From Hyperlinks to Hypercues : Entity-Based Affordances for Fluid Information Exploration*

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ABSTRACT

We introduce the concept of the hypercue, a complement to the hyperlink in the form of an interactive representation of real-world entities, e.g. persons, places, concepts, providing personalized access points to information. As a pendant to the hyperlink, hypercues create opportunities to flexibly discover, store and share information, organize one's thoughts and gain insights of the data.

We explore the design space of interaction techniques supporting entity-based information exploration. We reflect on these through the lens of eight essential features of exploratory search systems, to devise generalizable design principles. Our main contribution is a design template describing the hypercue. It consists of a minimal set of affordances that ensure all important features for supporting exploratory search can be addressed, while leaving enough design space to facilitate integration within a variety of systems. We describe the rationale behind the design template and discuss its implications through a case study.

KEYWORDS

entity search, interaction design, information exploration, fluid interaction

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1 INTRODUCTION

In the early 90s, document linking and embedding was described as the new hypermedia structuring paradigm [14], and the world wide web was quickly spreading, fueled by the miracle of the hyperlink.

Since then, users are guided from one source of information to another via fixed references determined by the content creators, and rely on search engines when they need a personalized access points to the information space. Although the same paradigm has subsisted so far, it is not suited to the current reality of information access, which brings both challenges and technical opportunities, and makes for an appropriate time to think of an alternative information seeking paradigm.

The amount of available information keeps on growing exponentially, and the access points provided by query-and-response search engines – the ten blue links – is too narrow to offer a sensible overview of available material related to a given query. We need options for broader and more personalized access to information, as well as support for making sense of it. Thankfully, new technologies in information retrieval create opportunities to address these problems and rethink on-line media access and structuring. As entity search and recommendation become a reality, the user's information trail relies less on documents linked explicitly by content creators. Users have now the opportunity to finely steer their progression within the information space, in accordance to their immediate needs, understanding and inspiration. Related information and overview of the data can be computed on the fly to suit the very specific needs of each user at any time during the exploration, providing constant access to more detailed or more general information, new directions and branching topics.

This work explores interaction techniques designed to support entity-based information exploration, and grounds it in available literature. Our main contribution is a design template describing the hypercue, a digital and interactive representation of entities that provides personalized access points to information, and which serves as a complement to the hyperlink. Hypercues create opportunities to flexibly discover, store and share information, and gain insights of the data. The Hypercue design template consists of a minimal set of affordances that ensure all important features for supporting exploratory search can be addressed, while leaving enough design space to facilitate integration within a variety of systems. We describe the rationale behind the design template and discuss its implications through a case study.

2 BACKGROUND

The present work utilizes entity search as an technical opportunity, towards *Fluid Information Exploration* as a goal. Here we clarify these two essential notions.

2.1 Fluid Information Exploration

When discussing interactions and user interface design, fluidity is often cited as a goal [7, 20]. White and Roth [25] mention fluid interactions as an important feature of future search systems when discussing novel interaction paradigms. They link that notion to human-machine symbiosis, and interactions through fluid hand gestures, citing the fantasy user interface from the movie Minority Report as en example of what a truly fluid interface could look like. However, that notion is not theoretically defined and is generally used while relying on the reader's intuitive understanding of the metaphor, something that flows continuously, naturally making its way around obstacles and adapting its pace to the environment.

2.1.1 Fluid Interactions. A satisfying operational definition is proposed by Elmqvist et. al [4] who work around the difficulty of defining fluidity theoretically by focusing on the properties we can expect from fluid systems. These properties are grouped in three sets with three different effects:

Fluid interactions promote flow: Flow is a mental state induced by immersion in one's activity, characterized by a loss of sense of time. The main actionable property for inducing flow, relies on letting the user feel in control, and employ just the right amount of skills to let her progress in her task at a pace that will feel neither too slow nor too fast, accommodating a person's continued and deepening enjoyment as skills grow [16].

Fluid interactions support direct manipulation: Direct manipulation describes an interaction paradigm in which digital representations of objects behave as objects themselves [24]. Direct interaction with these objects is enabled by reducing indirections between input and output spaces, e.g. the touch sensitive layer of a touch device is confounded with its display and calibrated so that inputs are registered precisely at the display location. The paradigm relies on a preference for physical actions, and immediate visible effects allowing rapid course adaptation and reversal of action [10].

Fluid interactions minimize the gulfs of action: The gulfs of action are a notion introduced by Donald Norman [17], who uses it to describe the gap between a user's expectation of a system and the actual state or possibilities of the system. It consists of two components, the *Gulf of Execution*, which describes the gap between a user's intent and actual possibilities for inputs, and the *Gulf of Evaluation*, which describes the gap between a user's expectation of the state of a system and its actual state.

2.1.2 Positive Information Practices. Our focus on fluidity is not exclusively motivated by performance nor the sole objective of making the user more efficient in accomplishing her task. Fluidity conveys open endedness, and the consideration that the process itself, through the potential discoveries it may yield, is just as valuable as the end product. The information flaneur [3] offers an inspiring model of information seeking centered around positive information practices, by opposition to considering information seeking as the fulfilling of an information need or addressing a deficiency. The information flaneur's *implications for research and design* offer design goals for fostering or enabling such experiences by considering explorability principles, e.g. orientation, visual momentum and opportunities for serendipity, as well as bridging gaps between information spaces, contexts and conceptual levels, by exploiting scalable or generalizable rules and common patterns. This focus on continuity and momentum of the experience of exploration complements the operational definition of fluidity

2.1.3 Fluidity as Design Driver. The present work reflects our commitment to such approach of information practices as we strive for designing systems that do not induce specific behaviors nor address any specific scenario. We envision a future of information exploration where users' interface of choice is not constrained by the data but by personal preferences, and which could indifferently and seamlessly be used to navigate academic literature, a movie streaming catalog, the news or social media posts. We work towards that goal by implementing the three properties in the operational definition of fluid interactions. We promote flow by enabling personalized and adaptive access to search and recommendation, letting a user seek additional information when she needs it and with respect to her own criteria, needs or inspiration. We support direct manipulation by enabling direct interactions with every bit of displayed information that is relevant to the user. This require to design for touch-enabled displays, and presenting information in the form of an object that can be manipulated. We minimize the gulfs of action by setting small sets of simple rules that are consistent across a given system. We achieve this by limiting the amount of widgets and separate views and preferring single sandbox-like workspaces. Through these principles, we attempt to facilitate memorization regarding operations, while enabling creative strategies and behaviors and potentially complex results.

2.2 Entity Search

In the field of information search, entities are references to real-world objects or concepts, e.g. persons, places, movies, topics, products. Entities are linked with typed relationships. For example, *Tom Hanks (actor)* and *Forrest Gump (movie)* are linked via "stars in". Together, they form a graph in which entities are nodes, and relationships are the edges. Such graphs are known as *knowledge graphs* and generally stored within *knowledge bases.*

In web search, a majority of emitted queries pivot around a specific entity [19]. Knowledge bases are useful to provide additional information around an entity and to recommend additional entities. In conventional web search engines, queries pointing towards an entity will usually trigger a first result pointing to an information source that provides the most general information about the entity, typically the corresponding Wikipedia entry, which requires the system to be able to match the typed query to the corresponding entity.

2.2.1 Entity-based Exploration. Google Search provides today for most entity-based queries, not only a relevant entry, but a knowledge graph with relevant information about the entity and recommended related entities, in the case of an actor, name, age, plus lists of movies and co-stars. Miliaraki et al. Miliaraki:2015:SGM:2736277.2741284

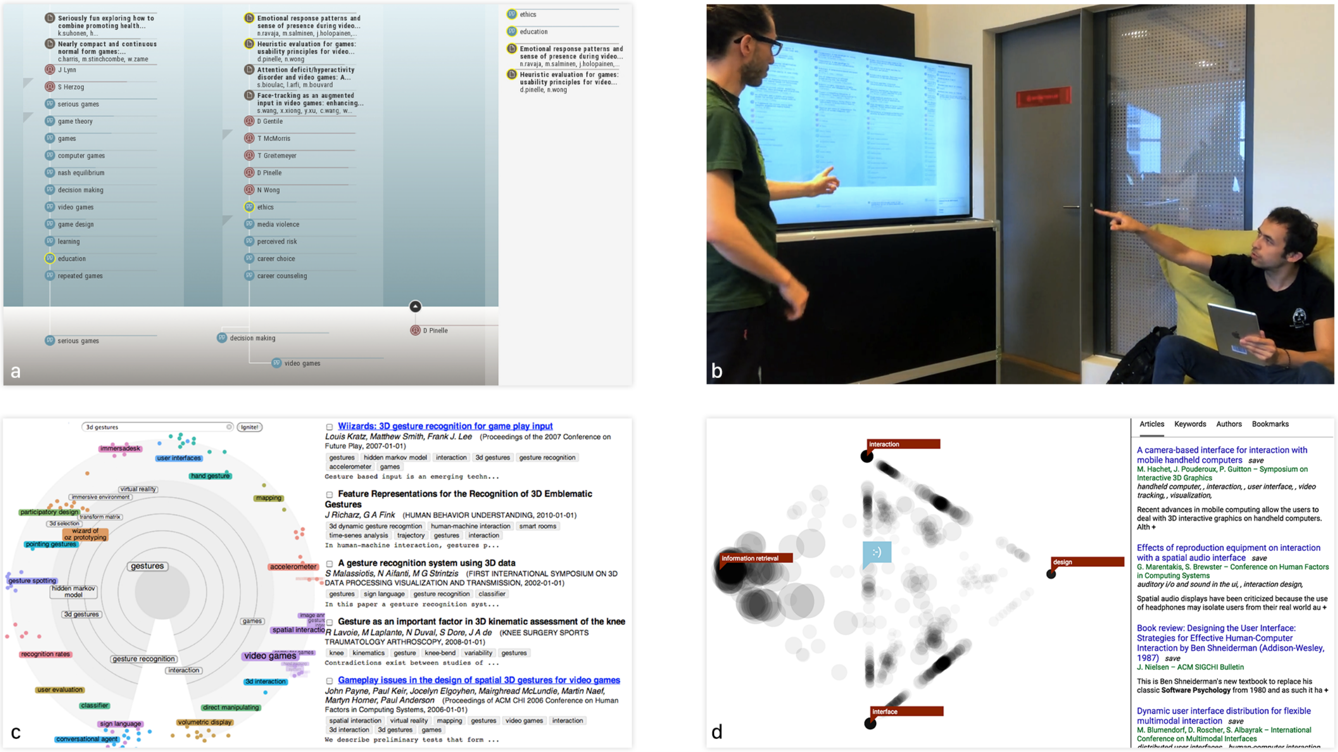

Figure 1: We have explored the design space of entity-based systems supporting information exploration through the development and evaluation of multiple prototypes: (a) ExplorationWall, (b) QueryTogether, (c) SciNet/IntentRadar, and (d) RelevanceMap.

studied the behavior of users of Yahoo Spark, a system that recommends related entities alongside Yahoo Search results, who take advantage of the system to engage in explorative entity search by discovering information through successive clicks on recommended entities. Such example explains why entity-search is considered an ideal paradigm for exploratory search, and an important topic in both Information Retrieval and Semantic Web communities. A large body of recent research work addresses challenges regarding the computation necessary for entity search, like finding and ranking of related entities, matching entities with occurrences in free text queries, and completion of entity list based on given entity examples. However, as techniques improve, it is difficult to find research work addressing interaction techniques that enable end-users to access and benefit from such rich information. That is not to say that no attempt has been made in creating interactive systems for entity search and exploration. However, all found examples are mostly feature-driven and target very specific scenarios and tasks instead of looking for a viable alternative to the de-facto query-and-response paradigm.

As entity-search becomes a reality, it creates plenty of opportunities for exploration, not only in the way relevance and ranking are computed, but in how we are going to interact with information within the new paradigm. Once available information is meaningfully structured, the information space becomes a high-dimensional medium ready to be unfolded as explorers pull its various threads and discover content according to their needs, inspiration or chance. The goal of entity-based fluid information exploration requires substantial thinking about the way we display and interact with entities, and to come up with fundamental principles that are generalizable to any search contexts, e.g. academic publications, social media, movie database, personal emails.

3 EXPLORING THE DESIGN SPACE

We have had the opportunity to explore the design space of systems that support fluid information exploration through the design, development and evaluation of several functional prototypes. These prototypes each addressed different aspects of information exploration, e.g. facilitating query formulation, facilitating query refinement, providing insights of the data, supporting collaboration. Through user studies, we have been able to demonstrate improvement of these various aspects over conventional approaches, and identify design principles that were responsible for these improvements. We have also been able to observe how user behavior and search strategies were affected by these principles. The next challenge was to use such collection of observations on individual systems, to extract fundamental actionable principles, that would outline a paradigm for fluid information exploration.

3.0.1 ExplorationWall. Figure 1a. shows the interface of ExplorationWall [11]. This work initially addresses challenges in performing exploratory search tasks using touch-based devices: Formulating queries in unknown information spaces, identifying new search directions and going through long lists of results with low information gain. Those challenges are all made more difficult on conventional user interfaces by the lack of physical text-input or text-selection peripherals.

A single workspace allows simultaneous display of several parallel search streams, each consisting of a vertical organization of entities as queries and search results. Each result set consists of multiple entities of varying types, e.i. documents, persons and keywords, and each entity can in turn be used as a query or part of a query in an existing search stream or a in new one. Entities can be easily manipulated (e.g. moved, stored, combined) and provide both content to be browsed, such as articles, or insights to further the exploration, such as new topics or authors.

ExplorationWall has demonstrated substantial improvement over regular interfaces in exploratory search tasks [11]. Results showed a higher amount of relevant information retrieved by participants, explained by a much more active behavior, measured in the search trail analysis in number of queries, as well as revisit and branching rate. In the end, participants that were given a topic to explore, with which they were unfamiliar, covered much more of all available relevant information by making a better use of multiple search sessions.

3.0.2 QueryTogether. QueryTogether has been designed to support exploratory search in a collaborative and spontaneous search setting, as shown on Figure 1b. To do so, we have adapted the interface of ExplorationWall so that it can be used across multiple devices, e.g. laptops, tablets, large touch displays, and supports both private sharing of information and broadcasting to all users.

The reading list has been adapted to feature both saved and received entities in a scrollable list, as well as user panel, which shows what user is active on the system. Users are identified by the name they entered at login, and their status, either *private* if they are using a private device, or *public* if they act as a session moderator on a large screen available to all participants.

Sharing is performed by dragging an entity over to the chosen user. The recipient will instantly receive a new instance of the sent entity in her side panel. If the side panel is closed, a visual notification in the corner informs the user of the number of new entities received. Next to each user label, a "Message" icon allows the user to send a short message along with an entity. The reading list can be filtered with respect to a chosen collaborator and will subsequently show only entities and documents sent to and received from that user. Filtering based oneself will display only entities that have been saved locally and ignore anything sent or received remotely.

3.0.3 SciNet/Intent Radar. SciNet is a search system for information exploration that builds a user intent model to better adapt returned results to a user's needs [5, 21, 22]. To do so, the system enables relevance feedback on a visualization of the user intent, which is here visualized separately from the result list, through the use of weighted keywords, as seen on Figure 1c. The benefits of a separate visualization are: a higher cue density, a comprehensive overview of the current intent, the opportunity to provide suggestions for future intents, and the practicality of being an add-on widget to familiar search interface. In this case, a user emits an initial query, which yields a regular result list, plus a set of the most central keywords extracted from the results, visualized on a radar (the closer to the center, the more central). This offers an overview of how the system perceives the query. The user can then adjust the weight distribution by sliding individual keywords closer to or farther from the center, and the result list will refresh accordingly. Another important feature of the system is the visualization in the outer rings of the radar of a variety of secondary keywords, chosen for their diversity, providing the user with insights about future search directions, as well as a way to redirect the search incrementally without having to change the initial query. The system has been shown to improve users' task performance in complex search tasks in which conventional query-response systems fail to assist users to direct their search [21].

3.0.4 RelevanceMap. RelevanceMap [12] provides the user with an interactive map of the whole document space with respect to the positions of multiple query phrases visualized as mobile markers on a 2D workspace, as seen on Figure 1d. This allows to visualize variations in information density with respect to elements of the query, even with large amounts of returned documents, which enables quick evaluation of the query and resulting data. Browsing is performed through a pointing gesture on the map, which re-ranks the whole document collection according to the location of interest. The corresponding result list appears in a conventional layout next to the map. The quick re-ranking interaction enables exploration of the multi-dimensional data structure.

This work is another example of visualization taking advantage of direct manipulation to interact with the data for sense-making purposes. But in this case, manipulation of the map allow the user to determine the scope of the higher level search task by outlining the whole document space using multiple queries and visualizing the whole set, i.e. thousands of documents instead of a small selection. The exploration is then performed through a re-ranking interaction over areas of interest on the relevance map. The user can now precise or change the focus of her exploration and refresh the result list through a pointing gesture instead of reformulating the query. This allows the user to explore large amounts of relevant information without interruption, while still permitting changes in the query at any time, thus adapting fluidly to the user's immediate needs.

RelevanceMap showed significant support in how users perceived the information space with respect to topics of interest, as well as in retrieval of information relevant to complex criteria [12].

4 FEATURES OF EXPLORATORY SEARCH SYSTEMS AS A LENS

In our exploration of the design space of systems that support information exploration, we have often taken advantage of the work of White and Roth [25] as a frame to ground our designs and explain their effects on user behavior and performance. Their work include a list of features of Exploratory Search Systems that explicit and exemplify essential aspects of supporting information exploration.

These features have been an important source of inspiration as they bring attention to different fundamental areas of exploration.

We reflect on our work through the lens of these eight features of exploratory search systems, to identify fundamental principles at work in our different systems, as well as new opportunities for entity-based exploration.

4.1 Support Querying and Rapid Query Refinement

Search tasks are commonly addressed through inputting queries in a search system, which then yields a set of related results. However, conventional text-based queries are mostly user-defined. Relying on the user's existing knowledge to formulate satisfying search directions limits the range of incrementation in the iterative exploration process. Support for querying is commonly addressed by providing the user with ideas for new queries or additional terms. Even auto-completing text entries with popular queries has shown to facilitate the querying phase.

When entity search is available, supporting querying and query refinement is readily achieved by augmenting conventional expression-based querying methods through entity recommendation, by enabling the use of entities as queries, to provide a set of related entities as a result. A document, a person, a place, a movie can each be used as a query, and yield a variety of related new entities of different types.

ExplorationWall showed how such support for exploration is embraced by users over text-based querying, and improves the overall exploration [11].

4.2 Offer facets and Metadata-Based result filtering

Being able to navigate a large result set according to personal needs and preferences is a central requirement of fluid information exploration. That is why the possibility to narrow down such results according to a variety of criteria that are both representative of what is available in the data, and complementary enough to provide a meaningful choice of search directions is an important feature to support.

Facets and metadata-based parameters are an attempt to structure information by linking documents semantically through common features, e.g. an author, a title, a date, a location. Entity search is the ideal paradigm for result filtering, given the richness and complexity of readily linked data. From an initial query-entity, a system would retrieve the most central neighboring concepts or elements and provide them as related entities to chose from. The initial result set can then be narrowed down or re-ranked with respect to the relatedness or dependency of each element to the chosen related entity.

Each result set in ExplorationWall displays facets in the form of recommended keywords related to the query. Adding such keywords to the initial query narrows down the results. For example, we have observed a user initiate a search with the query "rosetta". Results related both to the ancient translation stone, and the recent European mission to land a probe on a comet. By moving the recommended keyword "probe" to the query, the result set was then focused on the space mission. Then, after adding the recommended keyword "instruments" to the query, the result set became a catalog of Rosetta's on-board systems.

4.3 Leverage search context

A substantial part of context can already be harnessed by accessing contextual data provided by sensors, e.g. GPS signal, or personal account informations. From our interaction design perspective, we are more interested in techniques enabling inference of context through user's input, either explicit or implicit.

Explicit input of context implies providing a user with the ability to critique encountered information by providing relevance feedback that informs the system on the user's intent. SciNet implements such principle and has demonstrated substantial benefits for exploratory tasks. Implicit input of context relies on inferences made from user's behavior. What information is being saved for later, liked, or shared is often implicitly considered as relevant to a user's interest. What songs has the user put together in a playlist, what movies has she watched or positively rated, these are primary actions with implicit implications that create an opportunity to improve any associated recommendation or retrieval process. In systems where users can freely position selected information on a workspace, like RelevanceMap, the layout and proximity factors can be used to infer a user's intent, for disambiguation and to improve the results.

4.4 Offer visualizations to Support Insight and Decision Making

Interactive information visualization is an important tool for sense-making. Being able to encode data visually and to play with different parameters is a powerful way of discovering trends, understanding relationships, gaining insight of the data and ultimately inform one's decision. Entities in knowledge graphs generally make for inspiring material regarding visualization techniques such as node-and-link diagrams and adjacency matrices.

The challenge with information visualization is that the most appropriate form of visualization is highly dependent on the task and the data. In that respect, it is crucial to be able to adapt when necessary, through various techniques.

RelevanceMap uses user-driven mapping to enable multi-aspect search. Having multiple queries distributed on a surface makes it possible to consistently map a whole information space using dimensionality reduction techniques. RelevanceMap provided users with sensible insights of the data and possibility to explore tradeoffs with respect to multiple criteria to support decision-making [12].

4.5 Support Learning and Understanding

As it is necessary to offer some result-filtering ability for the user to take better advantage of a large set of results by narrowing down a list, it is also important to provide the user with an access to more general knowledge when necessary. Support of learning and understanding implies that a user is given the means to find information that is adapted to his current level of understanding. This is typically achieved through recommendation of related material. For example, any modern browser and eBook reader provides the ability to lookup the definition of a word or to link a concept with its corresponding Wikipedia entry.

More elaborate solutions consist of yielding a variety of recommended concepts or documents related to the information at hand, which provides the user with a conceptual overview of the topic with multiple options to gain knowledge directly useful to understanding the information at hand.

SciNet, additionally to visualizing the current intent through, displays on the outer rings a variety of diverse keywords, providing the user with options for future search directions, as a way to expand the information space without having to change the initial query.

As a second example, in the same way ExplorationWall enabled facets and narrowing down of the result set through multiple queries, similar technique can be used to expand the result set, by adding new entities to the query, this time from external sources, i.e. another result set or a typed expression.

4.6 Facilitate collaboration

Performing information exploration collaboratively is a common strategy to tackle large information spaces through the sharing of ideas and allocation of search tasks [8]. Collaboration can take multiple forms, with settings in which collaborators share the same space or not, i.e. co-located or distributed collaboration, synchronously or asynchronously.

Methods that support collaboration when searching or interacting with information are very diverse but often share the common goal of avoiding wasteful overlaps in labor between collaborators. This problem can be tackled at the start of a search session, through mechanisms supporting division of labour, like systems such as SearchTogether [15] or Cerchiamo [6], which allocate defined search areas to each collaborator. But the same problem can also be alleviated during the search/exploration by promoting awareness of collaborators' activity, by providing a communication channel allowing participants to share their progress in the form of interesting information snippets and sources, and make their search trail visible, like CoSense [9] or CoSearch [1].

Entity search creates opportunities regarding collaborative exploration, as the information unit of reference shifts from the sole document to a variety of references to real-world objects, e.g. persons, places, as well as concepts, expressions, or any combination of these. We can therefore envision systems in which users have finer control over the type of information and amount of context that is being saved and shared.

For example, using QueryTogether, users shared various entities to facilitate task allocation and to find common ground in collocated collaborative exploratory tasks. We can imagine implementing possibilities to exchange whole workspaces and search histories as a way to share more than information bits but whole contexts.

4.7 Offer Histories, Workspaces, and Progress Updates

Information exploration is a sense-making activity [13]. As such it is open ended, potentially long term, and changes continuously as the information need evolves [18]. The process often produce long and complex search trails with multiple branching and revisits. In such context, it is important for a user to be able to take advantage of previously encountered information, and keep track past activity to more efficiently recognize new and interesting information.

Entity-centric information is an opportunity to highlight updated and visited information both at a finer level than documents, and on overall areas of the information space. In visualizations taking advantage of the node-and-link structure, it is possible to use color to highlight visited or new areas in the knowledge graph, like we implemented in later versions of RelevanceMap, where visited areas of the information space were colored in a purple shade, traditional for visited links.

One of the central features in ExplorationWall is the endless horizontal workspace that allows to freely move and position parallel streams, i.e. query plus corresponding result set, and to create additional space in between streams. We noticed that not only did users take advantage of such feature to thematically organize multiple search directions, their natural tendency to add new elements to the right systematically resulted in naturally grown chronological search histories.

4.8 Support Task Management

As Information Exploration is potentially long term, it is important for users to have the ability to interrupt and resume their activity, and carry it over time and across devices. This require to be able to save more than selected information, but provide future access to whole workspaces, including histories and information configuration with which a user has engaged.

An important criticism of the way we commonly search for information, is the how ephemeral and secondary the search process is perceived. Users often invest a great deal of time and efforts finding information, and the process itself, including intermediate queries and results, is often lost after an endpoint has been reached. As we advocate for improved user control over the search process, often at a higher interaction cost, it is crucial to recognize its value. This implies ubiquitous computing solutions to enable saving and resuming search sessions across time, space and devices. We implement such feature in our systems by saving workspaces to the cloud, and, in the case of QueryTogether, porting the system on multiple platforms.

5 THE HYPERCUE TEMPLATE

A cue is a stimulus and a signal for action. We propose the notion of a hypercue as a complement to the hyperlink. A hypercue is an interactive representation of real-world entities, which offers affordances, i.e. possibilities for action, for the user to explore, share and organize her thoughts. Systematic inspection and exploration of the design space of each feature of exploratory search systems allowed us to identify three complementary affordances that are responsible for enabling these features, and together constitute a minimal design template for implementing hypercues. The following template aims to guide the creation of future interfaces for exploration, without over-constraining the design of such system, nor hindering possibilities to address specific cases through the choice of a specific form of visualization. The proposed affordances can also be implemented in most existing media-handling application, e.g. browsers, PDF and e-book readers. From a user perspective, the following template aims to build a base set of rules

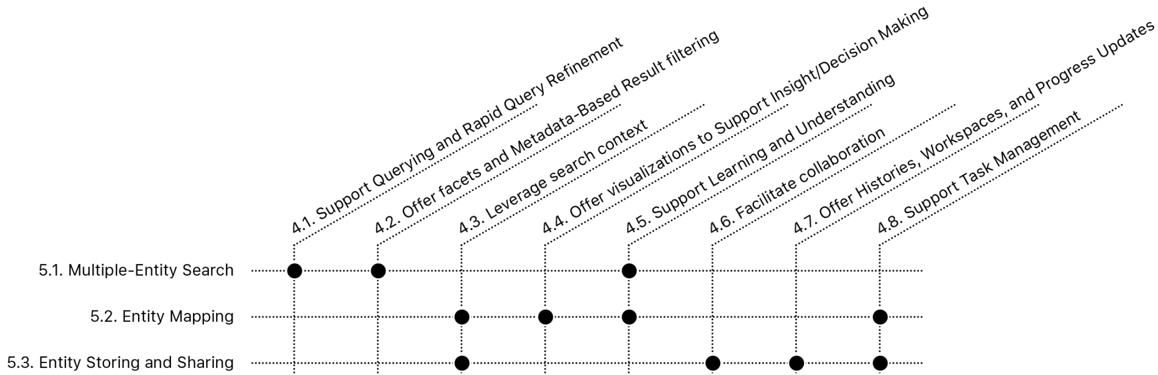

Figure 2: The three entity-based affordances for fluid information exploration together create opportunities for implementation of each of the eight features of exploratory search systems.

and expectations for users to facilitate their engagement in complex information behavior.

5.1 Multiple-Entity Search

Each entity – or combination of entities – can yield various new related entities, providing together an overview of the respective information space.

Modern browsers and OSs already implement affordances to inspect the definition of an expression, its corresponding Wikipedia entry, or related search engine results. Such affordances is here generalized, using entity search to yield a crop of related entities, from any selected object, e.g. expression, article, link. It is also expanded to allow multiple entities to be used together as a query.

Providing possibilities to create queries through direct manipulation of recommended entities has been shown to **support query formulation and facilitate query refinement**. The possibility to add components to the initial query makes it possible to refine it by narrowing down or expanding the result set. Adding external entities, e.g. somewhere else in the article or page being consulted, or from another source results in expanding a query, which **supports learning and understanding**. Adding an entity to the query from the result set itself **enables facets and Metadata-Based result filtering**.

5.2 Entity Mapping

Entities can be moved around, and users are provided with spatial freedom to organize a collection of entities of interest in a layout that reflects their understanding and mental representation of the information space.

Spatial organization of thoughts is a common behavior. We draw mind maps, we make piles of documents, we organize sticky notes, and store documents within directories or under consistent tags. Sense-making is an important part of exploratory search [25], and as such it relies on users building a mental representation of the state of the world, i.e. the information space at hand, and then iteratively confronting this representation against the real world, i.e. new information, to update it and acquire a progressively more accurate understanding of the information space [23].

Entity mapping provides support for mind-mapping which **supports learning and understanding**. It provides an implicit input channel for **leveraging search context**. It creates opportunities for **visualizations that support insight and decision making** by enabling multi-aspect search, and for addressing the need for **histories, workspaces, and progress updates**.

5.3 Entity Storing and Sharing

Entities and group of entities can be easily saved for later use and easily shared with collaborators.

Documents often serve as unit of information. We search for, bookmark and share documents. But such actions are not sufficient. The intent that led to bookmarking is soon forgotten and with it, the utility of the stored document. Some additional action is required, like giving bookmarks a context-relevant title, or organizing them within theme specific directories. Sharing requires the use of messaging channel as text messages are necessary to convey context and intent. Entity-centric information enables the use of variable and personalized units of information. We can search for, store and share references to persons, medias, excerpts, organizations. Taking advantage of affordances 1. and 2., exchange of information involves sharing – and collaborating on – potentially whole contexts in the form of organized entities, which **facilitates collaboration**. The same principle provides access to these contexts across devices, providing flexible **support for task management** and **enables histories, workspaces, and progress updates**. Stored or saved information also provides an implicit input channel for **leveraging search context**.

5.4 Summary

Figure 2 shows how the Hypercue template, through the three proposed design principles above, creates opportunities for addressing each of the eight features of exploratory search systems.

6 CASE STUDY

In order to illustrate our approach to designing systems that support information exploration, and the role of the hypercue in enabling relevant features, we describe and discuss a case that implements

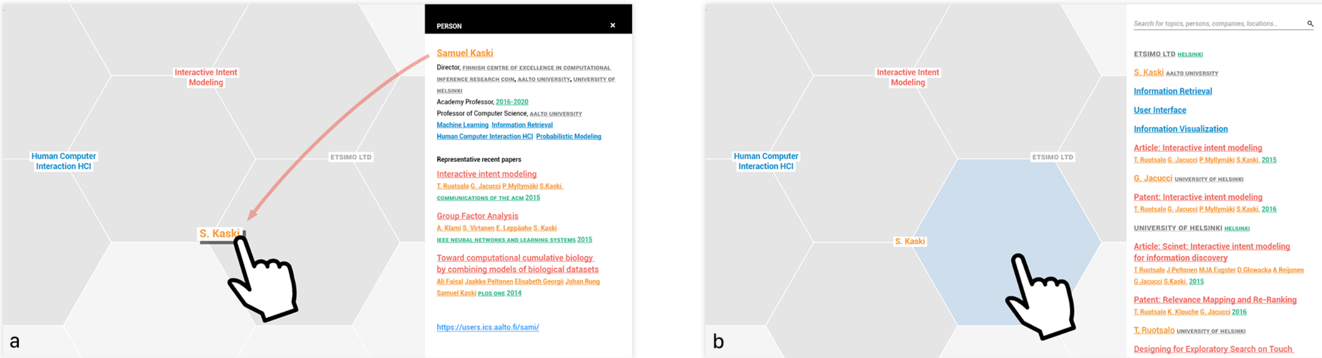

Figure 3: InnovationMap is designed for innovation exploration and discovery and implements the three principles of the Hypercue template. (a) A user is inspecting the entity of a researcher in the right panel. If it is of interest to her, she drags it towards the map. (b) The right panel now displays the search results corresponding to the selected cell (blue) selected by the user, which has two entities as a compound query. As results are saved in the cloud, the user will be able to resume her exploration later on a different device.

these principles together. InnovationMap is designed for an important European university to support innovation exploration and discovery. We present the system and discuss it from the perspective of Hypercue principles.

6.1 InnovationMap

The workspace consists of a map, with a panel on the right. The map is based on a grid of hexagonal cells. The scale of the map is variable through the use of the mouse wheel or pinch gestures. The companion panel has a text input field at the top, inviting typed queries, and displays the corresponding result set under it. Results consists of entities of different types, i.e. documents, persons, workplaces, topics. An initial text-based query yields a ranked set of mixed-type entities. Each entity can be inspected with a click or a tap, at which the panel displays all information about the selected entity, i.e. full meta-data, preview of and access to content if applicable, and available links such as dedicated website, Wikipedia entry, social media contacts. Closing the inspector brings the user back to the result list. Each entity can also be dragged towards the map where it will position itself at an intersection of the grid. A new entity in the map triggers a new search and refreshes the set of result. Navigation buttons allow the user to navigate between the successive states of the result set. The darker cells on the map are representations of different result set yielded from all adjacent entities. Tapping on a cell highlights it in blue, signifying that the corresponding result set is displayed in the panel. By dragging more entities to the map, users can search for information related to up to six different entities simultaneously for each cell. Users can freely drag entities to other parts of the map and explore the information space following multiple directions.

6.2 Scenario

An innovation manager for a large company is looking for opportunities for partnership in region X. She finds InnovationMap, an on-line tool for exploring research work, provided by the local university. Not yet familiar with local academic expertise, she starts by inputing an umbrella term that roughly covers her fields of interests, i.e. "Big Data". The system returns related fields and keywords, academic articles, patents, researchers and entrepreneurs. She consults the profile of some of the recommended persons, and inspects a few recommended fields. Soon, she drags "Human Computer Interaction (HCI)" towards the map, which refreshes the result set. Soon, she adds an article that describes a user modeling technique for search systems. The results now prominently show a startup based on the technology of interest, among other related elements. Inspection of the entity provides necessary information on the young company, with link to the website and contact information. In parallel, she drags "Information Visualization" to the map, towards the other side of "Human Computer Interaction (HCI)", and starts exploring the intersection of these topics in the information space, on a separate cell. Progressively, and without having to recall technical terminology nor reading pages of material unrelated to her interests, she not only collects useful information, but she builds a representation of the whole process, and an understanding of the information space that accurately reflects the data.

6.3 From a Hypercue Perspective

6.3.1 Multiple-Entity Search. The system lets users search using up to six entities simultaneously, which follows the first principle of the present template. Added entities can originate from within the initial result set of the same cell, with the effect of updating the result set by narrowing it down around the added criteria. Added entities can also originate from other sources, i.e. the result set of another cell, or the result set of a typed query, in which case the result set will expand and diversify.

6.3.2 Entity Mapping. InnovationMap provides a flexible canvas with a grid for the user to organize information. We have chosen a hexagonal grid because it provides more neighboring options than an orthogonal grid, increasing the freedom with which a user can scatter information, while being constraining enough to limit efforts towards keeping the layout clear and legible. The cell layout implements a variation of the distance threshold to combine entities together and yield a corresponding result set. Therefore, the various results are found in locations consistent with the user layout.

6.3.3 Entity Storing and Sharing. InnovationMap does not propose methods to share specific entities or entity structures with an other user for now. However, it is designed to remotely save the state of a session, which can itself be accessed later, or on another device. As a result, and without features designed specifically for collaboration, sharing access to a session with another user provides her with found information, but also context through multiple search directions and points of interests.

7 DESIGN CONSIDERATIONS

The present template consists of fundamental principles aimed at guiding the design of future systems supporting information exploration, while imposing little constraints on the overall design space. In this section we discuss aspects that are not addressed by the template, and attempt to outline the remaining design space.

7.1 Displaying Relationships

Many interactive systems for entity search introduce tremendous visual and operational complexity by emphasizing the role of typed relationships in exploring the knowledge graph. We posit that while some analytic tasks require fine control and perception of the nature of links between entities, such tasks are usually the lot of experts performing complex investigations focusing on the articulations of many instances of a common type, e.g. many companies or many persons [2]. In many common cases, there is little ambiguity in the nature of the relationship. Looking at academic papers, linked persons will most likely have an author status. Browsing for movies, linked persons will most likely be part of the crew, and if that person is identified as a director, there is little need for allocating resources to showing all typed links all the time, and it may suffice that the nature of the link can be inferred upon inspection of entities.

The present template does not constrain the type of visualization. It focuses on what a user can expect to be able to do with representations of entities, while leaving the design of visualizations and affordances for specific target users' needs to the discretion of tool makers.

7.2 Generating Hypercues from text

A central challenge in entity search, is to enable expressive query language, and matching entities in the data to entities referenced within free-text queries.

Hypercues are designed to be user defined, although they could additionally be recommended within contents. In the latest iteration of its OS for tablets (iOS 11), Apple has introduced a generalized possibility for drag and drop. Pictures, text snippets, news articles, hyperlinks, every bit of information pops out of its environment under the finger, becomes an interactive object to be dragged around across applications and be dropped into a message, a note, some cloud-based storage. Such interaction lets the user interact with predefined objects, as well as user-defined selections, and offers an ideal interactive base for integration of the present affordances.

7.3 Shape and Size

While the template does not inform about the shape and size of displayed hypercues, it is useful to discuss the requirements and provide some recommendations based on our experience. The first requirements of the hypercue marker is the identifiability of the represented entity, in a space that allows it to be moved and positioned in relation to other entities. A constant challenge when designing entity-based interfaces, is to find a balance between how much information to convey through the entity marker, against the amount of entities that can be comfortably displayed. In any case, it is necessary to provide the option to quickly inspect the entity, to access a comprehensive overview of what it is, through linked content and related material. However, it is essential to show enough information upfront to trigger recognition and incite interest. Modern desktop-based OSs offer a good model for representing files and directories as manipulable objects using an icon and two short lines of text. The most useful information depends on the task and information space. While movies are usually displayed through their poster and title and release year, finding the most relevant movie in a set might depend on its cast or on its rating. Likewise, finding useful academic articles depends on variable criteria, e.g. authors, venue, citations. The solution might lie in a balance of user-defined preferences and automated context-sensitive adaptive interface settings.

7.4 Identifying Entity Types

While in our early designs, we liked to use color or small icons to indicate the entity type and to quickly distinguish between documents, persons and expressions, we noticed that the type can usually be inferred from the name and displayed meta-data. The latter solution has the benefit of being scalable as it does not require to redesign icons and specific representations each time new type of entities or different data sets are introduced. We recommend the development of interfaces in which references to documents and concepts, and expressions/character strings, share the same standardized hypercue status and affordances. In such case, it is important to visually distinguish expressions from references, as a entity labeled "Berlin" could either be a representation of the city or a typed query. Such distinction can for example be done through text color or using italicized characters for expressions. If needed, disambiguation can be done explicitely in the label like it is the case in Wikipedia entries. For example, "Harry Potter (Film Series)" and "Harry Potter (Literary Series).

7.5 Integration With The Physical World

The reliance of these guidelines on direct manipulation and spatial layouts makes them easy to integrate with the physical world through playful tangible interactions. By registering an entity or a set of entities in a physical object it becomes possible to use and combine such objects to playfully discover information through machine vision or sensing surfaces.

8 DISCUSSION

The Hypercue template consists of a minimal set of affordances for interactive representation of real-world entities. It ensures all important features for supporting exploratory search can be addressed, while leaving enough design space to facilitate integration within a variety of systems, and sets a base of rules and expectations for users to facilitate their engagement in complex search behavior. The template has various potential implications regarding how we search for information.

An important one is that all interactions proposed in the present work require substantially more effort from the user, whom has now grown accustomed to content feeds, and the simplicity and immediateness of today's search engines. We advocate information practices in which users are more active, and we posit that it is the cost of more transparency and control over what information we encounter. However, such cost can be mitigated through fluidity, when every interaction serves an informational goal, letting a user get truly absorbed by her task, and rewarding her with persistent and constructive search sessions that remain useful in the long run.

The present work proposes guidelines that are generalizable to every information spaces. We can imagine that in the future our search interface of choice will be independent from the data being explored. As a result, we could use the same tool to discover information of interest within the news, academic articles, music or TV series episodes, and social media posts. Increasing possibilities for serendipity and creative solutions.

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