Light-Off Factory Systems to Be Fully Deployed in the Future?

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ABSTRACT

A previous study suggested that the full implementation of Lights-Out Manufacturing (LOM) remained a future possibility. Therefore, this paper looks at it from another point of view, examining how three important premises may converge to provide a rational basis for considering future LOM. This article presents three main premises that provide the logical basis for considering a future development in manufacturing. A different kind of infrared (IR) vision system is envisioned for the manufacturing sector sometime in the future, with potential economic benefits if it becomes practical. This provides a possible direction for future research on IR-based supervisory systems for LOM.

Keywords: Lights-Out Manufacturing, Technology Forecasting, Infrared Vision System, Manufacturing Automation

INTRODUCTION

The Lights-Out Manufacturing (LOM) is a term that has been devised among the manufacturing industry in some developed countries over the past few decades. Dark Factory or Light-Off Factory is probably another way to represent it. Then, it was a bit quiet until a more modern version called Industrial Revolution 4.0 (IR4.0) emerged (or soon towards IR5.0). However, to those who still cherish its philosophy, it sounds more sentimental than words like 'IR4.0' or 'Industrial Revolution'. It is also an expression that symbolizes a methodology or is more towards a philosophy in a fully automated manufacturing sector, which will probably become more pragmatic along with the current debate about what IR4.0 offers these days [1].

The LOM or Light-Off Factory or Dark Factory approach can also be implemented at night or can also be scheduled on weekends when some of the semi-automated work that was supposed to be in operation can be temporarily paused (operators involved have the opportunity not to be involved or perform other functions elsewhere). However, the practical way is to appoint at least some number of operators, thus ensuring the smooth operation of the plant [1] and supervision at the supervisory level [2].

This philosophy of LOM becomes more realistic by looking at the current automation equipment capabilities of a company. That is, the part that needs to be involved is when it can operate fully automatically with the most complete reliability and repeatability. The 'classic phrase' implies that when the factory operation completely does not involve any operator, the lighting or lights can be turned off (there is no need for anybody to see using light in the electromagnetic (EM) visible light spectrum). If this condition is extended, actually many more aspects can be translated this way: not only can the lights be turned off, in fact, air conditioning systems, heating systems, and other support systems for the life of the operator can be turned off when the fully automatic manufacturing mode is run. This could reduce costs and increase the company's profit and productivity.

Logical Basis for Future Lom

This section presents three conditions whose convergence provides a rational basis for considering the future

development of LOM.

$$(P1 \wedge P2 \wedge P3) \rightarrow R(LM)$$

where R(LM) represents a rational basis for considering the proposed IR vision supervisory system for future LOM.

*LM, If all three of the below conditions are eventually satisfied, then their convergence provides a logical basis for considering the use of an IR vision supervisory system in future Lights-Out Manufacturing (LOM).

*P1, As the industry moves towards a more advanced operator-less industrial revolution, the reduction of low-skilled operators in the fully automated manufacturing sector is expected to continue (however, this stage of maturity in manufacturing has not yet occurred in this direction before the visible-light band becomes no longer needed in an automated area where supervision is still required and currently depends on a visible-light source).

*P2, The application of IR light in low and medium wavelengths continues to be more useful in manufacturing operations, and the manufacturing machine itself is constantly generating heat in its operations (IR light with wider wavelengths). All of these developments, however, had not yet matured in this direction before the various applications of IR became sufficiently useful and advantageous for the effective use of IR vision systems in the manufacturing environment.

*P3, The IR camera vision systems are getting better in terms of cost and are continuously improving (advanced), through the development of military and security vision systems as well as advanced commercial vehicle systems (that have many new safety features at night through heat detection, etc.), plus other similar kinds of industrial systems (as a steppingstone). However, all these developments had not yet matured in this direction before IR camera systems became effective and economically practical enough that they can be applied as supervisory vision systems in manufacturing.

Supporting Argument & Related Issues

Relating to Premise 1

Beginning with the fact that some human jobs are being lost due to automation, observations for the various works that are free of problems still require humans [1]. At the same time, it is expected that there will be more employment in other sectors involving human relations and data [1]. This is probably true when people are given the opportunity to complain about goods which have been purchased thru online shop, usually, it cannot be resolved through robot-chat easily, and still needs a live-chat for a customer-satisfying solution. However, such jobs just can be placed outside the factory easily. The monitoring process of the factory can be done outside the factory as well.

However, the effect of automated robots (automatic manipulator machines) on human jobs involves work that has a very significant repetitive nature, but in the future, it is projected that it will have the potential to take over non-repetitive tasks as well, up until in the domain that challenge understanding or thinking to carry out the mission [3].

Regarding the new industrial revolution, which promises a new level of manufacturing (e.g. IR4.0), scholarly contributions come from various groups about IR4.0, thus making it increasingly blurry rather than increasingly concrete. The existing platform for IR4.0 also looks more towards vision (or mission) and so on, but still does not provide a clear definition. The generally accepted definition has not really succeeded.

The preceding paragraphs are some opinions (literature review) to demonstrate that, as some researchers discovered (and eventually concluded), companies actually face difficulties in moving and developing IR4.0 and are also uncertain about it [4]. Even the opinions between researchers and practitioners are conflicting [5].

However, despite the components, definitions and technologies, the objective may be to meet the needs of the customer, so (if this really is the main goal) it can be concluded that the result is actually to make the industrial plant more responsive [6]. Thus, related to this idea, it is suggested that a new kind of working-team, which is constantly analyzing consumer developments and making modifications on the actual manufacturing floor. However, it is expected that the new team could also be outside the factory or nearby (not requiring them to actually be inside the machining block). They may change the value of certain parameters remotely.

The brief discussion above has shown that certain levels of monitoring systems or control supervision are indeed still required even in the new industrial revolution (IR4.0), if we are expecting future LOM. It's too risky to let "robots monitor robots" (independent supervisory monitoring may still be necessary in highly automated manufacturing systems).

Relating to Premise 2 and 3

Another category of IR cameras called Short Wave IR (SWIR) cameras opens up many more possibilities for machine vision applications. Some examples of industries: Recycling industry, food industry, metal and glass industry, and molten metal process monitoring and inspection [7]. On the other hand, there are other various uses (industrial applications) that are beneficial in applying IR lighting in manufacturing operations, especially for process control or quality control [7, 8] and even the generation of manufacturing machines cannot avoid heat generation (longer wavelength). Therefore, with that, those things make IR light even 'glowing' in the manufacturing industry. Even the heating process that uses IR light along with the microwave and other common technique is getting momentum, and the IR heating process has already been widely used in industries due to energy efficiency, low investment and other benefits [9].

There is also research that has been able to demonstrate the compatibility between thermal cameras and high-speed cameras in applications for the manufacturing sector [10]. IR thermal camera and analytical technologies have also been found to evolve dramatically [11]. Finally, the number of industries and applications included in the list (related to IR cameras) may continue to increase [8].

The Night Vision Device (NVD), on the other hand, refers more to the night vision technology (not based exactly on IR, but on amplified light technology) and is ready to show its maturity in the military, defence and security [12]. However, with the pressure of competition from conventional cameras and thermal cameras, effectively returning the mature technology to the development phase [12], when compared to the forecasts in this paper in terms of future manufacturing industry use, it appears that this matter becomes advantageous directly in supporting premise no. 3.

From an economic point of view, as well as from the perspective of the cost of equipment, there is also a positive indicator. Contemporary research on IR heat detection technology has been found to have focused on lower costs [13], as well as higher performance in various aspects [14, 13]. Right now, night vision systems are available in some high-end luxury cars [15]. Like GPS, it is no longer an expensive item for a normal car at the moment, and this is expected to happen to the night vision system for a normal vehicle in the future as well. Furthermore, in the future, the night vision systems for such ordinary cars could also spread to various other fields [16].

Finally, regarding technologies in IR4.0 such as Augmented Reality (AR), which is generally considered one of the pillars of IR4.0. AR is said to be increasingly widely used as an innovative product in various fields. The AR market in the field of education alone has also been expected to increase [17]. AR has the potential to be very powerful and more effective if combined with other technologies [17]. Another part of the big family seems ready to go.

Apparently, the indications above tend to support the key ideas in premises no. 2 and 3 (interrelated). Therefore, the brief discussion in this subsection suggests that a supervisory vision system, supported by suitable and effective technology and economically practical conditions, could potentially be applied to the manufacturing system.

How is it possible if all the premises are true?

Returning to the earlier discussion of IR4.0's uncertain direction, one proposed measure is to rely on data from other parties. If the dependency is low, it can probably be implemented earlier without involving many other complex things (if the mind-set and culture are taken into account [18]). For example, connecting all robots and machines to achieve a more customer responsive manufacturing system (responsive system is also discussed by [6]) is expected to involve more data which leads to a high degree of dependence.

In contrast, building a new IR-based vision monitoring system, for example, may be less complex due to its lower data dependence, implying a lower risk associated with data integration. In the other words, the main idea also is to take advantage of naturally available energy, and not about highly integrated responsive factory system. Therefore, with a relatively low risk of action, it is likely to be one of the more reasonable options in the future.

Furthermore, in a situation of greater data dependence as expected in IR4.0, this situation also provides wider chance of cyber-attack [19], and even security issues are still the biggest factor to be considered [20]. With this low-risk project (or any low risk IR4.0 project that implements such an IR vision system), it is felt to be in line with the three barriers that have been identified in certain cases, namely mind-set, culture and competitors [18]. Therefore, again, with a relatively low risk of action, it is likely to be one of the more reasonable options in the future.

As technology advances, the philosophy of LOM can be pushed to a new next level. Actually, the study of the use of IR light is expected to open up new opportunities as an exploration of the advanced manufacturing environment in the future. This is because when artificial visible light between approximately 400-700 nm (other example of range: 400-750 nm [21], 380-750 nm [22]) is substantially reduced in the active industrial environment (lights off), most of the IR light, especially far IR, will remain present in the factory environment. This is reasonable, given that a continuously active factory produces repetitive operations, which undoubtedly generate a lot of heat and associated thermal radiation.

Among the main unknown possibilities (Research Questions), are like: Which part of the sector is the most likely to be more positively effective with the use of IR light? In what particular band? As well as, what things should be developed as a necessary preparation to make support for the proposed use of IR light vision system. In terms of monitoring, automatic control, security, image recognition, quality control, etc. Including the other new interesting research that is expected to be launched is an IR vision system that involves robots and moving environments. Since vision systems still continue to be the key to automation integration in the manufacturing industry [23], vision systems also provide a flexible advantage in the automation of manufacturing [24, 25]; therefore, it is expected that there will be an obligation for a new type of research in the IR world in the context of the LOM requirements in the future.

The purpose of the capabilities and supporting factors should be studied is to provide confidence to the industry on the usability of IR light as a new type of lighting. This is because it has never been used seriously as a general lighting system in the industrial sector (actually, a lot of naturally available energy is in the active manufacturing sector right now). Only security and safety in the mind are related to the IR camera system.

It is also an academic commitment in finding suitable methods, which makes it possible for its use to be very beneficial. As well as what is the solution, if there is any barrier wall to the desired application. Other studies that may be developed are in terms of human safety, training, work arrangements, the human interface concept and, in fact, a protocol of use. Not surprisingly, there is a need for research on such a protocol, since there was an attempt to find working protocols using IR cameras in the field of the construction industry [26]. It shows that in a related area, it will most likely undergo some changes to adapt to some new concepts; For example, there was also research on low-cost IR cameras, which can even be connected to a regular smartphone [27]. Therefore, the new mechanism (e.g. Internet of Things; IOT) which involves the new device and protocols towards a new revolution (e.g. IR4.0), is not impossible to be developed.

In principle, the things discussed; LOM with a new vision system in the IR region, are not impossible at all. However, to develop something out of the ordinary, there will most likely be skepticism or resistance. Meanwhile, Lean Manufacturing is the idea of perfection in production [28], if the naturally available electromagnetic energy can also be integrated into the philosophy of Lean Manufacturing, then it might be possible for Lean Manufacturing to advance its scope towards the idealism of LOM.

Finally, here, the subsection has been able to provide supporting arguments that are consistent with the expected conclusions, that is, the possible future development of new IR vision systems in the LOM's industry system.

FINAL DISCUSSION

Overall, supporting arguments (Section 3) are used to support key elements in the three premises that together provide a rational basis for considering the future use of IR in the manufacturing plant sector (new vision system) as a practical platform for LOM. This is expected to form part of the basis of LOM, as this article presents the key issues that provide a rational basis for considering the proposed concept. A broader study of the related underlying philosophy is necessary to appreciate the potential use of IR for LOM in the future.

CONCLUSION

This article suggests that a rational basis for considering the proposed development of LOM emerges when all three premises are eventually satisfied. The article also suggests the possible involvement of a new kind of IR vision system in a fully automated part of the manufacturing process. This contribution may suggest a possible direction for the future development of LOM and may open up a new research area.

AI Declaration

ChatGPT was used for language editing and wording refinement. The author reviewed and took full responsibility for the manuscript.

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