



Applications of Artificial Intelligence in Quality Technology

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Abstract

Statistical thinking is very important for modern management and technological personnel. When a manager or engineer is required for reporting related issues, if there is an additional objective statistical data to enhance the evidence of the report, then it will be easier to convince readers. Realistic conjectures without statistical data basis will be regarded as a metaphysics; the interpretation of the real status is supported by statistical data basis, and the cause and effect can be induced. With the deductive logic derived theory, coupled with the verification and induction of statistical data, you can be sure of the rationale. Quality practitioners should cultivate statistical thinking skills by themselves, and can thoroughly understand the quality problems from the ways of three quality principles: “essence of substance,” “process of business” and “psychology.” Traditional quality data are nothing but variable data, attribute data, defects, internal failure costs, external failure costs, etc., and these data are also collected through data gathering, data processing, statistical analysis, finding root cause, and so on. In the past, quality practitioners also relied on these so-called professional skills for a position in the company. When these quality data are collected, organized, analysed and monitored automatically by computer, if quality practitioners do not keep up with the steps of times, it will be confused or full of difficulties. Precision tool machines are also embedded in various IoTs due to the development of Internet and IOT technology, collecting machine operation status, component diagnosis, machine life estimation, consumables monitoring, power consumption monitoring, utilization monitoring, and various types data analysis, and so on. Production site data are transmitted to the cloud server through the Internet, such data mining and forecasting have been gradually integrated to be the Data Science, and it will be the future of quality field worthy of thinking.

Keywords: Data science; Big data; Quality trilogy; Statistical trilogy; Artificial intelligence

Big Data Thinking

Statistical thinking is very important for modern management and technological personnel. When a manager or engineer is required for reporting related issues, if there is an additional objective statistical data to enhance the evidence of the report, then it will be easier to convince readers. Realistic conjectures without statistical data basis will be regarded as a metaphysics; the interpretation of the real status is supported by statistical data basis, and the cause and effect can be induced. With the deductive logic derived theory, coupled with the verification and induction of statistical data, you can be sure of the rationale. Quality practitioners should cultivate statistical thinking skills by themselves, and can thoroughly understand the quality problems

from the ways of three quality principles: “essence of substance”, “process of business” and “psychology”. Under the guidance of Internet thinking, one is Big Data thinking, which is written like this: In the era of Big Data, enterprises strategy will shift from “business driver” to “data driver.” Massive data information of user’s consume behaviour looks chaotic, but behind it which is the potential logic of consumer behaviour. Big Data analysis can learn about the inventory and pre-sales of products in various regions, time periods, and consumer groups, and then conduct market judgments, and adjust products and operations based on this [1]. Users generally generate data, behaviours, and relationships on the network. The precipitation of these data helps enterprises to make predictions and decisions. In the era of Big Data, data has become an important asset of enterprises, even is

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core assets. The value of Big Data is not big, but the ability to mine and predict. The core of Big Data thinking is to understand the value of data, create business value through data processing, data assets become core competitiveness, and small enterprises must have Big Data also. Traditional quality data are nothing but variable data, attribute data, defects, internal failure costs, external failure costs, etc., and these data are also collected through data gathering, data processing, statistical analysis, finding root cause, and so on. In the past, quality practitioners also relied on these so-called professional skills for a position in the company. When these quality data are collected, organized, analyzed and monitored automatically by computer, if quality practitioners do not to keep up with the steps of times, it will be confused or full of difficulties. Precision tool machines are also embedded in various IoTs due to the development of Internet and IoT technology, collecting machine operation status, component diagnosis, machine life estimation, consumables monitoring, power consumption monitoring, utilization monitoring, and various types data analysis, and so on. Production site data are

transmitted to the cloud server through the Internet, such data mining and forecasting have been gradually integrated to be the Data Science, and it will be the future of quality field worthy of thinking.

Data Science

In November 1997, Dr. Chien-Fu Jeff Wu gave an inauguration speech when he was appointed as the H. C. Carver Chair Professor at the University of Michigan. The topic was: “Statistics = Data Science.” In this lecture, he described statistical work as a trilogy of data collection, data modelling and analysis, and decision-making [2]. In his conclusion, he coined the modern term “Data Science” and advocated that Statistics should be renamed Data Science, and statisticians should be renamed data scientists. Later, he also gave a lecture entitled “Statistics = Data Science” as his 1998 P.C. Mahalanobis Memorial Lecture. This lecture pays tribute to Prasanta Chandra Mahalanobis, an Indian scientist, statistician, and founder of the Indian Institute of Statistics [3]. The following is an excerpt from his slide:

<p>Statistics = Data Science? C. F. Jeff Wu University of Michigan, Ann Arbor</p> <ul style="list-style-type: none"> • What is “Statistics”? • A Statistical Trilogy • Frontier and Beyond • A Bold Proposal 	<p>The current state of statistical work can be described by a Statistical Trilogy:</p> <ul style="list-style-type: none"> • Data Collection (experimental design, sample surveys). • Data Modeling and Analysis. • Problem Understanding / Solving, Decision Making.
<p>Promising Current/Future Directions:</p> <ul style="list-style-type: none"> • Large / complex data: Neural network models, data mining (of massive data bases). • Empirical - Physical Approach: driven by data and mechanistic knowledge, mechanistic: <p style="text-align: center;"><i>Deduct i on</i></p> <p>unknown state → manifestation</p> <p>statistical:</p> <p style="text-align: center;"><i>I nduct i on</i></p> <p>unknown state ← observed data</p> <ul style="list-style-type: none"> • Representation and Exploitation of Knowledge: Representation of knowledge as a Bayesian prior model (possibly in high-dimensional space) computational algorithm, interaction with cognitive science. 	<p>Why can neural network modeling solve some complex / tough problems?</p> <ul style="list-style-type: none"> • Can model complex (i.e., nonlinearity, interaction) relationships. • Use cross-validation and other statistical techniques to find parsimonious models and gain predictive power. • Good at developing simple and efficient computational algorithms, develop problem-specific hardware. <p style="text-align: center;">Think Big, Learn from Others!</p>
<ul style="list-style-type: none"> • Tremendous progress has been made in image reconstruction: Penalized maximum likelihood, Bayesian Gibbs sampling. • Much less is known and much needs to be done in computer vision: “Vision is a <i>process</i> that produces from 	<p>Some suggestions:</p> <ul style="list-style-type: none"> • A balanced curriculum: more emphasis on data collection, <p>Scientific / mathematical basis for modelling, computing for large / complex systems.</p>

<p>images of the external world a <i>description</i> that is <i>useful</i> to the viewers and not cluttered with irrelevant information (Marr 1976)".</p> <ul style="list-style-type: none"> • Computer vision: An infusion of psychophysics, neural physiology, statistics, engineering and artificial intelligence. 	<ul style="list-style-type: none"> • Interdisciplinary training: Requirement of a cognitive minor, joint teaching by statisticians and scientists. • A radical idea: an applied master or doctoral program with 30% - 50% courses outside statistics.
<p style="text-align: center;">A proposal: "Statistics" → "Data Science" "Statisticians" → "Data Scientists"</p>	

The authors use limited statistical knowledge to interpret the foresight of Dr. Chien-Fu Jeff Wu, 20 years ago. He foresees that if Statistics develop in the direction of the current traditional statistical trilogy, it will inevitably become one of the tools in other fields. Statistical trilogy: Data collection, Data modeling and analysis and Decision-making, as shown in (Figure 1). Just as J. M. Juran advocated that there is a universal method for managing quality: quality planning, quality control, and quality improvement, which is called the Quality Trilogy. This view was put forward by J. M. Juran in 1986, and it was widely accepted by the industry and became the basis of Quality Management (Figure 1,2).

etc., and statistical technology would be one of the most common knowledge. Data Science helps professionals and non-professionals understand the problem by using a variety of relevant data. Data Science and technology can help us to correctly process data and assist us in research and investigation in the fields of Engineering Science, Biology, Social Science, Anthropology, etc. In addition, Data Science is also of great help to business competition. It is the same as Quality Management, the Quality Management is related to the field of Science, Engineering, Management, Sociology, Law, Education, etc. It is difficult to belong to one academic discipline, which means that they are one of the general disciplines. Knowledge is divided into professional knowledge and general knowledge of individual courses. Professional knowledge needs to be proficient, and general knowledge needs to be broad. Dr. Chien-Fu Jeff Wu suggested that in addition to the balance of the statistical trilogy, the courses of the Institute of Statistics need to increase cross-field courses, and even increase to 35-50%.

For the current / future promising direction of Statistics, Dr. Chien-Fu Jeff Wu suggested this as following:

- Large / complex data.
- Empirical - Physical Approach.
- Representation and Exploitation of Knowledge.
- Why can neural network modelling solve some complex / tough problems?
- Tremendous progress has been made in image reconstruction.
- Much less is known and much needs to be done in computer vision.

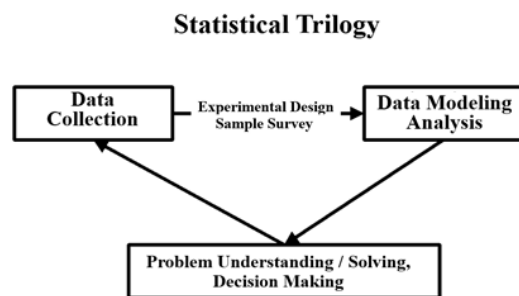


Figure 1: Statistical Trilogy.

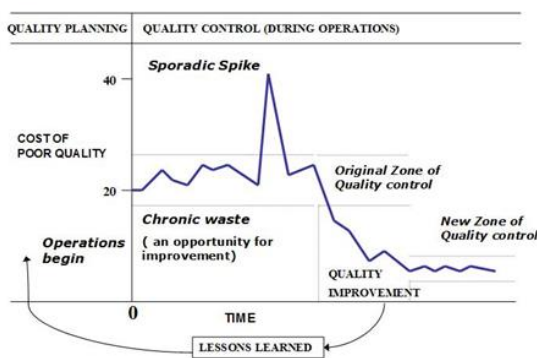


Figure 2: Quality Trilogy.

In recent years, Data Science has been a subject that uses data to learn knowledge. Its goal is to produce data products by extracting valuable parts from data. It combines theories and technologies in many fields, including Applied Mathematics, Statistics, Pattern Recognition, Machine Learning, Data Visualization, Data Warehousing, High-performance Computing,

Today, 20 years later, using Data Science as a keyword to search on Google website, whether it is in Chinese or English, there are millions of searches, a bunch of similar to Figure 3: Data Science pictures and article advertisements, especially this article: "Data Scientist: The Sexiest Job of the 21st Century", I don't know how many articles on newspapers and magazines have mentioned it. However, few people talk about the so-called new technologies such as Data Science, Big Data, Artificial Intelligence, etc., which are the inevitable products of the successful development and application of Information and Communication Technology after accumulating the research of diverse knowledge in the long run.

The following paragraph serves as a summary and echo of the teachings of Dr. Chien-Fu Jeff Wu (Figure 3).

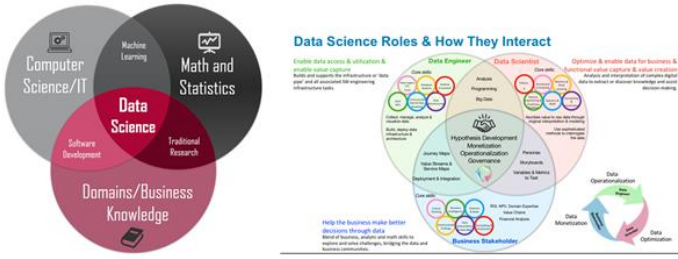


Figure 3: Data Science pictures and article advertisements.

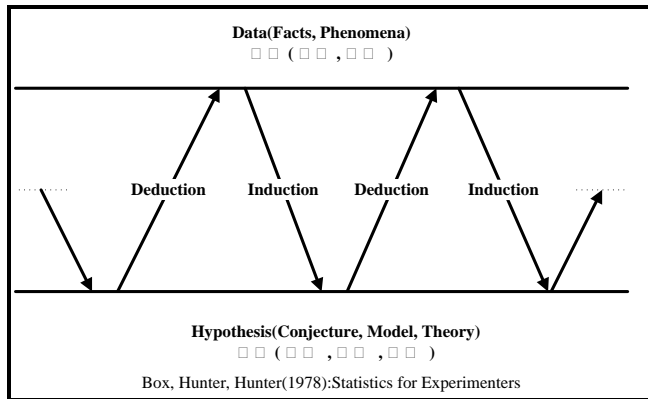


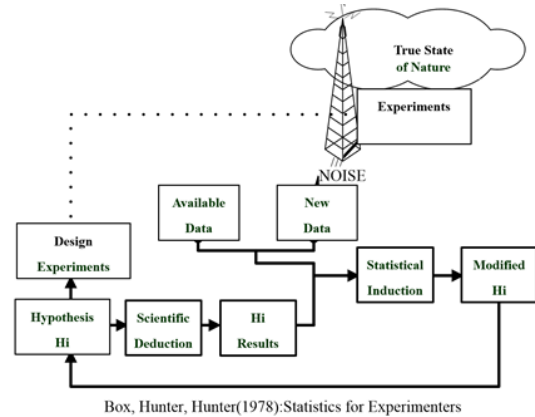
Figure 4: The Iterative learning process.

Scientific research is an iterative learning process. Deduction and Induction are both methods we use in inference. The purpose of statistical methods is to make this learning process more efficient. Statistical inference is based on the results of experiments or observed objective phenomena, that is, data, through estimation, comparison, and prediction to draw conclusions that are closer to the truth. This is the so-called induction method. The deductive method uses existing conjectures, models, theories, that is, hypothesis, through a professional deduction process that conforms to scientific logic, to deduce hypotheses that are more connected to the truth. This iterative learning process makes knowledge more and more complete, data generation and analysis of scientific research [4] (Figure 4,5).

Artificial Intelligence

The field of Artificial Intelligence (AI) refers to the technology that artificially realizes the wisdom of human beings. However, there is no technology that can achieve the same level of human intelligence, and the vast majority of AI in the world can only solve a specific problem. From the perspective of the information science academia, the following novel scenario that is similar to Western magic and Eastern martial arts may be more convincing [5]. The field of AI can be said to be the holy grail of Information

Science, or more like the Lord of the Rings. This imaginatively dazzling field has attracted generations of Information Science researchers to continue to invest in these difficult problems. I don't know whether it is because of courage or profit, Information Science researchers have been advancing courageously in this field. Many people have invested their entire lives without getting the results what they had imagined, and they have been killed without even entering the door. The theory in the field of AI has become a huge and monstrous creature, people who want to get started when they see such a huge creature, they often get lost before reaching the door, what about the others? After entering the door, there was no way out.



Box, Hunter, Hunter(1978):Statistics for Experimenters

Figure 5: Data generation and analysis of scientific research.

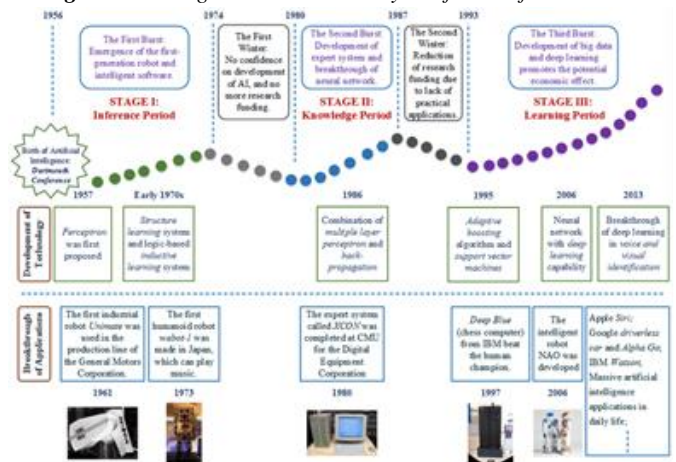


Figure 6: The three waves of AI.

“Looking up is high, drilling is strong, looking forward, suddenly behind.” this sentence is used to describe Confucius, and I think it is more appropriate to describe “Artificial Intelligence.” Often when a researcher thinks that he has already seen some solution, in the end he only discovers that it turned out to be a dream. When the problem seems so simple, in fact, there is a fairy or monster hiding in the door, and looking at you with enthusiasm. They plan to lead you into this field, after then killing you. People who lose their way in the field of AI are usually not eaten by monsters, but bewildered by fairies with beauty. In the end, they

thought they were in heaven, but they went to hell without knowing it. If you want to see the world where this fairy is, please follow me. Scholars who study AI may be more like the characters on Xia Ke Island in Jin Yong’s novels. After arriving at Xia Ke Island, they are fascinated by the exquisite martial arts secrets and are no longer willing to return to the original arena. They have studied martial arts throughout their lives, but is in vain. The characters on Xia Ke Island can only see the words in the secret script, but cannot see the iconic martial arts contained in the writing strokes, so they miss the real exquisite martial arts. Perhaps, scholars who study AI have the same problem. They are always obsessed with various seemingly advanced algorithms, but they can't see the whole forest but trees only, so that they can't see how the overall wisdom is formed. I am afraid this is a researcher in the AI field, challenges that must be faced in the future. The three waves of AI, so let the authors have a general outline of the development of AI and realize the above-mentioned AI novel scenario [6] (Figures 6,7).

From the standpoint of quality professional, after authors looking at Table 1: the methods used by AI, we dare not intend to develop new technologies in the AI field or make any contribution, because we know almost nothing; After we looking at Table 2: the related application of AI, the application intention in the field of quality professional is inspired, because we do not want to be absent from the wave of AI [7] (Table 1,2).

Integration of Science-Technology-Utilization

Referring to quality related science research, technology development, and application promotion, in order to discuss the process of the development of modern quality management, we cite a paper, which is in line with Management Sciences, Figure 7 is an excerpt from the paper that discusses the relationships among the sciences, technologies and utilizations in Management Science.

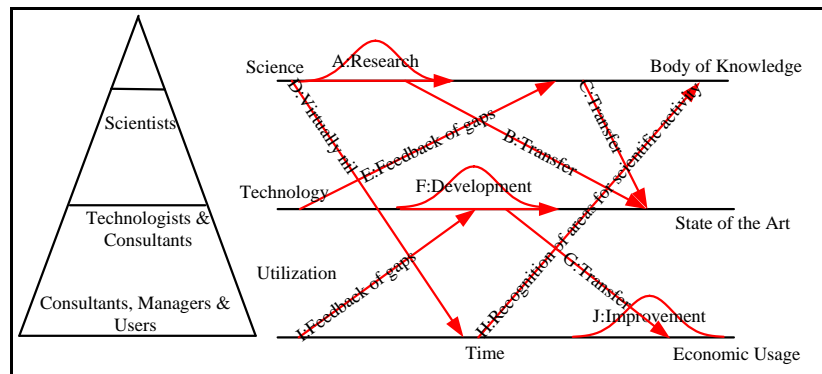


Figure 7: relationships among sciences, technologies and utilizations in management.

The relationships among are outlined in the following [8]:

- A. Research of body of knowledge;
- B. Transfer knowledge to be a state of the art;
- C. Transfer knowledge to be a state of the art;
- D. Transfer knowledge to be an economic usage, virtually nil;
- E. Feedback the gaps of body of knowledge;
- F. Develop a new state of the art;
- G. Apply a state of the art to economic usage;
- H. Recognition of areas for scientific activity;
- I. Feedback the gaps of body of technology;
- J. Improve the current application more efficiently.

Since the beginning of the last century, the development of the field of modern quality management has been going on for nearly a hundred years. It is also remarkably similar to the integration of sciences, technologies and utilizations in the development of “Management Science”. In the early days of the field of modern quality management, most professionals relied on the achievements of statistical science such as Control Chart, Sampling Acceptance and Orthogonal Experiments, and even

developed into a branch of statistical science: Engineering and Industrial Statistics. Solving the quality problems, statistical methods and thinking way is one of the important tools, but also need to integrate the methodologies of essence of substance, process of business and psychology. After years of professional integration in different fields, the quality management is gradually formed a multi-value organization team work mode, which is continuous improvement, leadership, management by objectives, full participation, common language, technology sharing, problem solving, response to change, cultural heritage and people oriented. It is the integration of statistical science, management science, engineering science, system science, information science, psychology, etc., in order to improve the quality of human life. The development and promotion of the quality professional field is definitely not developed independently. It would be developed accompany with the state of the community, society, country, region, and global fields, such as the development of politics, economy, society, and technology. Especially the defence industry, international trade, management

systems, business models, manufacturing systems, communications, computers, data processing, and people's living standards. Nowadays, the quality professional field should also exam the future development and promotion projects in the so-called "The third wave of AI", which something's are worth to do?

Applications of Artificial Intelligence in Quality Technology

Back to this topic: "The Applications of AI in Quality Technology". In recent years, the authors have gradually established the "Quality Philosophy" and "Core Values". Based on the "Quality Philosophy", which is continuous improvement, leadership, management by objectives, full participation, common language, technology sharing, problem solving, response to change, cultural heritage and people oriented; based on the "Core Values", which is practical application as the purpose, system integration as the means, pragmatic benefits as the inducement,

and sustainable development for good fruit. The process of brewing this issue requires careful consideration and painstaking effort. Since "Industry 4.0" began to be popularly discussed in the industry, the authors can only focus on the cultivation of personnel in the quality professional field and have no countermeasures. Also only focus on productivity 1.0 → productivity 2.0 → productivity 3.0 → productivity 4.0, which was in response to such global manufacturing trends, Taiwan Administration has initiated Productivity 4.0 which follows the historic long term plans of taking production automation as productivity 1.0, promoting to industrial automation as productivity 2.0, and expanding to industrial computerization as productivity 3.0, depict as Figure 8. Productivity 4.0 is based on intelligent automation and employing the internet of things, intelligent robots, and Big Data, coupled with lean management, will help domestic industrial upgrades and transformation (Figure 8).

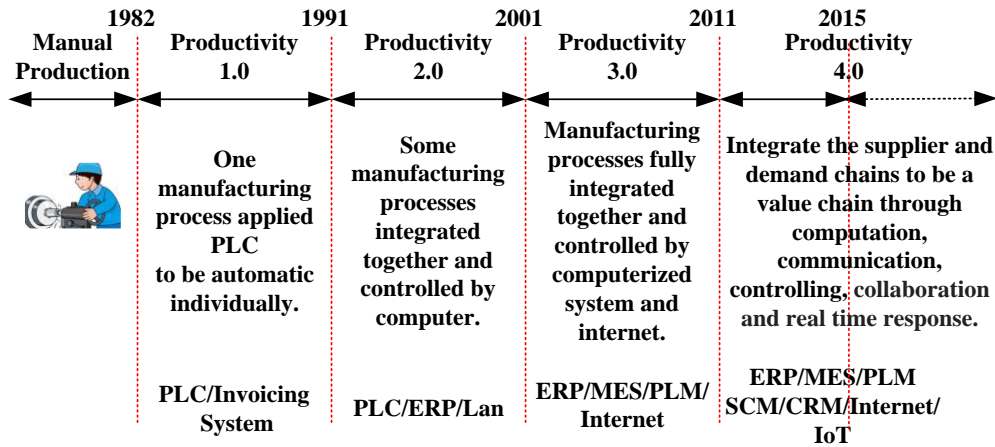


Figure 8: The historic long term plans of Productivity 1.0 to Productivity 4.0.

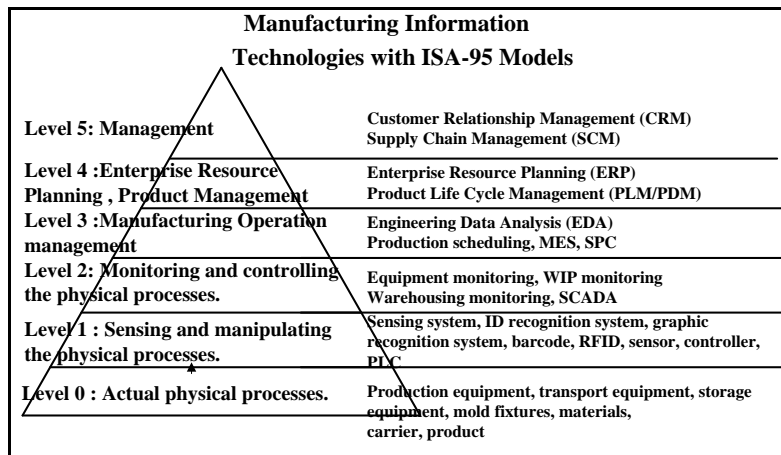


Figure 9: Manufacturing management system hierarchy.

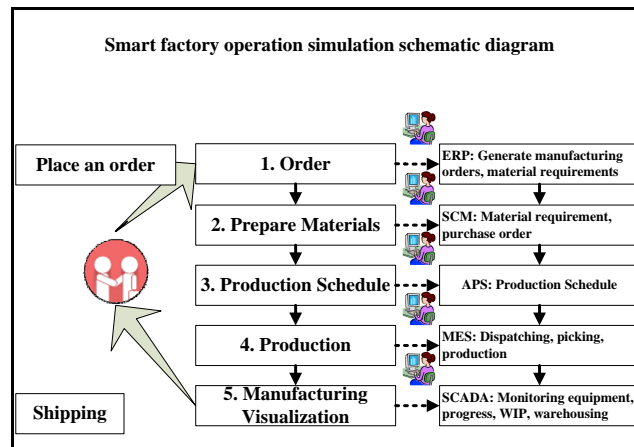


Figure 10: Smart factory operation schematic diagram.

Table 1: The methods used by AI.

Classification	Methodology
Search	DFS, BFS, Best-FS, A*, Min-Max+ α - β Cut, Dynamic Programming
Optimization	Greedy Algorithm, Simulate Annealing, Genetic Algorithm
Logical inference	Boolean Logic, First-Order Logic, Probabilistic Logic, Fuzzy Logic.
Neural network	Back Propagation Network, Hopfield Network
Probability statistics	Bayesian Network, Hidden Markov Model, EM Algorithm
Comparison	Pattern Matching, Regular Expression

Table 2: The related application of AI.

Simulation behavior	Related applications
Perception	Voice Recognition (ears), Image Recognition (eyes), Handwriting Recognition (eyes), Fingerprint Recognition (eyes)
Reasoning	Expert System, Computer Games, Computer Chess, Medical Diagnosis (brain)
Understanding	Machine Translation, Conversation System (brain)
Learning	Computer chess, expert system, medical diagnosis, identification (brain)
Action	Robot Soccer Game, Autonomous driving, Commercial robot, Smart Controller (hands, feet and body)

The author's view of "Industry 4.0" have always been the following paragraphs as the guiding principle: "From the perspective of micro-industry development, it will create many kinds of innovative business model via customized design and marketing. From supplier chain: purchasing, production controlling, incoming, production and shipping to demand chain: ordering, logistics delivery, retail, and maintain service, it can integrate the all processes to be a value chain through computation, communication, controlling, collaboration and real time response. This cross-company information system enables engineering collaboration and logistics collaboration under the internet platform architecture. Engineering collaboration: provide collaborative process of two-way interaction between customers and suppliers, and customers can inquire the engineering information needed from suppliers, to speed up customer quality analysis, quality improvement and design improvement process,

as well as shorten the customer's time schedule from pilot run to mass production. Logistics collaboration: provide customers and suppliers more transparent and complete information interface, from the customer's order to the production schedule, from the production order to status of the lot number, from the outgoing quality control to the shipping, customers can get the information from the system and analyse in advance, solve the common problems of both sides immediately." The above situation is the vision of the industry 4.0 for manufacturing operations management. Some advanced enterprises have already had the ability to self-improve to this level, however, the SMEs are lack of this kind ability. The MESA / ISA-95 standard have been defined the manufacturing management system hierarchy [9]. In general, SMEs can achieve the vision of Industry 4.0 operation by using Figure 10: Smart Factory Operation Schematic to improve

the quality of information of internal operations step by step (Figure 9,10).

Whether it is theoretical or practical in Manufacturing Management System, the quality professional field is not a mainstream system in the Manufacturing Operation Management system. For example, quality planning is attached to the PLM system; the Incoming Quality Control (IQC) is a voucher for accounts payable in the ERP system or is attached to SCM system; In Process Quality Control (IPQC) is a voucher of salary in ERP system or is attached to MES system; Outgoing Quality Control (OQC) is a voucher for accounts receivable in ERP system or is attached to CRM system; customer complaint processing is a voucher for sales returns and allowances in the ERP system or is attached to the CRM system. Quality Information System (QIS) is difficult and unnecessary to be an independent system. However, it may be possible to use the model of quality management system (ISO 9000 series) to dominate the management system, by using system integration technology depend on necessity, to digitize the quality control processes as a digital transformation from productivity 1.0 → productivity 2.0 → productivity 3.0 gradually aim to productivity 4.0, this will be a more practical and feasible option in the quality professional field. The authors once presented "Knowledge should be owned by Quality Practitioners in the IT Age" at ANQ Congress 2018 in Almaty, Kazakhstan [10]. Later, "Journal of Traffic and Transportation Engineering" invited the paper for publication. This article was finally published in Journal, and it can also be regarded as a starting point of author's pragmatic academic research in this topic [11].

Conclusion

According to the author's professional view, the development and promotion of the quality technology also needs to be developed in accordance with necessity of each enterprise, it does not need to be specific for AI. The development of AI similar to Productivity 4.0 which follows the historic long term plans of taking production automation as productivity 1.0, promoting to industrial automation as productivity 2.0, expanding to industrial computerization as productivity 3.0, and basing on intelligent automation and employing the internet of things, intelligent robots, and Big Data, coupled with lean management as productivity 4.0, it will help enterprise upgrades and transformation step by step. The digital application progress model of the enterprise must be optimized into: "From supplier chain: purchasing, production controlling, incoming, production and shipping to demand chain: ordering, logistics delivery, retail, and maintain service, it can integrate the all processes to be a value chain through computation, communication, controlling, collaboration and real time response." The quality requirements of all processes of the value chain of productivity 4.0 would be

much more transparent. As the demand chain, product and service will be required more accurate, speedy, reliable, safety, ecological, and environmental. As the supplier chain, the product and service will be required more easily to design, manufacture, change, transport, maintain, recycle and trace. Therefore, quality practitioners should pay more attention to the technologies of all processes of the value-added in the future, especially system integration engineering. It focuses on system-value-added integration between software and hardware. The process of value-added integration is nothing more than system planning, system analysis, and system design, project outsourcing and programming, unit testing, system and integration testing, user acceptance testing, and system acceptance. Figure 11 shows the V shape model.

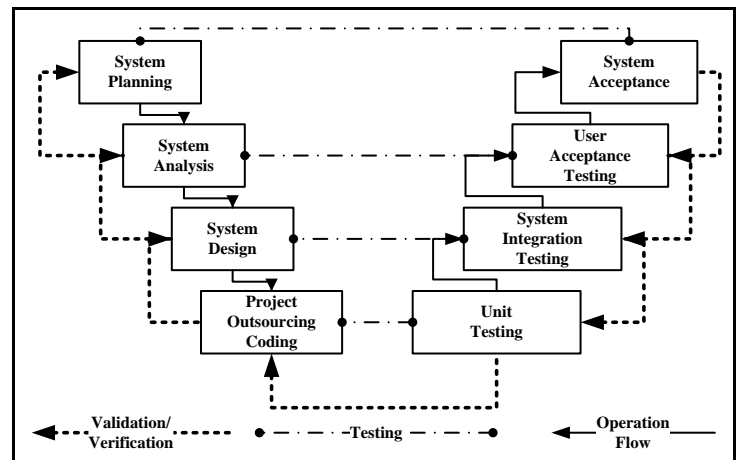


Figure 11: The V shape model.

Therefore, quality practitioners must focus on the development of relevant knowledge and technology in the AI development process, and they must also recognize that the development of AI in network information technology-related software and hardware knowledge is formed through a market economy business model. It is based on the market economy as its "core value": practical application as the goal, system integration as the means, pragmatic benefits as the inducement, and sustainable development of competition and cooperation as the good result. Based on the above, the authors have established a curatorial platform for innovation and quality management knowledge, to identify, create, acquire, capture, apply, share, store, and map these documented information and knowledge which can enhance quality of life, product quality, service quality, environmental quality. In application of AI, the following are the knowledge and technology which are the quality practitioners should have.

- AI contents and scientific research results understanding.
- The development and application of AI + IOT = AIOT.
- Basic knowledge of digitized documents and the Internet, and the ability to communicate and operate.
- Education and training of basic statistics and probability.



- Computer calculation, analysis software, Big Data, and other software applications (such as Excel, R language, Minitab, JMP...).
- Organize various levels of quality knowledge technology, such as CQT, CQE, CRE, CQM, and must eliminate the waste and keep up with the times, and then increase and modify to adapt "Industry 4.0" and "Artificial Intelligence".
- Project planning and development methodology of manufacturing products.
- Project planning and development methodology of service industry products.
- Application software such as MES, ERP, PLM, CRM, SCM, KM, Promodel, etc.
- Manufacturing process rationalization, information process rationalization and system integration technology.
- Application and promotion of Automated Optical Inspection (AOI).
- Continuous improvement mechanism and promotion knowledge (QCC, Six Sigma, Lean Production).

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