Memory Connected: Extending Memory on the Web via Human-Centric Knowledge Exchange Network

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Abstract: The Web is widely used to extend our memory and exchange knowledge with others. Unfortunately, our memory on the current Social Web is fragmented and locked in the "walled gardens" provided by the giant Internet companies. Such memory is big but not easy to be reused by the original contributors or others. In order to best extend our memory on the Web, the open nature of the Web should be respected. In this paper, we propose a solution called human-centric knowledge exchange network, i.e., an infrastructure that integrates human memory and the Web without compromising users' privileges on capturing, representing, organizing, exchanging and controlling their memory.

1. Extended Memory Locked on the Social Web

"The Internet has become a primary form of external or transactive memory, where information is stored collectively outside ourselves" [1]. Memory on the Web is not only supported by the nearly unlimited storage capacity offered by the Web, but also facilitated by powerful computing services that reduces the cost in capturing, organizing, retrieving and exchanging online memory. Therefore, the extended mind hypothesis states that "technological and informational elements of the Web can (at least sometimes) serve as part of the mechanistic substrate that realizes human mental states and processes" [2]. The value of combining human and machine also studied under the concept of Social Machine [3].

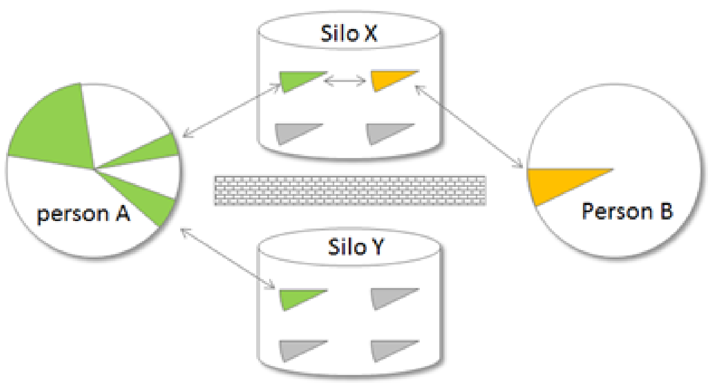

Figure 1. Individual's memory locked in disconnected silos on the Social Web

Thanks to the convenient user interfaces and the intensive social tractions granted by Social Web technologies and services, a large mass of online knowledge has been accumulated on the Web. However, the current Social Web also introduced the "Walled Garden" model [4] which limits the freedom of Web users to access and exchange their extended memory on the Web. For example, many people have published microblogs to capture their cool ideas, and follow others' microblogs for inspirations and social binding; however, it is still difficult to partition their tweets by themes, follow tweets just by topic, and integrate tweets with Facebook updates. The complaints about the "Walled Garden" are highlighted by the following two:

- *I am locked in a garden*. If we depict a person's memory as a pie (see figure 1), each "garden" (i.e. data silo on the Social Web) only covers a slice. A user's memory is *fragmented* in many different gardens, and each slice is often exclusively locked in a garden. Furthermore, our social interactions are also limited within individual gardens. Cross-garden memory exchange is typically embarrassingly limited: painful manual operations and non-trivial technical trainings are often needed for one to restore and query one's own memory slices in these gardens. Identities are also fragmented and not portable; discovery, conversation and notification are only supported within a garden. On such fragmented Web, we are digitally schizophrenic.

- *I can't find a garden*. Human's needs for memory are so diverse that creating a "garden" for every need is not economically practical. Many of these needs are not related to "social" life. In fact, the majority of human memory is believed still off the Web because users cannot find readily-available memory services on the Web to serve their needs. Furthermore, some knowledge were not memorized in brain (which can be deemed as yet another garden) because of human's limited capture capability.

2. Human-Centric Design

The Web should extend human's memory with better utility and less restrictions. Therefore, new specifications and tools on the Web are needed to (1) accommodate the diverse needs of millions of users and (2) facilitate the reuse and exchange of memory among the users regardless where the memory is stored and how the memory is organized. These specifications and tools should follow a **human-centric design** and make the Web a media suitable for **human-to-human knowledge exchange**. We emphasize the human-centric nature of "knowledge", i.e., memory on the Web is created, managed and consumed by human, and then facilitated by automated services from machines. This is not the same as the machine-centric knowledge in the knowledge management literature, i.e., knowledge is represented and organized to best fit machine processing. Meanwhile, our design does not drop the requirements on machine processing since machine power is still needed to help human in processing knowledge. Machine friendly design should be justified by the tangible benefits to human. In summary, we want to best utilize machine power to *make human smarte*r, rather than simply make machines smarter. Below are a couple of detailed principles for human-centric design.

Human readable knowledge. Abelson and Sussman claimed that "programs must be written for people to read, and only incidentally for machines to execute" [5]. This claim also applies to knowledge on the Web. Lessons learned from programming language design showed that high level and human readable languages (e.g. Javascript) got much more usage in programming than low level machine languages (e.g. Assembly). Similarly, JSON dominates as a data API syntax due to its simplicity to developers, and electronic spreadsheet prevails due to its convenient editing interface and embedded computing power. While original designs of RDF, OWL, and RIF reflects machine-centric design, recent advances in TURTLE and JSON-LD reflect the traction of human-centric design. It is clear that future knowledge representation and exchange specifications should prioritize human readability over machine readability and require human-friendly user interfaces to wrap machine automation.

Tangible rewards and cost-reduction. Maintaining memory is not free, and that's why we forget most of our observations in daily life. Tangible rewards is a critical factor for sustainable growth of the collective memory on the Web. These rewards can be money, reputation, freedom, utility or anything that is valuable to the owner of the memory. For example, programmers generate high quality answers on StackOverflow in return of better social reputation, people perceives freedom by using one generic instant messenger client to access their identities across isolated messenger networks. Meanwhile, reducing the cost of memory operations boosts users' adoption. For example, editable email filtering rules help users better organizes their emails, smart review aggregation services save users' research time on restaurant reviews.

Bottom-up growth scales. The scale free nature of the Web [6] grants the Web nearly unlimited growth space and exponential growth speed. It is clear that the memory on the Web should grow out of everybody's contribution instead of being enforced by few elites' top down directives. For example, Twitter hashtag has won huge adoption before it was officially supported by Twitter in tagging tweets. Bottom-up growth ensures that the development activity is well-founded in real world needs, results can be quickly validated, and the trade-off between quality and cost in development are more flexible and controllable.

3. Memory Connected

Integrating biological memory with the memory on the Web allows human to access nearly unlimited storage capacity and computing power of the Web, and leverage the collective memory of all Web users to solve problems that cannot be solve by an individual. Figure 2 illustrates an example of knowledge exchange network, where individuals' memory (big pie) are interconnected directly or indirectly by brokers (small circle), allowing knowledge (slice in pie) to be shared among individuals. We identify three key memory operations, namely capture, organize/retrieve and exchange.

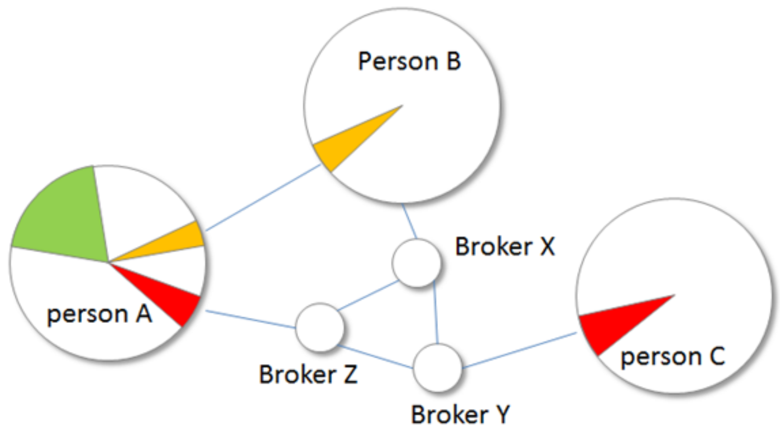

Figure 2: Knowledge exchange network enables open, distributed and connected memory

3.1 Capture

Memory on Web is captured to complement our brain memory storage and biological memory capture channels. For example, many of a person's past life are only memorized in her emails, not in her brain [7], and multiple cameras can visually capture more than what one can see. In Figure 2, a human-centric memory can capture all knowledge, including her local knowledge and her knowledge in data silos and external memory, to enable a unified access (e.g. query) of all the captured data.

Capture what was locked on the Web. Data should not be locked in a particular application because it may be reused by unexpected applications in the future. With convenient capturing tools to reclaim users' own data from the walled gardens on the Social Web, users can consume their data in the ways not provided by the data silos. For example, using a faceted browsing interface to access personal and followed tweets, and finding people I contacted last year using memory from Facebook, LinkedIn and Gmail). More exchange activities may spur more capturing activities.

Capture what has not yet been captured. Multimodal capture methods are now viable thanks to the advances of mobile and wearable devices. Richer contextual metadata and associated knowledge can be captured, e.g. recording GPS coordinates while taking photo. The capture activities cost less and interrupt less, e.g. using Google glass to take picture. Private space and data ownership helps users to fulfill goals that cannot (or should not) be processed by giant Social Web service providers, e.g. Facebook is not suitable for managing personal financial knowledge.

3.2 Organize and Retrieve

Huge memory is big data for an individual, and memory should be organized with effective indexing mechanisms for future retrieval. Different memory parts may be stored and organized differently according to their nature, personal preferences, costs and many other factors. In Figure 2, person A and person B may organize the same piece of knowledge differently and use different retrieval strategy, e.g., one may simply keep the original text of an article, while the other maintains additional structural metadata covering the author and date of the article.

Organization and retrieval are tightly coupled: the performance of retrieval depends on how memory is organized, and memory organization strategy is selected to meet retrieval requirements. From information publishers' perspective, the five star scheme for open data [8] provide a flexible plan for organizing data at different levels of quality. From consumer perspective, we identify the following three levels of cognitive retrieval mode with incremental organization cost. Memory management system should be flexible and cost-effective in supporting and switching between these modes.

- **Search mode**: When the knowledge lacks structure but is searchable (e.g., search by the presence of a word in a text document), we may search it using known hints. For example, we use keyword search as long as we know the words in a document. In this mode, user is required to explicitly know something that must exists in the search targets.
- **Exploration mode**: If the knowledge contains some organization structure and we have some clues about its organization (e.g., the set of attributes it may have), we may iteratively explore and filter the entire memory. For example, one may not recall his doctor's name, but he can recognize the name when it shows up in a list. Thus, he may first list all known person names from his memory and then go through the names one-by-one. Faceted search, tag clouds and visualization are frequently used in the exploration mode.
- **Association Mode**: If the knowledge in memory are well associated, and we only know some associated knowledge but not the target, we can use the above two modes to locate the associated knowledge and then navigate the associations. For example, I cannot remember my doctor's contact number, but I know that it was mentioned in an email around I booked my last year's vacation. Therefore, I would first locate the emails related to my vacation reservation and following temporal locality associations to find the email. Such link not only facilitates navigation, but also supports data mashup requests from app developers. In order to help knowledge owners focusing on the content, automated tools are needed to capture links while editing (e.g. auto-completion) and enrich text with associations (e.g. named entity extraction, social tag alignment).

3.3 Exchange

Individual's memory is often too limited in problem solving, and it is vital to exchange knowledge with others' memory, e.g. a company leverages StackOverflow's Career 2.0 to find job candidates. In Figure 2, person A can integrate external knowledge into his own memory by pulling memory from other persons directly (e.g. person B) or indirectly (e.g. from person C via brokers Z and Y).

Freedom. Communication protocols should be designed to enhance the freedom of exchange, e.g., referring to external memory by an identifier or locator (e.g. referring a URL in a blog), pulling external memory and making local changes (e.g. copy sample code and customize it), pushing notification of reused knowledge (e.g. trackback blogs) and combining knowledge streams (e.g., unifying two person's twitter walls). Knowledge exchange is not simply synchronization because the same knowledge may be organized differently by different people, e.g., I may copy files from my colleagues but reorganize them using my own folder structure.

Control. Knowledge exchange should be easily controlled by users at both outgoing and incoming directions. Information filtering grants incoming content control to users, e.g. filtering tweets within selected topics when following tweets from others. Access control grants security and privacy control to users to secure outgoing contents.

4. Conclusion

Openness is central in the growth of the Web. However, the current prevailing "walled gardens" on the Social Web made online data exchange limited, rigid and difficult. In the next generation Web, we shall encourage open knowledge exchange between individuals, assisted by pre-existing and/or just-in-time brokers. These knowledge are not limited to social web data, but also all the exchangeable knowledge about Web users' life, in particularly their memories, which may be magnitudes larger than today's social web data.

We discuss some desiderata of specifications and tools to encourage and facilitate the publishing and consumption of such memory. We argue that these should be human-centric, instead of being machine centric. To ensure user adoption, knowledge should human readable (and then machine readable). To ensure sustainable growth, tangible rewards and cost-reduction are required. To scale-up the network, a bottom up growth model should be followed. We also discussed the specific design considerations associated with the key operations, i.e., capturing, organizing/retrieving and exchanging, to best extend our memory on the Web.

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