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On Stochastic Analysis of the Quantities of Information in Economics

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ABSTRACT

In this paper, the definition of information and data are presented with examples illustrating the differences between them. To articulate the value of information, the definition of quantities of information, based on information theory, generally considered to be founded by Claude Shannon, has been quoted. In addition, with corresponding mathematical derivations, specific examples are employed to manifest the factors that make information valuable. At last, we generally discuss the importance of information in economics.

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1. INTRODUCTION

What are we talking about when we talk about information? People might enumerate plenty of examples including the application of information or commodities evaluated by the quantities of information or by the efficiency of information transmission. For instance, mobile phones, widely used in daily life, serve to exchange information in a vocal fashion; emails, for communicating over a long distance yet not demanding rigorous immediateness, convey text and multimedia information. In addition, when people talk, there are also information transmissions, for that people might learn something new while talking with others. Actually, in modern opinions, were there random occurrence, information would be engendered; the generation of information is never apart from probability.

Though as common senses for us as are they today, the above phenomena were difficult to be well depicted in quantities in early 20th century when information as an academic concept was never explicitly shown to academia, and applications of communication did not prevail in a developed sense; in failing to value information to an extreme extent, most companies at that time did not see how important information was to them, thus not aware of the importance of information collection and exchange as we are today. Subsequently, with the theoretical and practical development of information marked by series of milestones, people began to realize the importance of information, and the world saw the germination of what is now called an information age.

In 1948, the publication of Claude E. Shannon's classic paper *A Mathematical Theory of Communication* in the Bell System Technical Journal immediately became a worldwide sensation. It is primarily on this paper that the subsequent modern digital communication, still in a process of sheer progress currently, is based. Nowadays, this theory is not only confined in electric engineering, the realm from which it originated; rather it is applied in many other fields, such as economics, psychology and seismic oil exploration [4]. Furthermore, given that entropy illustrating the quantities of information (demonstrated below in detail) which is fairly common among numbers of specific electric and thermodynamical area has

already been a heated concept in economic areas, it is believed that information is playing a more and more important role in economic field [5].

The paper is arranged as following. In the next section, some examples are posed to illustrate the difference between data and information with the definitions or conceptions of information and data being in advance presented. In section III, the value of information will be discussed. With respect to a more mathematically rigorous form, some contents concerning information theory will be shown there too. Further we briefly discuss the impact of information on economics in section IV. Section V concludes the core concept of information and the interaction with economics.

2. DATA AND INFORMATION

As indicated in [2], data are raw facts. Data can either be generated by samplers collecting original numerical values from a specific object, or from computers that serve as a secondary stage of processing those raw values. However, data cannot tell us anything, which is why we always want to extract some information out of them. To be more specific, what we need is a certain context in which data make sense and thus are transferred into information. Accordingly, Information should be defined as raw facts within a given context. But, how do we define a meaningful context [3]? Giving some examples here would be helpful. A forecast provides us data about, say, raining possibility tomorrow in Beijing. Suppose the probability, namely datum, is given as 50%. With no context but only this number, we are able to spread it among people or store it in a digital facility, but still, we have no information. However, once provided that, for example, tomorrow we will go out, we have the certain information, the certain context, which infers that we should better take an umbrella with us with a 50% raining probability. On contrary, if we are staying at home tomorrow, we do not have to worry about the weather actually. In the second example, we consider a binary wireless channel (shown in Figure 1) through which a digit sent by a transmitter is to turn to either 0 or 1, with a 90%/10% probability, respectively. Here, the data are 90% and 10%, probabilities of a correct/an error transmission, whereas the context is the content transmitted through this channel – should it be a voice, image or a video stream, we could abide that error rate mostly, otherwise, if it were a package of binary text, no one would stand the given bit error rate. These two examples illustrate how context concerns the information drawn from a certain batch of data.

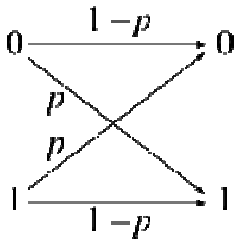

Fig. 1. An illustration of a binary channel

Once we have a need to make decisions or predictions, what we need is the relevant data and information underlying in them. For thousands of years, people have been searching for a better-optimized way in which we gather precise data and mine information from them. Erstwhile approaches of assembling data from changing circumstance were crude, either by counting or by initial machines within a limited range for sensing, thus obstructing the information extraction to an extent. In the meantime, by given sufficient data, people found it arduous to analyze them and, accordingly, failed to mine effective information from them. Till now this remains a challenge in computer science and electrical engineering even when we have powerful computers and advanced math.

As mentioned above, with data and given context, we are capable of gaining useful information. However, here comes the next question: despite the certain context we already know, how do we measure the information we claim to "abstract" from the data? This is important to be posed because it tightly concerns the effectiveness of the algorithms designed for drawing information from data, and it calls for a quantification scheme to formulate the value of information.

3. THE VALUE OF INFORMATION

According to a summarization in [2], there are such qualities determining the value of information:

1. Accuracy: Is the information correct? Can we rely on it?

2. Timeliness: How current is the information?
3. Accessibility: Can we access the information when we need it?
4. Engagement: Is the information capable of affecting a decision?
5. Application: Is the information relevant in the current context?
6. Rarity: Is the information previously unknown or confidential?

These parameters do directly provide us ways to collect information, and the standard includes quite a wide coverage, under which an analysis of the importance of each factor is listed thereby.

First, accuracy should embody application, which indicates the relevance between information and context. If the information has little to do with context, this information is not correct for sure. Moreover, the accuracy is likely to promote by means of a better mechanism of gathering data and a more agreement of information with context.

Timeless is an attribute depending on the time efficiency of the data collected for information, as well as the efficiency of the algorithm converting data to information. Improving this quality of information equals to improving the algorithm in charge of gathering and analyzing data.

Accessibility of information accounts for the accessibility of carriers of information and the difficulty of detaching the information from the carriers. For example, it is convenient to hear the voice from and talk by a cell phone, one, if just with usual functions, that most people are able to afford. The certain price of a common cell phone stands for the accessibility of the carrier – the phone; the hearing and talking, however, stand for the simplicity of detaching the information from the carrier.

Engagement refers to a series of features of information, like rarity, timeliness, and accuracy of information, which is more like a compound of these features rather than an independent one, but among such features, there lays a prior important factor that determines decisions mostly – rarity. Why is rarity the most important one that affects the decision? It is because the value of information, while the data and the certain context are given, is equivalent to the rarity of the information, based on a formula proposed by Shannon [1]. The formula concerning quantities of information of a random event should be considered in two cases, discrete and continuous, written as

$$\mathrm{I(m)} = \log\left(\frac{1}{p(m)}\right) = -\log\left(\mathrm{p(m)}\right)$$

$$\mathrm{h(X)} = -\int_{X}^{\infty} f(x) log f(x) dx$$

where $\mathrm{p(m)} = \mathrm{P(M = m)}$ is the probability that message m is chosen from all possible choices in the message space M. The base of the logarithm only affects a scaling factor and, consequently, the units in which the measured information content is formulated. If the logarithm is 2-based, the measure of information is expressed in units of bits. Information is transferred from a source to a recipient only if the recipient of the information did not already have the information to begin with. Messages that convey an already-known-by-the-recipient data involve no real information. Infrequently presence of messages contain more information than more frequently occurring ones, which means the rarer, the more valuable. For example, a prediction that claims a 100% probability of precipitation tomorrow contains less quantities of information than a 10% one, in that a 100% probability means a certainty that does not convey any information, whereas the 10% keeps the weather unknown – this is where quantities of information engender.

4. INFORMATION IN ECONOMICS

Considered to involve the above components, information is causing a great impact on every aspect of modern life, changing the way in which people think and act, and companies create their profit. It is now not weird to see that big companies have their data acquisition and analysis department for more precise information about itself and its opponents, and investment banks and consulting companies have been set up to help amass and analyze quantities of data. The fact that information itself, with the prosperity of computer science and operations research, have still kept its momentum of bulge in quantity, on one hand makes researchers come up with better algorithms to tackle them (e.g. collection and abstraction), on the other hand, leads to diverse profitable economic methods employed by modern institutions.

Other than being in the conventional state in which companies preserve exclusive information, currently exchange and delivery of information become crucial. With the erection of social networks, commercials, based on individual penchant provided by data mining algorithm, have implanted in a novel variety of ways in social websites, such as twitter, Facebook and Google plus. When we use search engines

like Google or Yahoo, commercials matching our palates are also seen everywhere. Owing to mechanisms like data mining, machine learning harnessed in social computing, the world is experiencing a period full of immediate information, yet problems like information security and communication capacity are still considerably open. Nonetheless, convenient exchange and precise delivery of information have completely changed our lives.

Fig. 2. Context awareness

As for the application - degree that information is relevant to the context, some exciting technology have been presented, about to improve our lives in another way. Far from an improvement of mere application, awareness of the user context (such as user profile, role, preferences, task, location, and existing project conditions) can enhance the delivery process of a construction project by providing a mechanism to filter information in a sense that is relevant to a particular context [6]. Context awareness (see Figure 2), through improved techniques for sensing and monitoring a user's context parameters, can also be used to improve security, logistics and health care and safety practices on construction site. A successful and reliable ubiquitous tracking system with guaranteed tracking capability should be able to track a user's position and deliver position-based contextual data continuously in both indoor and outdoor situations.

In conclusion, technology development involves information in economics and changes the way we live. In light of platforms of Internet and wireless technology, the world has seen information shared and propagating in a rate that transcends any other time before. While enjoying the convenience of the information age, we should also keep an eye on a particular set of security and ethics issues. Only by curbing inordinate implement, can we bring economics more benefits through the development of information technology.

5. CONCLUSION

According to the discussions above, we conclude by examples that information is knowledge derived from data, whereas data is defined as recorded facts or figures. Then the mathematical definition of quantities of information is provided to measure the rarity of information, and other aspects of information – accuracy, timeliness, accessibility, engagement and application of information – are presented to help comprehensively understand the value of information. To researchers, how to improve theories concerning information sharing and cooperation remains an open problem. Performing their particular methods to influence the information, engineers are responsible for implementing vehicles or carries of information, making them accessible to people. Then impacts of information on economics are discussed within a wide range of topics including the collection of data and derivation of information, commercials and social networking, awareness of context and security problems. At present time, information is crucial to the well-being of an individual, and a company, who should take care of the collection and analysis of related information, and apply it to marketing. In brief, to gather accurate information and make it valuable is what companies should pursue over time.

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