Emerging Technologies for Information Quality Improvement

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Abstract Emerging technologies can contribute to the improvement of information quality and revolutionize the way in which information quality is managed by organizations. Web-based technologies, for instance, are being used successfully by many companies to conduct a sizable part of their business on the Internet and to implement their business to business initiatives through extranets. High-speed networking technologies, such as Gigabit Ethernet, Asynchronous Transfer Mode, and Wavelength-Division Multiplexing will deliver vastly higher transmission speeds and will therefore make available the higher bandwidths needed for data access, an important dimension of data quality. These and other technologies such as Low Earth Orbit Satellites, Local Positioning Systems for object identification indoors, Personal Digital Assistants, Wearable computers, Active Networks, and Enterprise Resource Planning systems promise to significantly improve information quality, especially along the accessibility and timeliness dimensions. Other dimensions such as reliability, relevancy, richness, security, consistent representation, and understandability can also be improved.

1. Introduction

Advances in data communications have spawned a wide range of new technologies that promise to make access to information easier and much faster than ever before. Whether the information is stored throughout a company's enterprise network or is available on the Internet, its accessibility by consumers will be significantly increased. Although their specific benefits have been generally understood, the role of these emerging technologies has not been analyzed from the perspective of the consumers of information. In this paper we analyze how emerging technologies, such as high-speed networking technologies, web-based technologies, active networks, enterprise resource planning (ERP) systems, personal digital assistants (PDA's), wearable computers, low-earth orbit satellites (LEOS), and local positioning systems (LPS) contribute to improving information quality (IQ) (Wang, Storey & Firth, 1995; Wang & Strong, 1996; Huang, Lee & Wang, 1999, pp. 16-17).

The paper is organized as follows: in part 2, we briefly describe the main characteristics of the emerging technologies we are presenting; in part 3, we give some examples of how these technologies are used; in part 4, we discuss the IQ dimensions that can be improved by the use of the emerging technologies; and finally, in part 5, we have some concluding remarks.

2. Characteristics of emerging technologies

In this section, we introduce the emerging technologies that we have identified in the previous section and give a brief description of each one of them.

2.1 High-speed Networking Technologies

Asynchronous Transfer Mode (ATM) (Bates, 1998, pp. 209-215; FitzGerald & Dennis, 1999, pp. 252-259; Panko, 1999, pp. 140-142) is a high speed packet switching service that has the potential to carry data traffic over long distances at speeds up to 2.5 Gbps ATM transmits fixed-length (53 bytes) packets called cells that can deliver voice, video, as well as data traffic to destinations that can be next door or across the globe. ATM is intended to be carried over an underlying Synchronous Optical Network (SONET) (FitzGerald & Dennis, 1999, pp. 281-282; Panko, 1999, pp. 286-287) infrastructure and to deliver to a client/server architecture the capability of linking at very high speeds all local-area network to local-area network (LAN to LAN) and local-area network to wide-area network (LAN to WAN) services. Today, the most common speeds for ATM are 155 Mbps and 622 Mbps. In addition to its high throughput, another major feature of ATM is its scalability and the various quality of service (QoS) levels it provides for time sensitive traffic. Many experts believe that ATM will gradually displace private leased T1 lines and customer switching equipment used by corporations in their local-area networks and wide-area networks.

Gigabit Ethernet (FitzGerald & Dennis, 1999, page 245; Panko, 1999, pp. 303-304) represents the next generation of the 10/100 Mbps ethernet standard

which is currently the most widely used LAN technology. Gigabit Ethernet operates at speeds of 1000 Mbps (1Gbps) and uses the existing Ethernet medium access protocol for maximum compatibility with existing Ethernet networks. Gigabit Ethernet is routable and supports both switched and shared. Because of its high speed and its provisions for multimedia and explicit priority support, Gigabit Ethernet promises to meet the demands of such bandwidth-intensive applications as video-conferencing, medical imaging, and CAD/CAM. Gigabit Ethernet can also be used as a backbone between existing fast ethernet switches, routers (Panko, 1999, pp. 133-145; Riezenman & Sweet, 1999), and high performance servers (Panko, 1999, pp. 162-165).

Wavelength-Division Multiplexing (WDM) (Lange, 1999) is a high-speed transmission technology that promises to revolutionize both the Internet and the traditional telecommunications industry. WDM divides a strand of fiber into a number of separate wavelengths of light thereby increasing its capacity many folds. For example, Lucent Technologies has announced that it has devised a way to divide a single fiber-optic strand into 80 separate wavelengths resulting in a 400Gbps speed and allowing for the transmission of over 10 million voice phone calls over that single fiber. This 400 Gbps speed would be more than adequate to carry the world's Internet traffic at any given time on a single fiber. Moreover, scientists at Lucent Technologies are predicting much higher speeds in the near future which will most probably result in a video-based Internet with over 10,000 video channels to choose from. Internet II (Lange, 1998), the next generation Internet, will be used as a test bed for WDM technology.

WDM technology has the potential to dominate the other high-speed networking technologies described above. Because Internet II will use WDM technology, this can potentially change the way we access and use information and thus the way we work and live.

The main benefit of these technologies is higher transmission speeds. This translates into faster access to information with richer content (graphics, images, audio, video) and makes it possible to implement ERP systems in

enterprises and to use video conferencing systems to deliver a variety of content such as distance learning and on-line training.

2.2 Web-based Technologies

Web-based technologies use the Internet-based TCP/IP protocols to allow a web client, such as Netscape Navigator, to communicate with a web server using the HTTP protocol (Panko, 1999, pp. 41-57). In this client/server communication, the web server sends web pages to the web client for display on the user's desktop. The web client and the web server could be communicating either over a local-area network or the Internet. The World Wide Web (WWW) is a prime example of the use of web-based technologies on the Internet. Intranets and extranets (Austin & Cotteleer, 1997; Panko, 1999, pp.156-157,192-217) are another example of the use of web-based technologies. Intranets and extranets are being deployed by organizations at an ever increasing rate and, in many cases, are being used to replace older technologies in areas such as sales, marketing, order processing, and service and support. Web-based technologies enable users to access various kinds of information either on their local network or on the Internet using a consistent, graphical interface provided by a browser. An intranet is a web technology-based network that is used within an organization to provide an efficient exchange of corporate data and information among its employees. Generally, intranets are used to publish electronic copies of company documents, including employee manuals, product information, employee benefits information, and engineering drawings for collaborative work. Intranets are also being used to provide access to web-enabled applications. An extranet is similar to an intranet except that outside companies are allowed to access it only through the Internet from behind a firewall. Extranets enable organizations to have a direct relationship with their customers, suppliers, and dealers by allowing customers or authorized personnel from partner companies to exchange proposals, cost estimates, product specifications, and inventory levels in a timely manner.

The main benefit of web-based technologies is that they allow easy, universal, but also relatively fast and timely access to information regardless of its physical location and the type of servers it is residing on. Because the information is presented to the user in a graphical format and can include audio and video clips, such information is much richer than simple text. In addition, search engines such as Yahoo!, AltaVista, and others allow users to search through the overwhelming amount of information available on the web and to find what they need quite rapidly. Security and privacy problems are a drawback of web-based technologies, although encryption, digital certificates, and firewalls can be used to reduce these problems.

A new type of applications called web-enabled applications is emerging. Whereas in the past users had to learn a specific application to perform a particular task, they can now use a browser to do the same. The advantage here is that the user does not have to learn a specific interface to perform a particular task, he/she always uses the same interface, namely that of their favorite browser. Also, users can now perform their tasks anywhere in the world, at any time, from any computer as long as it is connected to the Internet. As an example, consider how Hewlett Packard (HP) Network Printers used to be configured and managed : one had to install the appropriate version of an application called JetAdmin on his/her computer. After that, the only way to configure and manage the HP Network Printers was to physically be sitting at that computer and to execute the JetAdmin application. Now, HP came up with a web-enabled version of JetAdmin called WebAdmin which, once installed and properly configured on a Web server, allows us to configure and manage the HP Network Printers from any computer that has a web browser. There is no need to install anything related to HP Network Printers on that computer. What this means is that a network manager could be in Paris on vacation or on business and can now use his/her a laptop to connect to the Internet to configure and manage the HP Network Printers located in his/her company's network back in Boston.

2.3 *Active Networks*

Active networks[1] are "networks which can identify users and content to optimize information delivery according to business priorities." Because these networks understand who is on the network and what they are doing, they can use business policies to deliver different levels of service that are matched to the content, applications, and users that run the business. This new generation of networks will use three main components: a common network identity, some policy-based management tools, and an optimized delivery mechanism. Digital certificates issued to users, content, and equipment by servers such as Netscape SuiteSpot or Microsoft BackOffice will provide the common network identity. These digital certificates will prove beyond any doubt the identity of those users, content, and equipment. Distributed directories such as Novell's NDS, Microsoft's Active Directory, and Netscape's Directory Server will store these common network ID's and will link them to their privileges. Policy-based management tools will translate business rules and priorities into policies which are then associated with common network ID's stored in the directory. For example, we might have a rule that says CEO's videoconference at 3 p.m. has top priority. This rule will be stored in the directory and will be automatically accessed by switches and routers that will make sure the CEO's videoconference receives the highest priority. Also, traffic statistics and directory services can be used by accounting software to generate reports on users, applications, and equipment activity. This will allow a company to link traffic volumes with specific users IDs and to relate faults to specific users, applications, and equipment when something goes wrong. Once the credentials of users, content, or applications are established using the business rules stored in the directory, switches and routers can then set aside adequate bandwidth to ensure that certain transactions (e.g., ERP transactions) are completed without being disrupted by concurrent large multimedia downloads. In addition, popular content can be brought closer to users once it is identified by content

management software such as PointCast's I-Server or Microsoft's Proxy Server. A particular user can then access the closest copy of content using an intelligent service locator, such as Cisco's Distributed Director, which will automatically check the directory services for the closest copy of content. Currently, Microsoft and Cisco are working together on active networks that will make use of Microsoft's Active Directory and Cisco's Enterprise Security Architecture. This alliance will surely help in driving users to adopt active networks.

2.4 Enterprise Resource Planning (ERP) systems

Enterprise Resource Planning systems (Davenport, 1998; Panko, 1999, pp. 230-232), also known as enterprise systems, are off-the-shelf software solutions that can, if properly implemented and used, provide efficient and state-of-the-art methods for keeping a company's entire supply chain better informed and for integrating the information produced and consumed by the various parts of that company. One of the major benefits of an ERP system is that it integrates into a single product all of the major business functions, such as order processing, inventory, and accounting. Using an ERP system, a company will be able to communicate the progress of orders and projects throughout the supply chain as well as manage complex and/or large customer orders that can include manufacturing, delivery, setup, and service. In addition, the company using such an ERP system gains the ability to track the costs and availability of value-added services. Such a company can now let customers know whether their latest order was received, whether there is available inventory to service their order, and when their shipment is expected to arrive. Some ERP systems even allow customers to directly track their orders and check on supplier inventory levels, thereby giving them the ability to follow and control parts of their business that they could not before.

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[1] Forrester Research Report, 1998.

Initially, ERP systems grew out of the manufacturing environment where cross-functional file sharing was needed. Once companies implemented ERP systems, the concerns over data quality became more obvious.

2.4 Personal Digital Assistants and Wearable Computers

Personal Digital Assistants (PDAs) (Dutta-Roy, 1999) are hand-held devices with features such as built-in communications capabilities for remote access and network synchronization of files, as well as business applications such as an e-mail reader, an expense tracking application, and software to keep track of meetings, contacts, or projects. These devices can also be used to input data in the field and have it uploaded to a database server using either a direct link or a wireless link. Various vendors are bringing out PDAs which will run a new Microsoft operating system named Jupiter and which can be connected to legacy networks or the internet using wireless modems. These devices can be used to receive data, process it, analyze it, and act upon it before transmitting back the results in real-time.

Wearable computers (Dutta-Roy, 1999) represent a relatively new breed of PDAs that can improve information quality especially through wireless access to the Internet. Wearable computers usually comprise the following:

- A main case that contains a 233-MHZ Pentium processor, up to 128 MB of memory, and a removable hard disk. The case is designed to be worn around the user's waist or wrist.
- A headset with a monocular video display, a microphone, and an ear piece.
- Built-in speech software to allow the system to work without a keyboard.

PDAs and Wearable computers configured with wireless access to a network or the Internet can be used as a client device to access the Web, e-mail, and to input (capture) data at the source before uploading it to a database residing on a server in the network.

2.6 *Low Earth Orbit Satellites (LEOS)*

Low earth orbit satellites (Miller, 1998) are positioned at a very low altitude of about 350 miles from earth so that the communication delay is very small which, in turn, allows them to handle Internet-style traffic. Teledesic[2], for example, is planning to build a constellation of 288 LEO satellites that will serve as a global, high bandwidth "Internet-in-the-Sky"This network will provide affordable, worldwide access to telecommunications services such as Internet access, videoconferencing, high quality voice, and other digital data needs for businesses, schools, and individuals anywhere on the planet.

Initially, high earth orbit satellites were used for telephone and TV transmissions only. These satellites are expensive and require large, usually fixed and expensive land-based systems. With LEOS, we can have much wider accessibility and cheaper access and mobility.

2.7 *Local Positioning System (LPS)*

Local Positioning System technology for indoor object identification (Werb & Lanzi, 1998) is another technology that can improve data quality. Specifically, inventory management in warehouses and the accurate position of objects within a building can be achieved efficiently. This technology uses a tiny transmitter tagged to an object and a receiving device that is capable of picking up the signal emitted by the object's transmitter and then determining with accuracy the position of that object using a technique similar to the traditional Global Positioning System (GPS).

Table 1 summarizes the main characteristics of the emerging technologies we have described.

[2] Information obtained from Teledesic's web site www.teledesic.com

Table 1: Emerging technologies

Technology	*Main Characteristics*
Web-based Technologies	Allow consistent access through a browser to various kinds of information available either on a local network or the Internet
High-speed networking technologies (Gigabit Ethernet, ATM, WDM)	Use advanced switching techniques to achieve very high transmission speeds (1 Gbps for Gigabit Ethernet, 155 Mbps - 2.5 Gbps for ATM, and 400+ Gbps for WDM)
Active Networks	Identify users and business policies to deliver different levels of service in an optimized manner
ERP systems	integrate enterprise-wide information
PDAs, Wearable Computers	Used to receive and/or input data in the field, process it, and upload it to a database server using either a wireless or a direct link
LEO Satellites (Teledesic, Iridium)	Allow access to information from anywhere in the world at speeds up to 64 Mbps. A constellation of satellites will provide an Internet in the sky"
LPS for indoor object identification	Uses GPS-like technology coupled with a communication link to a Database server for accurate identification of objects and their position indoors.

3. Application Examples

In this section, we provide examples of how many companies are already using some of the emerging technologies under consideration.

3.1 High-speed Gigabit Ethernet network

The Institute of Nuclear Power Operations (INPO)[3] was established to facilitate better communication and in turn better safety and reliability- in the operation of more than 400 nuclear power plants worldwide. It communicates with each plant on a regular basis to assist in problem aversion and resolution by collecting, analyzing, and disseminating large amounts of safety information. INPO needed to upgrade its network so as to be able to handle the high volumes of traffic to and from the more than 400 nuclear power plants. By replacing its existing network infrastructure with Gigabit Ethernet, INPO was able to achieve

network speeds nearly 80 times faster. So now INPO is not only able to handle the higher volumes of traffic but it also planning to deploy desktop videoconferencing systems and put training videos on the network.

3.2 High-speed ATM network

W.L. Gore and Associates[4], a leading producer of medical equipment such as heart grafts and coronary implants, was faced with a bandwidth shortage in the IT network that connected its main distribution center in Phoenix, Arizona, to an eleven building site in Flagstaff used for research, development, and manufacturing. Since "any blockage in the system's bandwidth could be life threatening to business", this company needed a technology that would provide high levels of on-demand bandwidth. This was made even more pressing because they were also rolling out a new ERP system that required a lot more network bandwidth. They decided to use ATM technology both for their WAN and LAN needs. This new high-speed network allowed them to provide for the high-speed data access needed for the ERP system in addition to the necessary bandwidth required to carry both data and voice across the entire wide-area network. In the future, W.L. Gore and Associates believes that the network has enough bandwidth to handle the addition of desktop videoconferencing which would minimize employee travel time between sites, increase productivity, as well as decrease decision-making time and allow better interaction between on-site and off-site employees.

3.3 Web-based technologies

Ford Motor Company uses an intranet to allow controlled access to a large number of web-enabled applications by employees and suppliers (Austin & Cotteleer, 1997). One such application allows employees to order a vehicle from the company's car lease program and select the features they want along with their corresponding cost. In addition, users can also view a picture of the vehicle

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[3] Nuclear gigabit network, LAN Times, October 26, 1998

in whatever colors they picked. Another application allows Ford product engineers to evaluate products from their competitors by examining a competitor's vehicle to the level of its smallest parts. This is made possible by capturing images of parts from teardown locations and posting them on the intranet. Consequently, whereas in the past these engineers had to travel to a physical teardown location where competing products were actually disassembled, they can now use their browser to visit, virtually, in a matter of seconds. Ford engineers also use the intranet to collaborate on the design of related vehicle components: one engineer would post the drawing of a component on the intranet, another engineer working on a related component and located somewhere else can then pull up this drawing, make any necessary changes, and then e-mail it back to the original engineer. Finally, through its B2B (Business to Business) server, Ford provides an extranet that allows its suppliers secure access to the appropriate areas of the Ford intranet.

American Oncology Resources (AOR)[5] uses an extranet called SecureNet to match a patient with clinical cancer studies in real time and, in case a match is found, send out an e-mail notification to the patient's doctor. For those patients who do not respond to traditional therapy, clinical trials can be the last option in their fight against cancer. Without SecureNet, patients have to rely on a paper-based method for finding patients who might be appropriate for the clinical trial of a new drug. Usually, by the time the appropriate forms have been submitted and processed, many patients find themselves closed out of the limited number of eligible positions. Using SecureNet, a doctor or a nurse enters the patient information including name, date of birth, site of the cancer, and the stage of the cancer on a scale of 1 to 4, with 4 being the worst. As soon as the information is submitted, the patient's profile is run against every open trial in the AOR network. When a match between the patient and a clinical trial is found, an e-mail notification is sent to the patient's doctor. An example of the efficiency of this

[4] ATM builds fit backbone, PC Week, October 12, 1998
[5] Web joins war on cancer, PC Week, October 19, 1998

extranet is a practice in Tulsa, Oklahoma, which received seven trial matches correlating with a variety of cancers during the first day of using SecureNet.

3.4 ERP systems

A 1998 Forrester Research report describes how Yotec, a leading maker of steering systems and oil and water pumps whose facility has more than 40 production lines, is using the ERP system it has recently implemented. When the company started outgrowing the manufacturing resources planning (MRP) system running on its mainframe computer, it selected an ERP system developed by a company called Glovia in Los Angeles. This ERP system was integrated with its existing electronic data interchange (EDI) system in such a way that orders received through the EDI system were now transferred through the network to the ERP system which took care of the task of creating the necessary production schedules and manufacturing resource plans. Now, the ERP system allows the purchasing managers at Yotec to tap into the system to order the necessary parts. Also, as products are built on the production line, workers enter specific codes associated with the products into radio-frequency units connected to a data collection system. These real-time data are then used by the ERP system to track the status of orders and inventory levels. In addition, when orders are complete, the appropriate advance shipping notices are generated and sent to the customer using the EDI system. Yotec is planning to use these advanced notices as the invoice for payment for customers such as Honda.

The same Forrester Research report describes Derby Industries in Louisville, Kentucky, a manufacturer of sub-assembly and die-cut component parts for major appliance and automotive companies. Derby Industries operates manufacturing, warehousing, and distribution plants in 15 locations in five states filling hundreds of orders every week, with 200 line items each. Because its orders and production schedules change frequently, Derby needed a system that would allow it to minimize the impact on both the supplier shipments and its

customers' shipping schedule. This system would permit Derby to keep orders going out to its customers with minimal disruption. Derby selected the Millenia ERP software from FocusSoft in Louisville, Kentucky, which had a scheduling tool that allowed the company to adapt its production and shipping to ever-changing customer order dates. Using simple drag-and-drop functions, manufacturing planners could now see how a change in one customer's schedule would affect all other customer commitments. In addition, by integrating purchasing with customer orders and schedules, Derby was able to reduce inaccuracies and duplicated efforts. The company also plans to give key customers access to its ERP data so that they can track orders in process, inventory levels, etc. Recently, the ERP software was upgraded to allow order entry over the Internet, thus providing manufacturers with the ability to securely conduct transactions over the Internet.

3.5 PDAs and wearable computers

For some time now, UPS has equipped its US fleet of more than 60,000 delivery trucks with handheld systems[6] called DIADs (Delivery Information Acquisition Devices) which can use two-way radio communication over the Ardis radio network provided by American Mobile Satellite Corporation. These devices are used to provide fast package tracking information by uploading package information immediately upon receipt.

As for wearable computers, the following two scenarios illustrate their possible use (Dutta-Roy, 1999):

- A maintenance staff using wearable computers can browse through the pages of a repair manual that are specific to a seldom-encountered problem.
- Paramedics rushing a patient in an ambulance to the emergency room of a hospital can use a wearable computer to send data, and perhaps even pictures, about their patient to the specialists waiting at the hospital

[6] UPS: delivering network innovation, PC Week, September 13, 1999

emergency room and receive new instructions on the best procedures to follow while still on their way to the hospital.

3.6 Low Earth Orbit Satellites

Teledesic describes itself as the "Internet-in-space company backed by Bill Gates and Craig McCaw" It is building a global, broadband Internet-in-the-sky using a constellation of 288 low earth orbit satellites that will allow any computer equipped with a special antenna to connect to the system from anywhere in the world. Users and companies located in areas where no phone or cable connections are available can then use this space-based, high-bandwidth Internet to access data and video services[7].

3.7 Local Positioning System (LPS)

PinPoint Corporation developed the 3D-iD Local Positioning System (Werb & Lanzi, 1998) that allows the tracking of assets over distances up to 120 feet through walls, closets, desks, and doors. This new technology provides a cost-effective and scalable solution for electronic asset management in healthcare organizations, in distribution management, in manufacturing management, and in high-value asset security. For example, once tags are affixed to assets, LPS will allow healthcare organizations to quickly find and track expensive medical equipment such as portable pacemakers, infusion pumps, or motorized wheelchairs. They can also ensure that assets remain in the facility by making sure that individuals leaving the facility with a piece of equipment are actually permitted to do so, otherwise an alarm will be sounded. In addition, doctors, nurses, and even special types of patients - Alzheimer's victims, newborn babies, patients with highly infectious diseases - can be quickly located at critical times. This can help in finding the cardiologist who is the nearest to the emergency room or in ensuring the safety and security of Alzheimer's, neonatal, or psychiatric patients by sounding an alarm if the patients leave certain

[7] Information obtained from Teledesic's web site www.teledesic.com

designated areas. LPS can also be used in distribution center management to locate, track, secure, and inventory containers and fixed and mobile assets such as parts, pallets of raw materials, cases or racks of finished goods, portable equipment, and people. The LPS system allows for the continuous, real-time monitoring of assets so that we can tell where a particular asset is at any time.

4. IQ Dimensions that Emerging Technologies can improve

In this section, we identify the IQ dimensions that can be improved by the use of theses emerging technologies.

Table 2 lists the IQ dimensions that can be improved by the use of a particular emerging technology. When seen from the perspective of the consumer of information, these emerging technologies can help improve the quality of information along many dimensions, in particular, accessibility and timeliness. Many of these technologies also improve other dimensions such as reliability, relevancy, richness, security, consistent representation, and understandability.

Table 2: IQ dimensions that can be improved

Emerging Technology	*IQ Dimensions to improve*
High-speed Networking Technologies	Accessibility, Timeliness, Reliability, Security, Richness
Web-based Technologies	Accessibility, Timeliness, Interpretability, Consistent Representation, Richness, Value-adde
Active Networks	Accessibility, Timeliness, Reliability, Richness, Relevancy, Security
ERP Systems	Accessibility, Timeliness, Interpretability, Reliability, Relevancy , Security
PDAs and Wearable Computers	Accessibility, Timeliness, Reliability, Relevancy, Reputation, Value-added
LEO Satellites	Accessibility, Timeliness, Richness, Relevancy, Value-added
Local Positioning Systems	Accessibility, Timeliness, Reliability, Relevancy, Reputation, Security, Value-added

5. Conclusion

The emerging technologies we have identified in this paper can help improve information quality from the perspective of the information consumer mainly along the accessibility and timeliness dimensions. Other dimensions such as reliability, relevancy, richness, security, consistent representation and understandability can also be improved.

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