Profiting From IoT: The Key Is Very-Large-Scale Happiness Integration

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Abstract

Big data without link to value is merely a cost. We have studied how to profit from data with Internet-of-Things technologies for over 10 years to reach the answer: the Wearable Happiness Meter. It allows us to integrate the measure of both wellbeing and productivity of 7-billion people worldwide, which was the dream of the 18th-century philosopher Jeremy Bentham, numeration of the greatest happiness of the greatest number to measure the right and wrong. Knowing right and wrong with the 10x speed over conventional financial feedback accelerates the growth of the enterprise, the economy, and the individual to maximize the worldwide happiness. Here the integration is not only on a chip, but in the distributed massive chips embedded in the society.

Knowledge-Worker Productivity

The growth of business and the economy depends on the productivity of knowledge workers. There have been attempts to apply the Taylor's Industrial Engineering (IE), which has lead to success in manufacturing and enabled the economic growth in 20th century, to knowledge workers. However, there is a clear distinction between knowledge workers and manual workers, for whom work processes and production outcomes are clearly defined. Naive porting of the IE, effective for manual workers, to knowledge workers is not effective.

Can we measure knowledge worker productivity to 21st-century growth? Conventionally, surveys based on questionnaires have been used; however, the results are not convincing. If the answerer is conscious of the possibility that the results may be seen by the boss, the reliability of the results would be lowered. More fundamentally, self-reporting cannot reflect the contribution of unconscious behavior, which is known to be bigger than that of conscious behavior and is something even the answerer is not aware of.

This is why slogans such as “knowledge worker productivity is essential” or “what cannot be measured is not manageable” are in vein.

The authors’ objective is to change this situation. We believe that introducing wearable technologies allows us to enhance knowledge-worker productivity and economy.

Happiness Drives Productivity

We focus on the issue of the happiness or subjective well-being of employees and customers. This might sound like a matter of philosophy or religion. However, recently, the concept of happiness has been attracting attention as an important factor for the national index, which complements the economic index, such as the GDP. Nations such as the UK, France, Austria, Butan, and Japan are investigating or adopting the index for this purpose.

More importantly, the happiness of employees has been revealed to have an impact on business performance. A higher happiness group, as compared with a relatively lower happiness group, is reported to show better sales productivity by 37% and better creativity by 300% [1]. Moreover, salary-raising, promotion, marital success, friend relationships, health, and longevity are enhanced by happiness [2]. Firms with happier employees are reported to have a higher profit per share by 18%.

It should be noted that happiness is neither the result of success or health, but it is happiness that enhances the probability of success and health.

However, the problem here is how to quantify happiness. Conventionally, questionnaires are also used for this purpose; however, there is difficulty with reliability and repeatability.

Our study is to establish real-time quantification of happiness as the same as scientific measures, such as temperature or weight.

Hidden Link between Physical Motion and Happiness

We have collected over one-million man-days of high-resolution human-behavior data for over 9 years and established a methodology for analyzing happiness [3,4,5]. Millisecond resolution data from wearable sensors have allowed us to discover characteristic physical-motions correlated with happiness.

The form factor of the sensor is in the shape of a badge in order to be worn on the chest (Fig. 1) [6,7,8] (Fig. 1). It includes sensors for human behavior and the environment. An accelerometer is used to quantify physical motion. Fifty times a second sampling enables the recording of high-resolution three-dimensional physical motion and the angle. The wearable also senses infra-red signals for detecting face-to-face meeting and location, sound-level, and temperature .

We discovered, from the massive amount of motion data, a surprising “law of sustainability of the physical motion.” After your physical motion is categorized between “rest” and “non-rest,” your successive non-rest period is more likely to be sustained as the sustained non-rest time gets longer [9,10,11,12]. “Non-rest” includes subtle motions such as nodding, typing, and talking as well as walking and running. This is clearly different from naive prediction where, if one continues an active motion, one is likely to get tired and become non-active. The data clarifies that this is not the case. A human becomes more active as one continues an active state. This might be comparable with the law of inertia, the first law of Newtonian dynamics, which states that matter sustains its constant velocity when it receives no force. Denoting the sustained time of non-rest state as T hereafter, the above law is that the longer T is, the lower the probability of becoming rest state is, i.e., it is approximately proportional to 1/T [9]; this is called the "1/T law."

However, the fitting of an observed distribution to the law is not perfect. There is always deviation from the ideal 1/T curve, which depends. This deviation might correspond to the second Newtonian law, which describes the effect of force.

We have identified the meaning of this good fitting to (or less deviation from) the 1/T law [13]; it is strongly correlated with the happiness of people (Fig. 2.) We collected data by using wearable sensors from 468 office workers from 10 organizations of 7 firms. The total was 5 billion acceleration-data records for 5000 days.

The subjects were requested to answer 20 questions on a questionnaire related to happiness. The questionnaire is called the Center for Epidemiologic Studies Depression Scale (CES-D) [14]. The CES-D asks about happiness, focus, enjoyment, hope, sleep, botheredness, appetite, depression, effort, loneliness, sadness, etc. by using 4 levels of numbers, which are tabulated to a total score ranging from 0 to 60. What is asked is not the mood at the moment but the experiences in the past week. A variety of factors related to wellbeing or happiness (or unhappiness) is included.

CES-D was originally designed as a self-screening test for depressive tendency. However, a happiness measure, at least, is expected to cover the change in subjective happiness (or unhappiness, which is logically equivalent, except the sign) from depressive tendency. Therefore, this is used as a necessary test for quantifying happiness.

An individual-level questionnaire score is not very reliable. Instead, we used an average score of questionnaires for each organization, the size of which is 47 people on average (from 18 to 93) to level out the individual erroneous deviations in answers.

The index of the fitting to the 1/T law (called "1/T index," hereafter) strongly correlated with the average questionnaire score (Fig. 3). The correlation coefficient was as high as 0.92, and the accidental occurrence of this observation was lower than 1 over 1 million. A high happiness group as identified by CES-D clearly showed better fitting to the 1/T law as compared with a low happiness group. This means that the high happiness group showed a long tail of sustained active time T governed by the 1/T law (called "Mount-Fuji-shaped"), whereas the low happiness group showed a shorter tail (cliff-shaped, Fig. 2.).

This index has no correlation to the physical activity level also obtained from the accelerometer. This should be, because a sales person who shows a higher activity level from walking in a day should not necessarily be happier than a programmer who shows a lower activity level due to mostly sitting in a chair.

A wearable sensor for quantifying 1/T index correlated to happiness has been successfully developed and called "Wearable Happiness Meter."

Fig. 1 A wearable for happiness index.

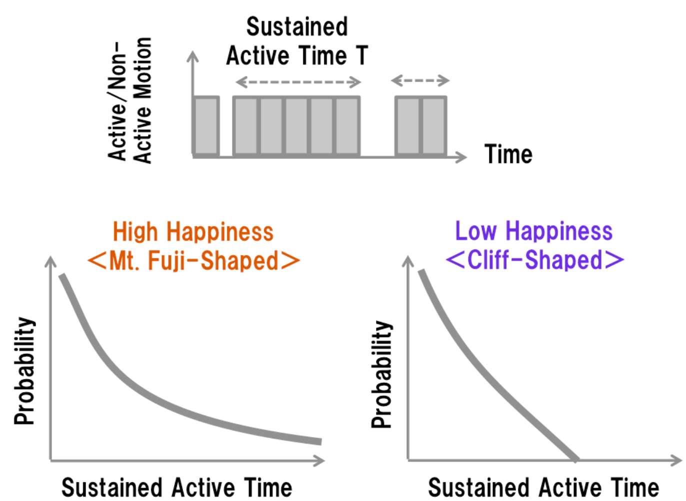

Fig. 2 Unconscious pattern of physical motion correlated with collective happiness

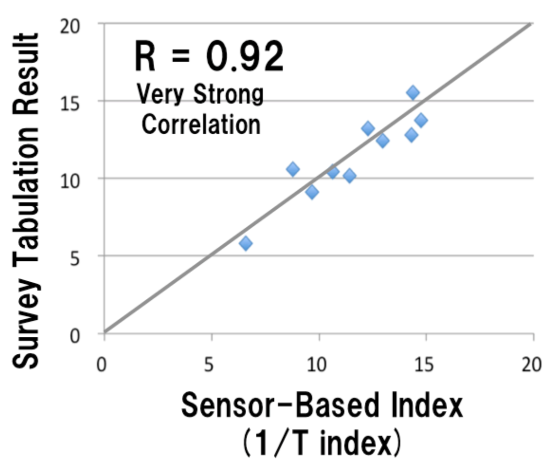

Fig. 3 Sustained physical motion (non-rest) pattern quantifies 1/T index, which is correlated with questionnaire result of subjective happiness for 7 firms, 10 organizations, 468 persons, 5000 man-days, 5 billion records.

Productivity Enhancement at Call Centers

Readers might take the concept of happiness in the following way. Because happiness is subjective, pursuing happiness is pursuing self-satisfaction, i.e. staying comfortable and avoiding challenges. Instead, having anxiety and a sense of crisis should make a person extract one's potential capability.
The data reveals a different story. Our experiment was conducted in 2 call centers having 215 employees, who put wearable sensors on their chest for 29 days (6 billion pieces of acceleration data recorded for 6235 man-days) [13,15]. The job is to sell a service to potential customers on the phone, called an "outbound operation," in which productivity is measured by the sales per hour.
Productivity depended strongly on the day. There was a roughly three times deviation in the productivity. This was due to the change in the 1/T index correlated with the subjective happiness of employees (Fig. 4.) When the 1/T index of the employees was higher than the average, the sales success rate was 34% higher than those of the lower 1/T-index days.

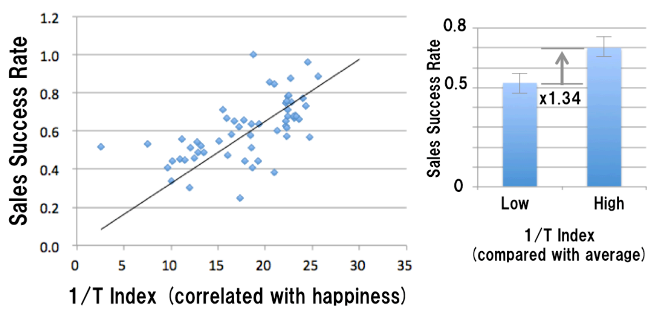

Fig. 4 Happiness (1/T index) is directly linked to the productivity of call centers.

There is no doubt that, under high 1/T-index conditions with both high happiness and high productivity, one is neither comfortable nor easygoing. It is known in psychology that the happiness level of a person under comfortable conditions is not high because one approaches "boredom," according to Mihaly Czikszentmihalyi [16]. One needs a challenge that can be achieved only by stretching one's skill for experiencing enjoyment. However, one experiences anxiety when facing challenges that are too high, which narrows one's view and lowers problem-solving capabilities. The high 1/T-index condition correlated with happiness corresponds to the ridge between "a valley of boredom" and "a valley of anxiety." Measuring the 1/T index assists us in being on the ridge.
As for the call centers, one unexpected thing was revealed to affect the happiness of employees [15]: physical activation during rest time. The rest area is a place to sit and rest. Physical motion during rest time is interpreted to be chatting among employees. It was revealed by the wearable sensors that both the happiness level represented by the 1/T index and the productivity are high on days when the chatting among employees is active during rest time.
It should be noted that the productivity of an employee who shows active chatting is not necessarily high, but the productivity of total employees is high when the average chatting during rest time is high. Physical activeness, happiness, and productivity are collective phenomena. Although this job looks like solo work, in fact, the employees are mutually connected with each other.
The massive amount of data also tells us how to encourage chatting during rest time. It was the supervisors talking to the telemarketers during work hours. It drives active chatting during rest time, which enhances both the happiness level and productivity. On the basis of the analysis, a cloud-based application for supporting supervisors to tell them whom to talk to was introduced, and productivity was enhanced by 27% continuously for a year.

Shortening the Business Cycle

This tight link between the happiness level and productivity should not be limited to call centers. It was reported that the productivity of creative work is more sensitive to the happiness of employees than that of sales jobs. It is naturally understood that complex and creative work is more strongly influenced by the positive mindset (or happiness) of the employees.
In most knowledge work, the financial outcome produced by daily activities comes after a considerable time interval. For example, the development of a complex product produces a financial outcome typically after a year or more. Corporate sales representatives' outcome is also constrained by the corporate-customer budget cycle of a year. Research produces a financial outcome in years to come.
After some time period is passed, an outcome is influenced by many factors, including changes in the external circumstances and more people being involved. It becomes more difficult to identify what the key is to a success or a failure. This is why it is difficult for a knowledge worker to get appropriate feedback for the today's action. The 1/T index correlating with happiness and productivity provides much quicker feedback and allows knowledge workers to learn and grow.
There are many means to enhance happiness in the work management, such as task assignment, feedback, restructuring, and promotion. The first thing to utilizing happiness quantification is to look at the changes after these management actions are taken to learn "what is effective." In this way, the business PDCA cycle is expedited.

Money-Making IoT Systems

For making money with big data and IoT, data representing the value is needed as well as the data for phenomena. Here happiness quantification is essential, because quantified happiness is the precursor of profit and allows us to link the data to the value even for the businesses in which there is time interval between action and profit.
Then, the obstacle is how to discover the key factors that influence an outcome, such as happiness. The number of combined factors for explaining the outcome becomes easily almost infinite. This is called "combinatory explosion." Based on this, conventional machine learning assume that it is human to hypothesize the candidates of combined variables. Therefore, methods for computers to find the weights of variables have been established, such as support vector

machine. However, this hypothesis testing approach will not fully utilize the potential of big data for new discoveries.

To overcome this difficulty, we have developed an artificial intelligence named <H> [9] (abbreviation of Hitachi Online-Learning Machine for Elastic Society.) <H> automatically discovers the combinatory variables that influence an outcome from an almost infinite number of candidates. Millions of combined variables are automatically generated, and key variables are automatically selected. By using the 1/T index as the outcome for the analysis of <H>, one can discover key factors and the relationship to enhance the outcome, i.e. profit and happiness.

This is how we make profit from an IoT system. Such an IoT system is to control variables to maximize happiness of the related people. One example is the air conditioning system of a building. Conventionally, temperature is controlled at a constant target temperature. IoT system is capable of maximizing the collective happiness of the people inside the building by controlling the variables of air conditioners.

A similar system is a city transportation system for maximizing the happiness of the citizens. There are many factors that can be optimized for happiness in addition of the mechanical transportation throughput. Another possibility is an area healthcare system for maximizing the happiness of people in the area. There are many controllable variables in addition to medication quantity.

Jeremy Bentham, an 18th century philosopher, states that it is the greatest happiness of the greatest number that is the measure of right and wrong. With an IoT system which maximizes the happiness, the people and the machine will continuously seek what is right and wrong for employees, organizations, and even society.

These big social infrastructure systems require technologies for flexible adaptation of the variables, based on massive sensors and actuators embedded in the real world, and gigantic artificial intelligence in the data center.

Unlike the conventional computer systems based on the fixed logics for automation, this new IoT system requires flexible changes in decision policy, enabled by AIs. In the 20th century, humans had to adjust themselves to fixed rules and systems. In the 21st century, rules and the systems are adjusted flexibly by maximizing happiness with the wearable technology and AIs.

Invisible Hand of Data

The call center case gives us new insights into the value of quantifying happiness. The firm intended to make money by further enhancing the productivity of workers with wearable sensors. The answer provided by the computer and massive data was "to make a workplace where employee happiness is enhanced with more chatting during rest times." It is impressive in a sense that a computer's answer sounds more mindful to humanity than even that supposedly given by a human. This is not by chance. Massive data objectively tell us the story of human realities including the relationship between happiness and productivity without prejudice.

Adam Smith, an 18th century philosopher, described the mechanism that the pursuit of individual self-gain promotes the good of society. This principle that self-interest is the royal road to altruism is called the "invisible hand." Contemporary big data enforces this principle deeply in the real world. The call center case allows us to hypothesize that the pursuit of profit through big data is to lead to the happiness and wealth of society. We call this renewed principle an "invisible hand of data [9]." Now, work, business and society will usher in the era of the "invisible hand of data."

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