributes include agreement activity descriptors, financial performance descriptors, and network structure properties such as centrality and cluster coefficient computed from the agreement network. Within the scatterplot, company nodes still react as in the other connectivity views: expanding (double-clicking) on a company adds its partners at their appropriate x,y scatterplot positions according to the current metrics shown, connected to the initial company via gray edges. The analyst is able to zoom into a particular region of the scatterplot by mouse drag-selection of that region.

The benefits of attribute-related network node positioning have been illustrated in systems such as PivotGraph [46], Semantic Substrates [42] and GraphDice [12]. dotlink360's ScatterNet view amplifies this idea and provides network-connected nodes embedded in a flexible multivariate scatterplot. It could be used for multivariate network data from many different domains as well.

Figure 7 shows the ScatterNet view populated by HP, Seagate Technology, and both its partners. The x-axis encodes portfolio diversity

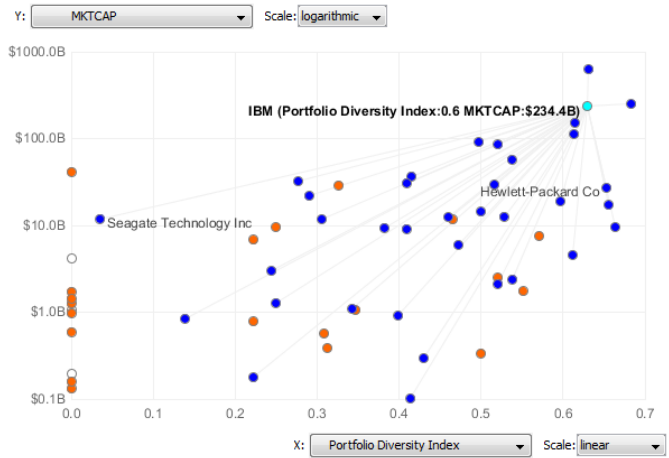


Fig. 7. The ScatterNet View that embeds a network visualization in a scatterplot. Here, portfolio diversity index and market cap uniquely determine company positions. The mouse cursor is over IBM so its partners, including HP, are blue.

index on a linear scale and the y-axis encodes market capitalization along a logarithmic scale. Hovering the mouse over IBM, a shared partner of HP and Seagate, displays its values for the two metrics in a tooltip. This view allows the analyst to observe HP's position relative to its agreement partners along these key metrics.

5.3.4 Geography

The Geography view (Figure 8) provides an additional perspective on the network of companies and agreements. In this view, nodes are placed on an interactive world map, located at latitude and longitude coordinates derived from the primary address for each company. Analysts interact with nodes as previously described for the other connectivity views and can zoom, recenter, and toggle the display of labels and network edges. In addition, analysts can pan the map by clicking and dragging anywhere in the main visualization.

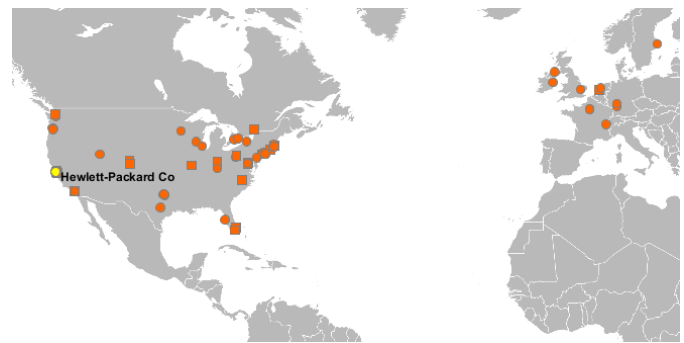


Fig. 8. The Geography View, here zoomed in to show HP's headquarters location and the locations of its partners in Europe and the U.S.

Considering the running example of HP, an analyst places its node on the map by dragging from the navigator panel, or by broadcasting from one of the other views. Double-clicking on HP's node adds its partners to the view. This operation provides a convenient means of observing the physical distribution of partners in a company's network. In this case, we note that many of HP's partners are nearby, the details of which can be examined by zooming into the Bay Area around San Francisco. Other groups of partners are visible around the world, including Europe, the UK, and Scandinavia.

5.4 Implementation

dotlink360 is implemented in Java on the NetBeans Platform [1]. The system design follows a model-view-controller paradigm. The system architecture includes a low level database layer, a middle level API layer and a high level user interface layer. The database layer consists of a relational database and a NoSQL-implemented graph database. Because SDC does not provide a programmable interface, the data is periodically retrieved manually, then parsed and stored in dotlink360's two databases. The API layer queries data from the database layer and calculates various agreement and network metrics. The user interface requests data through the API layer upon user interaction.

The UI is implemented in the Java Swing framework. The Timeline and the Composition views are implemented in Java Swing, while the four connectivity views (Path, Segment, ScatterNet and Geography) are built on top of the Piccolo2D graphics framework [3] which has built-in support for a zoomable user interface. For the world map in the Geography view, we considered several map APIs, but eventually decided to use a static high-resolution image as the background for a Piccolo window. This allows us to provide company nodes that support the same set of interactions as in the other connectivity views.

6 USAGE SCENARIO

This section and the accompanying video present an example scenario of how dotlink360 might be used to explore a high-level analysis goal. Consider the case of an analyst seeking insight into the component sourcing strategies of the mobile device market segment. Based on existing knowledge, the analyst is aware that Nokia's once-dominant position has eroded, with much of its share lost to offerings by Apple. Given these changes, the analyst would like to know if there are common elements shared by these two companies today.

The analyst begins by dragging both companies into the Composition view as well as their common market segments: Platform Providers and Device Manufacturers (Figure 9). Upon visual inspection, the companies have a similar number of total agreements, but different proportions among agreement types. Nokia has relatively more Strategic and Supply agreements, while Apple has more R&D, Marketing, and Licensing agreements. These differences are noted as possibly reflecting changing requirements for success, but the analyst is more interested in what the companies have in common.

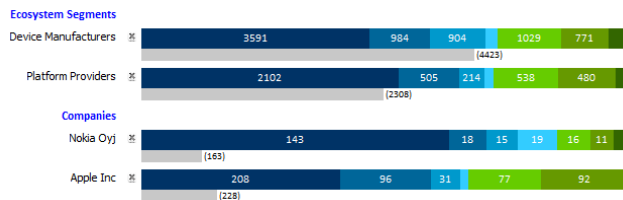


Fig. 9. Nokia and Apple and their two common market segments in the Composition View.

To provide another perspective, and to determine if Nokia and Apple share any agreement partners, the analyst uses the broadcast function to send the two companies to the Path view, which shows that there is no direct connection. To gauge activity, using right-click menu options, the analyst displays agreements for each company by date (Figure 10), and expands details for the newest entries. This reveals a pending agreement between Nokia and Oracle, and a rumored agreement between Apple and Sharp, both dated quite recently.

The analyst then expands both companies by double-clicking their nodes, adding partners to the view for each. This reveals that both companies have relatively equal network sizes and substantial overlap between the partner networks; among the 55 partners for Nokia and the 50 partners for Apple, 20 partners are shared. The analyst uses the Grid Layout function to isolate shared partners, which are displayed midway between the two leader nodes (Figure 11). To facilitate examination of the shared nodes, the analyst zooms in and turns on all labels. The shared nodes include a number of prominent companies, among

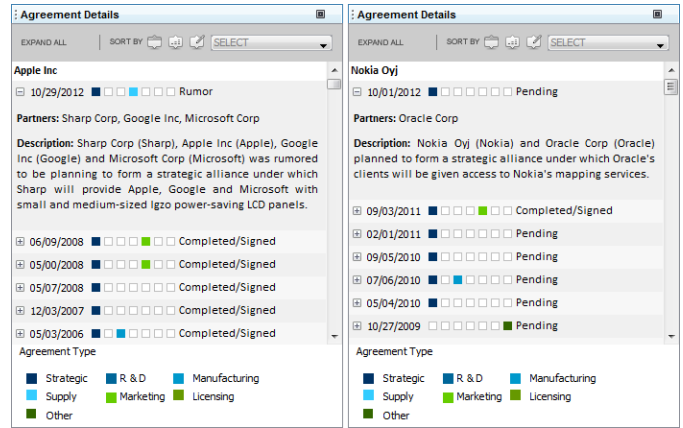


Fig. 10. Agreement details for recent alliances by Apple and Nokia.

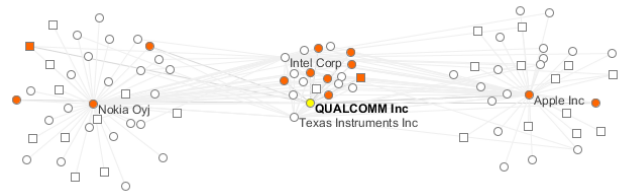


Fig. 11. Nokia and Apple in the Path View. The applied grid layout shows shared partners in-between.

which the analyst observes several leading component providers, including Intel, Qualcomm, and Texas Instruments (TI).

Knowing the importance of these three companies in the overall mobile ecosystem, the analyst switches to the ScatterNet view, dragging in the Silicon Vendors & Other Component Providers segment. Seeking evidence that distinguishes these three vendors that Nokia and Apple share, the analyst plots R&D agreements versus R&D expenditures for the segment, and uses the search function to locate Intel, Qualcomm, and TI. This does not produce a clear result, so the analyst plots Licensing agreements versus R&D expenditures (Figure 12). With this choice of variables, the targeted vendors stand out clearly from others in their segment.

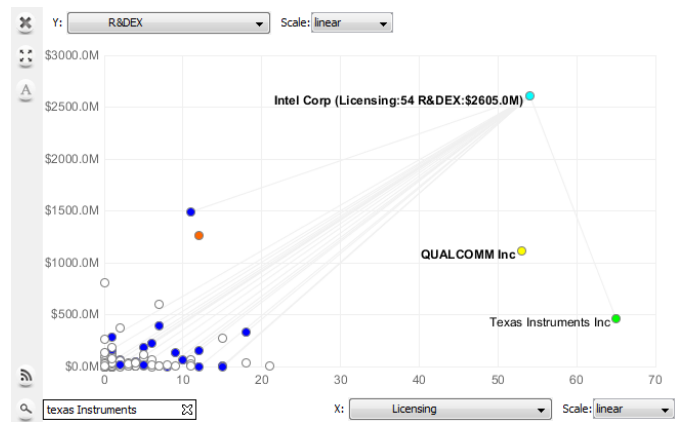


Fig. 12. Key component suppliers Intel, Qualcomm, and Texas Instruments in the Scatternet View with company positions determined by R&D expenditures and number of licensing agreements.

The Segment view provides another lens for examining how these vendors relate to the mobile ecosystem. Switching to the Segment view, the analyst drags in Intel, Qualcomm, and TI, and adds partners

for each by double-clicking. The analyst also adds Nokia and Apple to understand the relationship between these companies and the segments (Figure 1). Visual inspection indicates similarity in the segment distribution for partners of Qualcomm and TI, and greater variety in the distribution for partners of Intel. The analyst notes that these subjective impressions are supported by quantitative measures of diversity and clustering accessible via the structural properties for each vendor. Finally, ordering segments by size, the analyst observes that Qualcomm operates in two diverse market segments, while the others do not. The analysts notes that this makes Qualcomm a particularly interesting mobile device component supplier.

7 USER STUDY

We conducted a user study with the objective to assess the potential usability and usefulness of dotlink360 for the analysis of the mobile ecosystem. We also sought to assess fulfillment of the design requirements described in Section 4. The study had participants answer specific questions about interfirm relationships in the mobile ecosystem and conduct an open-ended analysis in a realistic scenario. We also gathered feedback about potential capabilities to add in dotlink360. We opted for a predominantly qualitative user study, complemented by a small survey, as we believed that broad and deep insights would be best attained through observation in combination with an open interview format. We intentionally did not perform a formal usability evaluation or utility assessment. Instead, we sought to learn potential usability and learnability issues, observe what aspects of the system would and would not be used, determine what capabilities provided the most value, and identify gaps and missing capabilities. This approach has been shown to be appropriate for a project such as ours [14, 29].

7.1 Participants

Six prototypical users (2 women and 4 men) participated in the study. All participants had extensive technology industry experience (20+ years) in leading executive, analyst, investor, or research positions at large organizations. Five of the participants had direct mobile ecosystem industry experience. All of the participants were potential users of dotlink360 for their current work and were familiar with business ecosystem concepts and issues. However, none of them had seen or tried dotlink360 prior to the study. They did not receive any compensation for participating in the study.

7.2 Tasks and Procedure

Each participant’s session was conducted individually and consisted of three main phases. The first phase (tutorial) focused on learning about the system. We provided an overview of dotlink360 and a description of the underlying data. We then performed a step-by-step walk-through of the interface components and their basic functionalities. In pilot sessions, we observed that it was beneficial for participants to gain hands-on experience performing operations on the interface. Thus, we included a component in which we directed the participant to perform specific operations in each view and they performed the operations using the system. We also allowed them to explore the interface a little and we answered any questions they had. This phase typically lasted about 15 minutes.

For the second phase (practice) of the study, we created a set of 3-5 questions for each view, with the questions growing in difficulty within the view. For example, in the Segment view, one question was “Which private media & entertainment providers does Hewlett-Packard have agreements with?” We had the participants attempt to answer each question on their own. When they had difficulties or did not know how to proceed, we assisted and showed how to determine the answer of the question. We also reminded the participants about particular capabilities when it appeared that they had forgotten about them. We decided to use specific questions, rather than open-ended exploration, because we felt that this type of directed analysis would better ensure that participants encountered most aspects of the interface. Furthermore, if participants could not answer these small, direct questions, then open-ended analysis likely would suffer as well. This phase took between 30 minutes and an hour.

In the third phase (evaluation), we gave participants a set of 7 questions to answer. These questions were similar to the more challenging ones from the practice phase. For these questions, we did not direct the participants to any view – they started working on each question from a blank initial screen. The motivation for this phase was to understand if participants had learned about the views and their operations and if they could determine which would best help solve the problem. We logged whether the participant was able to answer each question correctly or partially, and how long it took. We next gave each participant one open-ended analysis task to work on with the system. Specifically, we asked them to explore, analyze, and then describe to us the agreement portfolio and network structures of Intel and Qualcomm. We requested that participants “think aloud”, describing what they did, why they did it, and potentially also what they would like to do. We sought to learn which aspects of the system the participants would employ and ultimately to learn whether it would help them complete this task. Finally, we asked participants to complete a short Likert-style survey about their impressions of the system, and we asked them a series of interview questions about their opinions. This phase typically took about 20 minutes, making the complete sessions range from 1.5 to 2.25 hours. One investigator from our team directed all the sessions and assisted participants throughout. Other investigators observed, took notes, and documented the sessions.

7.3 Results

The user study produced both encouraging results and helpful feedback about the design of dotlink360. The overall assessment from the users was that dotlink360 would be useful in business ecosystem analysis, as illustrated by the numerical rating in the post-study survey shown in Figure 13. Responses for the ease of use, learnability, and usefulness statements had a group mean value of 3.75 (2 statements), 4.00 (1 statement) and above 4.00 (3 statements), on a scale from 1 to 5, with 5 indicating strong agreement. The six individual views were also rated very useful, with a mean rating of 3.67 out of 4 for all views. The Segment and ScatterNet views were rated the two most useful, with an average of 4.00 and 3.75 respectively.

The “think aloud” approach and our post-study interview with the participants provided a more nuanced view of opinions. We summarize our findings into four areas: ease of use and learnability, usefulness for ecosystem analysis, task performance, and desired features.

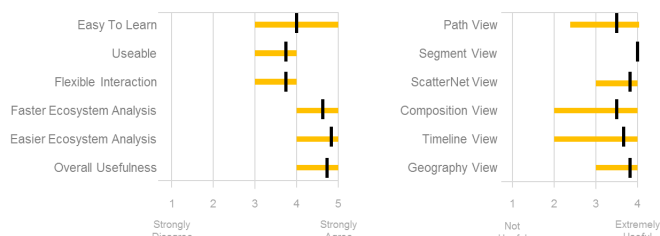


Fig. 13. Results of the post-study survey. The left chart depicts subjective assessment regarding the ease of use, learnability, and usefulness of dotlink360, measured on a 5-point Likert Scale. The right chart depicts the usefulness of individual views, measured on a 4-point Likert Scale. Vertical black bars denote the mean value and horizontal orange lines denote the full span of assessments.

Ease of Use and Learnability. All six participants found dotlink360’s UI design simple, intuitive, and easy to use. Five out of six participants particularly liked the ability to add ecosystem entities to views using drag and drop functionality, and to access multiple comparative views using tabs. All six participants were receptive to the ability to quickly browse through long lists of segments, companies, and countries using a familiar explorer-like navigator panel. Because of these design aspects, participants were able to use the system and learn about basic functionalities quickly. However, three participants commented that given the range of functionalities, additional time was necessary for mastery.

Usefulness for Ecosystem Analysis. All six participants expressed that dotlink360 is a relevant, flexible, and useful tool for business ecosystem analysis. All participants appreciated the ability to explore individual companies, segments, and countries using multiple views. Four participants considered dotlink360 useful for complex ecosystem analysis tasks. In particular, two participants suggested that dotlink360 is helpful for managers and consultants who need to understand an industry and develop strategic insights quickly. One participant noted “dotlink360 would be a great tool for a strategy consultant who needs to learn about an industry and brief a client the next day.” Another participant suggested that the system would be particularly useful for “investors looking for acquisition targets.” All six participants expressed that dotlink360 would help to accelerate their time to insight and help to improve decision quality.

Task Performance. The evaluation phase revealed that participants were able to successfully answer most of the questions. Figure 14 summarizes participants’ task performance. The first five evaluation questions were answered correctly by all but one participant. The last two questions, which we considered to be the most difficult, were answered correctly by two participants each, and partially by the other four. These two questions required participants to evaluate more complex interdependencies between segments and firms, using a combination of views and features. It appeared that successfully answering these questions required more experience than was afforded by the tutorial and practice phases.

Task	Number Correct	Time (min)
1. How many strategic agreements did US-based companies form in September 2012?	5/6	1.50
2. In what countries do Random House’s partners originate?	5/6	0.75
3. Of the companies having agreements with both Microsoft and IBM, which has the highest market capitalization?	5/6	2.17
4. How many private companies have an agreement with Oracle but not with Microsoft?	5/6	2.00
5. Which of NBC’s partners have the most manufacturing agreements with other companies?	5/6	2.67
6. Which of Rambus’ Network & Infrastructure Provider partners have partners in the Content Provider segment?	2/6	4.17
7. Do Microsoft and Intel have any strategic agreements with the same company(s) based in South Korea?	2/6	3.00

Fig. 14. Results of task performance of the evaluation tasks.

The open-ended analysis task showed that dotlink360 enabled participants to gain a number of interesting systemic insights into the agreement portfolio and network structure of Intel and Qualcomm. We observed that all participants used all six views and the details panel. The sequence in which they navigated through the views depended on the type of insight they were seeking. Three out of six participants began their inquiry by examining the global footprint of each company using the Geography view and correctly noted that Intel had a far more global reach than Qualcomm. In the Path view, all six participants compared the relative size of each company’s network, and identified several common partners using one of the two layout algorithms. Specific relationships between two companies were further explored using information in the details panel by four participants. Using the Composition view, four participants identified commonalities and differences in agreement portfolios including segments and countries, and identified that Intel has twice as many agreements as Qualcomm, but Qualcomm has more licensing agreements. Through the ScatterNet view, participants were able to quickly and correctly identify that both companies stood out from their peers along various metrics. All six participants used the Segment view to determine the segment distribution of the companies and their partners’ segment membership. Two of the participants were surprised to find that Intel collaborates with companies from a more diverse set of segments than Qualcomm. Only three participants took advantage of the broadcast operation, perhaps not recalling its availability.

Desired Features. The user study resulted in several suggestions of desired features for dotlink360. Three participants expressed interest in the ability to save and output information and visualizations pro-

duced during a session. Half of the participants requested an “Undo” function to return visualizations to a previous state.

Two participants requested more flexible ways to select sub-networks and individual nodes via an operation such as rubberbanding. The ability to present a subset of the visualization in a traditional list form, perhaps in the right details panel, was also repeatedly mentioned (4/6). The sets of companies referenced in these requests usually were in some particular area or region of one of the four connectivity views. One participant requested filtering mechanisms for ecosystem entity characteristics and time windows. We interpret these suggestions as an indication for more focused analyses capabilities.

Two participants also mentioned a preference for the ability to open multiple instances of individual views for simultaneous examination of different contexts. All participants were keenly interested in additional data sources (e.g. patents and press releases) and the ability to import their own data. One participant suggested implementation of a what-if capability that would allow analysts to explore and understand the impact if hypothetical companies or agreements were added.

8 CONCLUSION

We have described the development process, design, instantiation, and evaluation of a system, dotlink360, for helping corporate analysts gain insight into business ecosystems. Our particular domain of study is the mobile ecosystem, including nearly 3000 companies and a rich set of business attributes about each. The system emphasizes the exploration of agreements between companies so that analysts can understand how corporate alliances influence the ecosystem and potentially benefit these companies. We believe that dotlink360 has significant practical relevance for analysts, investors, and executives as it enables them to make sense of the complex interfirm landscape and conduct competitive intelligence analysis.

The contributions of this work include a requirements-driven analysis of the domain, with insight gained from an initial field study and from the design process and evaluation of the system. The dotlink360 system itself provides a number of design ideas that could be employed by others working on similar problems or even in different domains containing similar data collections. In particular, we feel that the system’s suite of four network visualizations provide a powerful environment for exploring connection data. They employ an “expand on demand” [44] strategy and provide a simple topological layout along with three attribute-based [46, 42] layouts (geographic, segment membership, and business metric). Ultimately, this design study contributes to the relatively unexplored, but promising area of exploratory information visualization in market research and business strategy.

Our design process and system evaluation uncovered a number of promising directions for future research, a few of which were described in the previous section. Incorporating other sources of data such as patent filings, press releases, personnel transitions, etc., would provide further analytic power. The challenge in adding such additional data would be to do so in a manner that does not introduce significantly greater visual complexity and make analysis more difficult.

As with any research, our study does have some limitations. A more extensive, longitudinal deployment study with practicing analysts, perhaps using their own data/problem, may provide new insights. Rich temporal analysis also remains an ongoing problem. We are currently working on temporal filters and sliders to address this issue. We also feel that providing more filtering capabilities (by attribute, data source, or even display position) in such a system will improve the user experience and enhance analysis. While our system can easily handle several thousand nodes, we acknowledge that scalability may be a potential concern. A comparative study of our system with more traditional, OTS visualization tools could also prove valuable. Each of these limitations provide interesting future research opportunities.

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