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Usage-Driven Health Information Portals: A Concept and Design

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Abstract

Health information portals (HIPs) are now an established channel for providing reliable and relevant health information. Recently the concept of smart health information portal was proposed to advance its learning capability and the use of smart technology to sustain its operations and content quality assessment. This research investigates the concept of usage-driven design as an important dimension of smart HIP. Such capability is argued to be important to bridge the gaps between the system design and the users’ needs. This paper describes a design-science research which proposes and illustrates an approach for utilizing insights from usage data to address search issues. A conceptual approach and a modified HIP architecture to enable usage-driven capability are described. This is followed by two specific applications, a HIP-specific content issue reporting tool and a topic search feature, to demonstrate how usage data can enhance usage in HIP while being adapted to fit the context of a health portal. Empirical findings suggest that the adaptation of usage-driven approach for health information portals needs to concentrate more on content management, which is generally overlooked compared to information retrieval functionality. Based on the implementation, the paper identifies design principles to ensure effective operation of the approach.

Key words: health information portal, design research, usage-driven design, usage data analysis
1 INTRODUCTION

Consumer-oriented health information provision on the Internet is gaining much momentum, due to the sheer volume of health information, the need to provide regulated health information and the rise of consumer Internet technology. The recent Pew Internet: Health survey (Fox 2012) estimated that 80 per cent of Internet users look online for health information with even more doing so with emerging media such as smart phones (53 per cent of smart phone users). In this landscape health information portals (HIPs) in particular are an established means to provide trusted health information on the Internet, providing a tailor approach to cope with the vast amount of online health information, as well as to avoid content with dubious quality (Fisher et al. 2009). Many governments, information providers and community groups have set up HIPs to meet the health information needs of the consumers (Fisher et al. 2009).

Notably, research in user-centred health information provision has contributed many positive outcomes to the development of health portals. The user-centred paradigm gained much attention for empowering consumers’ access to health websites. Smarter search functionality (Zeng et al. 2006), user-centred quality reporting (McKennish et al. 2009), user-sensitive resource description (Burstein et al. 2005) are a few prominent examples.

Research contributing towards enhancement of search functionality in HIPs is more focused on addressing the problem of information retrieval (how to locate relevant information out of large collections of documents (Soualmia and Darmoni 2005)) while overlooking the fact that there are many other intrinsic issues that occur due to weak design and management of health portals. Information overload, as well as lack of content, is good examples in this regard. Users face lack of content due to emerging needs, new topics of interests, seasonally spiked demand of content, new terminology to formulate the search based on social trends and new commercial products (Zeng and Tse 2006; Herskovic et al. 2007). The inability to integrate dynamically changing needs of users into the HIP functionality is therefore a major causes leading to unsatisfactory search (Nguyen et al. 2011).

Despite recent advances in technology improvement for HIP, there is a research gap concerning the lack of usage-driven capability for HIPs, which we argue to be the missing piece of the user-centred health information provision approach. Usage-driven capability is defined as the capacity of a system to respond to the dynamic changes of usage and to reflect the real needs of users, rather than being static or dictated by human experts (Stojanovic et al. 2003). The problematic nature of this research gap is confirmed in a recently published paper (Nguyen et al. 2011), revealing that many of failed searches in a HIP are in fact due to the mismatches between the users’ needs and the portal content and design.

Accordingly, there is a lack of a mechanism to gather insight from usage data into HIPs’ functionality in order to guide the improvement process. While recent models of user-sensitive HIP have incorporated advanced features to support users, many components of HIPs are still static and do not dynamically adapt to usage changes. There is also a shortage of applied research which can produce concrete specification of methods and tools to apply usage-driven design philosophy in HIP context. This paper investigates such approach, in particular focusing on two core capabilities of health portals which are content management and content search (Luo and Najdawi 2004; De Silva et al. 2012).

One motivation of the paper is to contribute to a line of active applied-research focusing on developing technology for empowering users of health information portals. This includes recent advances such as the concept of smart health information portals (Burstein et al. 2006; Evans et al. 2009), advanced health searches (Chen et al. 2003), improved content management and personalisation (De Silva et al. 2012). This paper therefore also documents the technical experience and lessons learned from the development and deployment of such approach in a working health portal.

The central research question addressed in this paper is:

**How can usage-driven design improve health information portals?**

To address this question the following sub-questions have been considered:
1. How can usage-driven capability be enabled within a HIP architecture?
2. How can usage-driven tools be implemented in HIP?
3. How feasible and viable is the approach? What constraints of HIP should be considered in its implementation?

The first sub-question aimed to study the conceptual approach, the second one researched the implementation process, whereas the third one looked at the feasibility of the proposed approach in HIP context.

This research used Breast Cancer Knowledge Online (BCKOnline) health information portal as the implementation context (www.bckonline.com.au). Developed as an outcome of the research project this portal pioneered the concept of smart health information portal, which was developed in collaboration with domain knowledge experts and a community group. Architecturally, BCKOnline followed a typical health information portal model. It comprises a repository/catalogue of externally developed resources and a personalised search interface. The innovation of it comes from a user-centred resource description, user-sensitive personalisation approach and a domain-expert dashboard to manage the resource collection (McKemmish et al. 2009). While the portal serves a specialised domain (breast cancer), BCKO employs a glossary and a MESH-based ontology which is generalizable to many other health information portals.

The next section presents a literature analysis which allows us to identify a conceptualisation of the usage-driven approach for HIP. In section 3 we present a design-science research methodology. Section 4 presents the conceptualisation while Section 5 describes the implementation. We discuss the findings and identified design principles in section 6.

2 LITERATURE ANALYSIS

Health information portals can be defined as a centralised catalogue with feature for retrieving information (Luo and Najdawi 2004) or a “one-stop shop” for health information (Turner et al. 2002). Recent studies have introduced various advanced concepts and tools for improving health portals. Early work by Quintana (1998) mentioned the concept of user-sensitive, intelligent health portals as a solution for filtering health information in a user-centric manner. For example, Burstein et al. (2006) introduced intelligent features as part of HIPs to enhance its decision-support capability by providing users with relevant context information to aid their decision making. McKemmish et al. (2009) proposed the concept of user-centric quality report for empowering users. Chen et al. (2003) approach to intelligent health search includes a suite of user-supporting tools such as automated thesaurus searching, self-organizing map to refine results, graphical browsing of medical topics.

While most studies focused on external tools for building user-centred improvement in health portals, few have looked at improving the internal management processes and the architecture of HIP itself. Some exceptions are the work by Madle et al. (2006) proposing to gather usage data to drive the redesign and evaluation of a health website; Xie (2009) looked at sustaining the quality-assessment process of HIP, and a recent work looked at automated content discovery to aid domain experts in content curation tasks (De Silva et al. 2012).

2.1 Usage-driven design

There is an emphasis for large information repositories to be usage-driven in order to accommodate the growing user needs (Haase et al. 2005). In information portals, Stojanovic (2003) emphasised the importance of usage-based input to acquire new content for the resource collection and to assist users in formulating query as these two areas are particularly not self-sustainable. Stojanovic et al. (2002) also found that because information portals are often built around a centralised and controlled ontology, the employment of usage data in the portal’s knowledge management is necessary to ensure a balanced and all-inclusive approach to all aspects of searching and resource management.
According to Garde et al. (2007) sustainability of an information system refers to the capability of a system to be easily adapted and updated to the changes of the external environment. It is argued that usage-driven capability is an important determinant of sustainability of HIP (the ability to remain relevant and viable in the long term). It is because HIP does not create content but rather acquires and manages them, which is inherently a dynamic process (De Silva et al. 2012). Below we review the relevancy of usage-driven design to the two core capabilities of HIP which is content management (De Silva et al. 2012) and content search (Luo and Najdawi 2004).

Content management in HIP is underpinned by a manually curated collection, where domain expertise is required to manage resources such as the content collection, the index and the glossary (Miller et al. 2000). Many aspects have to be managed and sustained such as the sufficiency, currency and permanence of content, which rely on monitoring usage from time to time (e.g. for identifying unused resources or updating popular content) (Pernotto et al. 2003). It is suggested that the content needs to be usage-driven to avoid being static, out of date or inaccessible for users (Cline and Haynes 2001). Regular usage analysis to identify content gaps is recognised as important to the viability of the portals, to maintain an advantage over general Internet search engines which more likely contains new content (Madle et al. 2006).

With content search, a number of research studies focus on harvesting user-friendly terms from usage data to generate a user-centred index that complements and existing document-centred indexing (Fidel 1994; Zhang et al. 2008). This is also useful to identify a lay language used for searching (Keselman et al. 2008). Evans et al. (2009) mentioned the concept of folksonomy which relies on usage terms to build emergent, rather than pre-determined controlled vocabulary. Another potential strategy is to learn from usage data to make search engines more robust to failed searches, such as by pre-identifying failed-search situations and designing better system response (McCray et al. 2004).

### 2.2 Usage issues in health information portals

A comprehensive study reported three major categories of issues that users faced when using HIPs: content issues, user issues and system issues (Nguyen et al. 2011). A taxonomy was developed to detail the types of issues and explain why such occur. For example, content issues include deficiencies which are caused by the content management failing to meet the users’ needs, such as lack of content, indexing issues (mismatches between indexing terms chosen by domain experts versus users’ terms), lack of information diversity to reflect users’ interests or lack of permanence. User issues describe the difficulties of users in executing their search and in dealing with medical queries. System issues include UI issues, the failure of the system to provide effective searching outcome (such as precision and relevance of the results) and the lack of support when users failed their search.

In summary, content management process is complex and socio-technical in nature, because managing resources in HIP involves not just technology, but also requires access to some domain expertise (Evans et al. 2009). Searching is known to cause distress for health information consumers if they fail to retrieve (possibly due to user issues) and the system is not responsive to the situation (Kim et al. 2007).

### 3 DESIGN SCIENCE RESEARCH METHODOLOGY

The main objective of using the design science research methodology is to address a complex problem by developing and investigate the utility of the proposed solution artifacts (Gregor and Jones 2007). In our case, a problem was to improve HIP by proposing the usage-driven capability, as discussed in section 1. The proposed solution was informed by the usage-driven design philosophy as discussed in section 2 (Stojanovic et al. 2003). System development was used as a design research approach (Nunamaker Jr and Chen 1990; Burststein and Gregor 1999) allowing the researchers to gain insights and theorise about the fitness of the artifacts through iterative implementation process. Figure 1 describes the process of the design science research in relation to the organisation of the paper, as well as the outputs of the research. We report on the conceptualisation of the usage-driven design approach
and the method for applying the approach (section 4), the instantiations (section 5) and the design principles (section 6).

Figure 1: Process of the design science approach in this paper

We note that the paper presents an illustration of the approach through the instantiations without the complete evaluation of its effectiveness at this stage. The details are as follows:

- First, the research identifies a conceptual approach for extending and adapting usage-driven design philosophy to HIPs, grounded on the literature on usage-driven design and HIP usage issues. An architecture of usage-driven HIP is proposed. In order to realise this approach, the paper proposes a specification of a problem-solution framework, detailing usage-driven solutions to the problem areas. This is grounded on the theoretical findings of a usage issue analysis in HIP which was presented in earlier research (Nguyen et al. 2011).

- Second, the research examines the development of systems’ components, acting as the expository instantiations of the design approach (Gregor and Jones 2007). The paper describes how the ideas of the approach are realised in an operational health information portal and highlights novel features in a concrete context. A set of design principles are generalised from the lessons learned from this implementation, (see section 6).

The rest of the paper is organised accordingly.

4 CONCEPTUALISING THE USAGE-DRIVEN APPROACH FOR HEALTH INFORMATION PORTALS

This section is addressing the argument that current architecture of HIP is inadequate to respond to the dynamic nature of health consumers information needs, making HIP unsustainable. For instance, the mismatches between the needs and the content are visible at the “back-end” functionality such as the resource database, the indexing terminology or the lack of support in failed searches. Some of the mismatches are attributed to the controlled nature of HIP which is typically overseen by the domain experts (Evans et al. 2009). In the “front-end” area (e.g. searching interface), a lack of usage insight will limit the guidance provided to users.

To extend the usage-driven capability (section 3.1) to HIP, it is imperative to augment HIP architecture to be capable of taking input from a usage channel. Figure 2 illustrates the flow of usage data as part of the augmented architecture focusing on both front and back end of HIP.
When enabling the usage-driven content management function of HIP, it is important to integrate it with the socio-technical structure of HIP. HIP’s structure typically integrates with the portal maintenance team/domain experts to control the resources including the regular updates to the content database, the index and the glossary. Based on a business analytics perspective (Mühlen and Shapiro 2010) a purposeful usage-driven solution (for instance, a usage-issue reporting tool) needs to support specific workflow of the domain experts and enable them to take specific actions (e.g. acquiring content or revising the index) rather than just report generic, purposeless information.

In applying usage-data to front-end (user interface and search tools), in this paper we only focus on extending usage-driven capability to searching, although there may be some other strategies for addressing HIP issues, as discussed in section 2.2. We pay attention to the role of usage data to provide usage-based recommendations for users to broaden their searches and to avoid failed searches by offering relevant, retrieval-guaranteed topic search alternatives.

The approach is realised by the codification of a problem-solving framework, detailing the usage problems where intervention from usage data can lead to improvement. The framework is based on the usage issues taxonomy as suggested by (Nguyen et al. 2011). An excerpt of the framework relevant to the approach is provided in Table 1.
<table>
<thead>
<tr>
<th>Proposed system development</th>
<th>Issue targeted</th>
<th>Usage-driven solution</th>
<th>Nature of the problem</th>
</tr>
</thead>
</table>
| Content-issue reporting tool | Lack of content | Identify from usage logs the topics of interests but failed to retrieve due to absence of content in the database, especially emerging or recurring failed searches. New categories may be created | Recurring
| Improving and sustaining the content collection, by bridging the gaps between users' needs and the system | Imbalance of content distribution | Review content distribution and reorganize the content, based on the identification of mismatches between usage and content distribution across categories. | Recurring |
| Indexing issues | Mismatch between topics distributed in the systems and topics pursued by users | Usage-driven indexing based on real search; acquire user-generated terms for indexing. Review mismatches between the metadata being used for indexed and metadata (search profiles) preferred by users, to detect possible metadata tagging faults (by domain experts) | Recurring |
| Failed search without guidance from the system | Recommendations which are usage-based that can suggest alternatives for users, including: Usage-based topic search to broaden their search space the change from broad query to more specific query relaxation of too narrow search options avoidance of one-word query recommendation which is profile-specific (e.g. users who are above 70 are found to more likely failed due to simple strategy, suggestion could encourage them to explore other search modes) | One-time |

| Table 1 Extract of a problem-solution framework for usage-driven improvement |

The solutions prescribed are the basis of the implemented system features. Text in *italics* provides the descriptions of the tools and the issues where applicable.

5 INSTANTIATIONS

Below we describe the implementation of two instantiated artifacts corresponding to the two proposed system development presented in Table 1, serving as the proof-of-concepts of usage-driven improvements. They apply to the content management and content search features of HIP.

5.1 Content-issue reporting tool

The tool is designed to add usage-driven capability for the content management process in a HIP. It comprises of the following features:

- Reporting on lack of content usage cases: emerging searches not accounted for in the database
- Usage-driven indexing: reporting on failed searches due to mismatches between user-generated terms and the system’s indexed terms. It also suggests alternative usage-based candidate terms to be harvested for indexing
- Reporting on the mismatch concerning the system’s topic diversity and the users’ interests
- Isolating failed searches which are due to users’ issues (e.g. misspelling or due to improper use of search options)
The following key techniques are used when implementing the tool:

- A rule-based classification technique is used to automatically differentiate the content issues. The rules are based on the following: content presence in the database with/without stripping of search options (to identify lack of content); comparing user terms and glossary terms for indexing mismatches; comparing topical distribution in the system and users’ searches if two few results are returned.

- The prioritisation rules are based on checking user search history: repeated failed searches from one user, repeated visiting users or popular failed searches are considered more important.

- Other sanity checks include in-scope and misspelling are performed on the glossary database.

Figure 4 presents the screenshot of the usage reporting tool, with other smart features for enhancing the tasks which we will discuss below.
In the following sections we highlight the *smart* features of the tool which provide effective insights for the content management tasks in the portal.

### 5.1.1 Focused decision-making support

The menu in Figure 4 (A) acts as a detailed listing of specific issues relating to the content issues in HIP. It allows the domain experts to zoom in and inspect each specific issue, and decide on the actions that can lead to an improvement. This is an improvement of the previous versions of the raw data reporting tool where only data, but not *insight*, were presented, hence making it difficult for domain experts to filter useful insights specific to each issue. A rule-based classification mechanism automatically sort failed searches into specific issue, so if a domain expert works on content addition task, she would be able to focus on only *lack of content* cases. Application of such rules experimentally shows that through iterative development it becomes pivotal for reducing the complexity of content management task.

### 5.1.2 Integrated insights on content issues

In Figure 4 (B), we demonstrate the *smart summary panel* feature of the tool, which provides a summary of *lack of content* cases. The summary presents a listing of suspected failed searches, each with context-specific insights on the issue, so the domain experts can decide whether or not to take actions on them. The insights include: the diagnosis on why the search failed (e.g. an empty search because the query is not present in the database, even when removing the effect of poor search options). The function allows seeing all search parameters being used; the search history of the user,
including their profile and other details recorded in the log. Another enhanced function is based on the concept of *Importance*, which prioritises more important failed search cases for the domain experts to deal with. The one we consider here is based on the frequency of the failed searches – i.e. the ones with many users failing the same searches, or emerging content requirement is ranked higher. Therefore, the domain expert has potentially a reduced data overload to deal with.

5.1.3 Actions recommendations and future integrations with other dashboard technologies

The panel also provides specific suggestions, as represented in Figure 4(C) that can be used to initiate actions with regard to the issue, thus providing a direct translation from knowledge to action. The actions are customised to the workflow of HIP content management. For instance, the *lack of content* might lead to the addition of a new content or a new topic, a perceived *indexing issue* will relate to the task of fine-tuning indexing terms for a resource or to harvest new user-based terms. These actions can be integrated with future automated dashboard functionality, such as an automated content discovery function as suggested by (De Silva et al. 2012).

5.2 Usage-driven topic search

In this section we discuss another strategy for improving content search in HIP by considering usage data as part of the front-end search functionality. It is envisaged that such feature can provide users with more alternative search topics if their current search failed, or to inform new possibilities in searching, thus removing the constraints associated with users’ narrow bag of keywords or ineffective search strategy (Zeng et al. 2004). The approach is customised to meet certain requirements for searching in health portals. The data is user-generated but subject to verification by the domain expert to ensure they fit to the portal’s scope and address the existing content. At the same time the search feature dynamically catches the useful topics generated by the users in addition to those suggested by the domain experts.

5.2.1 Usage-driven dynamic search interface adaptation

Figure 5 describes the approach behind the enhanced topic search feature which adds an explicit representation of usage-based topics along the side to those suggested by the domain expert. We also illustrate how such feature was integrated as part of the BCKOnline interface (see Figure 6). The left column refers to the extraction of most popular topics as provided by the system, represented a system-view of the topic search.
Figure 5 Design of the usage-driven topic search feature

The right column extracts most popular topics sought after by users, represented a user-view. Both topics are aligned to a content spectrum which is characteristic of a health portal, as illustrated in Figure 7. The notable features are described below:

- **Duality user interface**

  The duality user interface (Figure 6) is considered a novel feature in HIP. It presents a dual user/system view of topics so users are best informed what content they can search for. If users are only present with system-generated keyword suggestions they might not be able to broaden their search, limited by what is known by the system (and informed by the domain expert view of the problem domain).

  On the other hand, if users are only presented with user-generated keywords (similar to many other health portals including MedlinePlus) their search choice might be irrelevant and might fall out of the scope of the system’s content without knowing.

- **The provision of usage-based topics while adhering to the information spectrum of the health portal (B)**

  The lessons learned from failed usage cases have highlighted the need to help users avoid zero-search results situations as a priority (Nguyen et al. 2011). This includes verified alternative search options (that are known a priori to retrieve better results), search terms, query syntax or changing search strategy (e.g. using every day layman terms rather than commercial or scientific jargon). Some of these aspects are reflected in the implementation of this feature. The significance of the feature is also noted, given the high level of frustration for users if they cannot get anything when pursuing medical information seeking (Evans et al. 2009).
The topics being endorsed by the domain-experts before delegated to the front-end

Similar to the content management, there is an integral role of the domain experts in the design and maintenance of the topic search features. This mechanism is enabled in the design of the tool. As the usage-based topics can change dynamically, such monitoring is necessary to ensure the search topics remain relevant to the portal’s knowledge base. An internal feature allows the domain experts to review and endorse the user-generated topics before being delegated to the front end without complicated website overhaul.

6 DESIGN PRINCIPLES IDENTIFIED FROM THE IMPLEMENTATION

The implemented system tools provide an illustrative case study which demonstrates how the concept of usage-driven improvements can be instantiated in HIP. Based on the lessons learned from the iterative implementation process, Table 2 presents a set of criteria to ensure that the approach is functional, viable and sustainable. These can be considered as the design principles, which safeguard the proper implementation of the conceptual approach. It is noted that the claimed contribution in developing the prototypes is mainly in the proof-of-concept and in testing the feasibility and fitness of the approach to the requirements of HIP context. The research does not claim the contribution in terms of the performance or effectiveness of the tools at this stage. This will require further evaluation. The example implementation reported here, however, has practical value since they provide empirical knowledge and have been subject to domain experts’ consultation. We summarise them in the following table followed by further comments.

<table>
<thead>
<tr>
<th>Design Principle</th>
<th>Integration with domain knowledge to provide relevant usage data interpretation</th>
<th>Smart and scalable information extraction</th>
<th>Clear problem-solution prescription</th>
<th>Smart user interface in usage issue reporting</th>
<th>Providing only endorsed usage-based suggestion in topic search</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applies To</td>
<td>Content management</td>
<td>Content management and topic search</td>
<td>Content management</td>
<td>Content management</td>
<td>Topic search</td>
</tr>
</tbody>
</table>

Table 2 Lessons learned from the implementation of usage-driven approach in HIP
• **Integrate with domain knowledge to provide relevant usage data interpretation**
  This principle suggests that domain-specific knowledge such as ontology, glossary, spellchecker and context information relating to each issue needs to be employed when analysing usage data.
  Significance: To ensure knowledge extracted from usage data can be relevant, accurate and domain-specific (e.g. ensure accurate identification of lack of content which is dependent on the content scope).

• **Smart and scalable information extraction:**
  This principle articulates the need to reduce information overload by extracting only relevant insights, and use of prioritisation rules.
  Significance: Ensure the sustainability of the approach in handling large-scale, recurring usage data.

• **Clear problem-solution prescription**
  This principle asserts the importance of translating usage knowledge into specific case-based, actionable solutions, rather than providing generic usage information.
  Significance: Provide clear directive to address the solutions and to reduce the complexity in analysing usage data. The use of rule-based classification (section 5.1.1) is an example of how the usage issues can be differentiated to help the analysers focus on each issue.

• **The use of smart user interface in usage issue reporting to enhance decision making**
  This principle recommends the use of streamlined user interface, configured to support specific workflow of domain experts. For instance, information relating to lack of content would display different context information and recommend actions tailored to the task.
  Significance: To reduce the complexity of usage reporting, and enhances the capability of focused problem-solving and decision making.

• **Providing only endorsed usage-based suggestion in topic search**
  A practical experience from the deployment of this feature shows that even usage data are employed to broaden users’ search, it is still important to regulate them and pay attention for data sanity, in-scope and relevancy.
  Significance: To ensure usage-data when deployed can meet the relevance of HIP as well as aligned with the information spectrum.

7 **CONCLUSION**

In this paper we have proposed and illustrated an approach for introducing usage-driven capability to HIPs. The paper has demonstrated the importance of the approach, mainly in terms of enabling HIP to adapt to the dynamic nature of usage in both content management and content search functionality. As set out in the motivation, this applied research contributes a concept and tangible improvement in line with recent studies in the direction of smart health information portals.

Through the conceptualisation and implementation, we have provided novel system features and practical experience in deploying the approach to fit the environment of HIPs. As a preliminary work on the concept of usage-driven health information portal, this paper paves the way for a number of interesting future research problems. These include investigations into the benefit of such approach for real health consumers. An evaluation of the effectiveness of the proposed functionality would require a longitudinal study involving usage data collection, monitoring and analysis, as well as the potential of adopting such an approach to other problem domains and user-centred information systems in general. To some extent, utilising usage data part of effective HIP design fits well with the Web 2.0 philosophy in which user communities are fully engaged in a socio-technical fabric of the system design.

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