IS WEBCAM PERFORMANCE SUFFICIENT FOR THE INVENTORY CONTROL OF INDUSTRIAL WHOLESALE ITEMS WITH NO CUSTOMER INVENTORY BALANCE RECORDS?
Case: Technical Wholesale Items

Ari Happonen, Erno Salmela
Department of Industrial Engineering and Management, Lappeenranta University of Technology
Skinnarilankatu 34, Lappeenranta, Finland

Jukka Nousiainen
Department of Information Technology, Lappeenranta University of Technology
Skinnarilankatu 34, Lappeenranta, Finland

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Abstract: This research considers the technical performance of modern webcams for the remote monitoring of the inventory balance of industrial wholesale items. In this case study suppliers were technical wholesalers and the customers were from machinery industry. Paper presents a study on the suitability of webcams for the remote monitoring. In order to establish a remote monitoring system, the images must meet certain quality criteria, thus enabling the assessment of inventory levels. Paper presents image quality tests performed on a webcams in varied conditions, and compares the results to the Finnish Illuminating Engineering Society's lighting regulations for industrial work. The quality tests aimed to ascertain whether the image quality was sufficient in typical industrial conditions. The results indicate that the image quality of modern webcams is sufficient for remote monitoring within the limits set by the distance of the camera from the objects and by lighting conditions. However, according to the tests, the technical performance of surveillance cameras on the market five years ago, taking budget constraints into consideration, was not adequate for monitoring.

1 RESEARCH MOTIVATION

The studied cases utilize the VMI (Vendor-Managed Inventory) model, which is inventory replenishment carried out by the wholesaler delivering items to customer in accordance with the agreed management models. For customer items could play a critical role because their absence may stop entire production lines. Shortages must be avoided and usually this is achieved by using large stock buffers and frequent visual assessment based inventory checks for customer's replenishment needs. To reduce customer site visits a reachearch on camera based remote monitoring was started for at least visual inspections level of inventtory balance information.

Wholesalers have recently promoted VMI research on the use of technology in remote monitoring of items (Happonen and Salmela, 2007). But still there are many items which cannot be monitored easily (cost and space efficiently). Typical reason for limited use of technology in inventory management services is that tehcnology is concidered to be too expencive compared to manual work. The objective of this research is to ascertain whether it is possible to produce images that reveal the inventory levels of items (order point data) in Finnish industrial facilities. As the research of VMI concentrates on collaboration and forecasting (Vigtil, 2006; Salmela and Happonen, 2007; Holweg et al. 2005) as a way to improce order-delivery process of the supply chain and as the information exchange is not as easily arranged between different supply chain parthners as it should be, this research study considered the capabilities of the modern day web cameras as a information source of the item balance information on the VMI relationship.

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2 INDUSTRIAL CONDITIONS AND CAMERAS

Industrial facilities do not offer optimal environment for the technical equipment. Dust, humidity and temperature in the facilities could cause problems, but usually these may be prevented by a casing etc. In the industrial facilities in this study, the storage facilities adjacent to the production area were quite clean. In addition, storage areas were mostly relatively clean too. The camera usability problems lie more on illumination and focal length areas.

2.1 Illumination in Storage Spaces

With regard to the quality of the images, one of the most important factors is illumination. The Finnish legislation does not defined any minimum values for industrial illumination levels, but the adequacy of illumination in work spaces may be evaluated e.g. based on publication 9 of the Illuminating Engineering Society of Finland in 1986: Valaistussuositukset, sisävalaistus (Lighting recommendations, indoor lighting). The illumination levels recommended for storage conditions are presented in Table 1. Levels which exceed 50% of the recommendation are considered sufficient. Based on field research general lighting in modern production plants, exceeds the recommended limits. However, the lighting in warehouses varied more.

Table 1: Illumination Recommendations for Storage Spaces by Finnish Illumination Engineering Society.

Space and usage	Illum. (for work)	Illum. (general)	Notes
Small items on shelves	300 lux	200 lux	Localised light sources are recommended
Medium size items on shelves	200 lux	200 lux	Light sources should be between the shelves not over a shelf
Large items on shelves	100 lux	150 lux	
Corridor spaces	150 lux	150 lux	

2.2 Technical Features of the Camera/ Camera Technology

If the lighting conditions are poor, the picture is taken with a long exposure and/or increased exposure sensitivity. A long exposure and increased sensitivity create a random noise in the image. This noise may be technically removed to some extent, but due to such filtration, the sharpness of the image will suffer (McClelland and Eismann, 2003).

If the image quality is not sufficient for assessment of inventory levels and the quality cannot be enhanced through post-processing an efficient monitoring system is not possible. The factors of the image quality are optics, the camera's imaging sensors, and physical imaging conditions (e.g. illumination). Optics focal length may become a problem since webcams are typically designed for access monitoring, where as wide an angle as possible is needed (Hedgecoe, 1992). So the interrelationship of the camera angle and image quality may be unfavourable to remote monitoring.

2.3 Capturing an Image and the Importance of the Time of Day

Capturing images during the day is usually difficult due to "disturbances" caused by people and machines. Therefore, images should be captured outside the customer's regular working hours. For instance, if the image is captured at night, no disruptions are caused by people or machines except when people work in three shifts. On another hand, the amount of lighting may be insufficient to take the pictures at the night time. Fortunately at least some modern cameras enable the remote control of external equipment (such as light fixtures), which helps to avoid such problems.

2.4 Analysing the Image

Classifying items inventory balance category level from images and placing orders compose an essential part of a camera monitoring system. The label or mark that indicates the item "count" and order point must be identified either manually or automatically. Analysing the image on a computer and marking the appropriate order point would allow the implementation of a system in which the computer places orders independently.

3 CAMERAS AND TEST GOALS

Image quality tests were conducted in laboratory environment on a modern camera (Axis 207MW), and on one that represents technology that dates a few years back (Axis 2120) from the Axis Communications producer of surveillance equipment for industry. New camera operates on a ¼", 1.3 megapixel CMOS sensor, which produces a 1280x1024 pixels image. The lens has a 3.6 mm focal length and a f1.8 luminous intensity. Based on the sensor and focal length, Figure 1 presents size of seen area on pictures at different distances from the object. The previous camera generation is represented by the Axis 2120 webcam from the 2001 product line. Its highest resolution is 640x480 pixels.

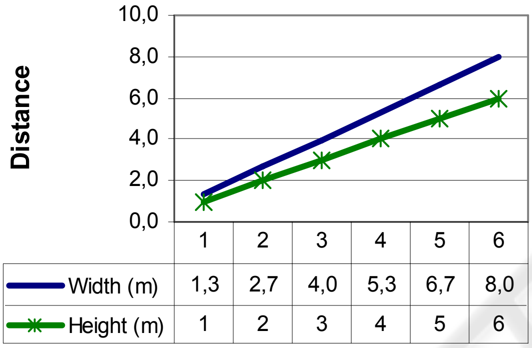

Figure 1: Visible area on picture related to the distance on the object from the Axis 207MW camera.

3.1 Quality Test Arrangements

The test images were captured at four different distances and illumination levels. Illumination in the tests was adjusted from 15 to 200 lux where the 200 lux is minimum level recommended by Illuminating Engineering Society. This range covered illumination levels from the worst case to the recommended levels. Target boxes were placed at a 230 cm distance from each other, and they were tilted at a 30° angle compared to the horizontal level and cameras were 120 cm over box level. Items were positioned as if they were in a typical industrial environment. Black labels were attached to the targets to indicate the order point. Black was chosen as it creates good contrast on many backgrounds.

3.2 The Goal of the Measurements

The technical image quality was analysed by measuring the noise in the pictures. The sufficiency of the image quality for monitoring was visually estimated for a typical machinery industry case.

The measurements aimed to shed light the following points:

- The effect of illumination on noise
- Image quality in industrial lighting conditions and affect of distance to image quality
- The maximum usable distance in the recommended lighting conditions
- The adequacy of the resolution for identifying the item inventory balance category

4 ANALYSIS OF THE MEASUREMENTS

The images were analysed, and the sufficiency of their quality at different parameters was checked.

4.1 Noise Measurements and Results

The images were analysed in accordance with the ISO 15739 standard at 12 different points to analyze the vertical and horizontal noise. Figure 2 present measurements of the AXIS 207MW and depicts the noise levels for each measurement point which relate to the darkness of the point; number 1 is the darkest. The vertical axis describes the amount of noise and each illumination level is presented as data series. In 18 lux lighting, especially the darker measurement points, there is considerably more noise than in other illumination levels, but in other illumination levels results are similar to each other.

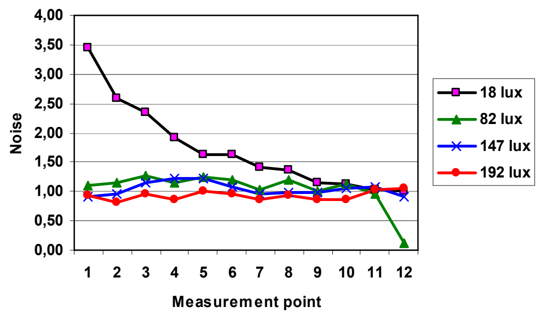

Figure 2: Vertical noise.

Figure 3 depicts horizontal noise. Illumination level of 18 lux clearly differs from the others as noise level is considerably higher than in other series. Only the very lightest points had similar noise than higher illumination levels had.

In Figure 2 and Figure 3 there is an outlier in measurement point 12 as the camera over exposure the image affecting the measurements of point 12 which was taken account on calculations of the average noise for the Figure 4 (last values were not included).

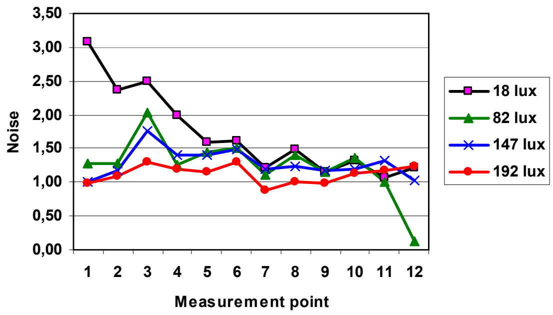

Figure 3: Horizontal noise.

Figure 4 shows the noise averages for each illumination level and indicates that the lowest lighting level had clearly the highest noise level. The illumination levels of 82 and 147 lux show no considerable differences, but the 192 lux level had slightly less noise than the others.

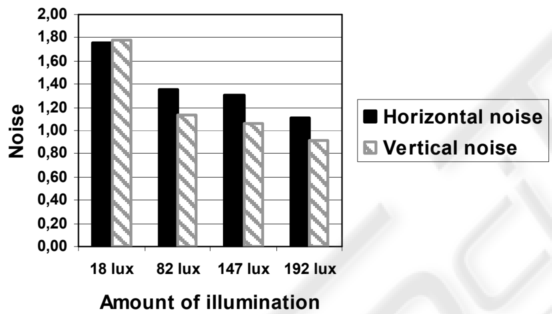

Figure 4: Average amount of noise in different illumination levels.

The Figure 4 shows that the 18 lux level produces the most noise and in practice the graininess of the image makes the interpretation of small details rather difficult. The 82 lux illumination level had significantly less noise, and the effect of the noise on the image was not large. A visual assessment revealed no remarkable difference between 147 and 82 lux levels, which relates well on the results of the noise analysis. Improvement was only minor from 147 lux to 192 level. Based on the tests, the lighting conditions in industry is appropriate for obtaining sufficient image quality. The lighting recommendations of the Illuminating Engineering Society are good enough for taking pictures with little noise.

The noise was significantly higher when capturing images of darker tones than ones of lighter tones. From image usability point of view it was interesting that the surrounding environment of the target had little impact on the noise on target area. Therefore, even if the environment of the industrial hall or the frames of the shelves were dark, it would not considerably affect the interpretation of the image. Noise in pictures of the actual monitored items is determined by the tone of the target itself. As the boxes in industry are often of a dark shade, at low illumination levels, they do not provide the best background. But in sufficient lighting of over 100 lux, there is hardly any difference between dark and light shades with regard to the amount of noise. However, the amount of noise does not significantly decrease as lighting exceeds 100 lux, which indicates that cameras can be used in normal industrial halls, provided that the lighting conditions are unvarying and no shades are cast on the target.

4.2 Image Quality

In the quality tests, the image quality, the visibility of items, amount of the items and order point signals and marks were visually estimated. The estimation was based on how well and how efficiently details could be distinguished from the image. The results of the analysis are presented in Table 2.

5 FINDINGS

For the Axis 207MW the most appropriate range proved to be 3 to 4 metres. At these distances, the width of the view is 4–5.3 metres, which allows more than one shelf to be monitored. Generally four-metre distance should be enough for most cases to allow good placement of the camera. As for the illumination it had little impact on image quality at the levels in industry. The older camera, AXIS 2120, could not produce image quality required for inventory balance level monitoring. AXIS 207MW, on the contrary, was sufficient for remote monitoring both in terms of image quality and other functions.

6 CONCLUSIONS

This study aimed to establish whether the image quality of webcams was sufficient for remote monitoring of inventory levels. A webcam-based system could be applied to the operative order-delivery process of technical wholesale items with

Table 2: Image usability for inventory balance detection in different distances.

Range	AXIS 207MW	AXIS 2120
2 m	Under 20 lux; some problems to "see" the amount of items, because of shadows by boxes on top. Other illumination levels are ok.	Under 20 lux; the image is not clear enough for inventory monitoring. Higher illumination levels have lower noise levels, but low resolution is a problem.
3 m	Under 20 lux; image inspection starts to be too slow process. Other illumination levels are problem free.	Under 100 lux; image not clear enough for inventory monitoring. Higher illumination levels have lower noise levels, but low resolution and distance from the objects makes image inspection almost impossible.
4 m	Under 20 lux; for industrial usability more light is needed, 100 lux should be sufficient.	Low resolution and "high" distance limits AXIS 2120 in over 3 metres distances.
5 m	Under 100 lux; problems because of shadows by boxes on top. Maximum range for the resolution. Produces usable images in over 100 lux levels.	As above.

no customer records on inventory balance. Although laboratory tests indicate that the remote monitoring of small technical wholesale items is doable, basically monitoring is best suited for the large and medium sized items. For small items, the system would require labels or other signals, which would increase maintenance costs. As camera based monitoring itself is not easily adopted to all item sizes and types the camera monitoring would be at its best as a part of an extensive remote monitoring system as an expansion of systems capabilities.

Camera monitoring is at its best when items are consumed sporadically in large volumes. Regular on-site replenishment inspections meet the customer's normal replenishment needs, and camera monitoring assures that individual consumption peaks do not cause shortages in the meantime. The webcam system thus helps to increase the efficiency of operative order-delivery processes through remote monitoring and replenishment decisions.

7 FUTURE WORK

The correlation between camera monitoring and replenishment efficiency should be studied from a financial perspective. Does the arrangement of the camera and shelves have an impact on the replenishment efficiency (e.g. installing shelves side by side and at centralised locations) or do efficient camera monitoring and replenishment efficiency contradict?

As this research study was part of the TEMO – projects research topics (Häkkinen et al., 2007) and as the result of the scale based system have been really promising (Happonen and Salmela, 2007) a new development research project is on preparation for a integrated remote inventory monitoring system which will allow many different monitoring methods to be used side by side to deliver complete remote inventory monitoring system.

REFERENCES

Bavister, S., 2002. Digitaalikuvaus ja kuvankäsittely, WSOY.

Elvander, M.S., 2005. A theoretical mapping of the VMI concept – A literature review. Report ISRN LUTMDU/TMTD-4016--SE, Lund University. 40 pages.

Happonen, A.., Salmela. E., 2007. Automatic & unmanned stock replenishment process using scales for monitoring. In Webist'07, 3rd International Conference on Web Information Systems and Technologies. INSTICC Press.

Hedgecoe, J., 1992. The Photographer's Handbook, Alfred A. Knopf, New York, 3rd edition.

Holweg, M., Disney, S., Holmström, J., Småros, J., 2005. Supply Chain Collaboration: Making Sense of the Strategy Continuum, in European Management Journal, Volume 23, Issue 2, Pages 170-181

Häkkinen, K., Hemilä, J., Uoti, M., Salmela, E., Happonen, A., Hämäläinen, H., Siniluhta, E., Nousiainen, J., Kärkkäinen, M., 2007. VMI teollisuudessa – Teoriaa, teknologiaa ja sovelluksia, VTT, Finland

Illumination Engineering Society of Finland. Publisment no 9/1986. Valaistussuositukset/Sisävalaistus.

McClelland, D., Eismann, K., 2003. Real world digital photography, Peachpit Press, Berkeley, 2nd edition.

Salmela, E., Happonen, A., 2007. Applicability of CPFR on Inventory Replenishment Operation Model of Low-value Items. Finnish Machinery Industry - Case Study. In Proceedings of the 12th International Symposium on Logistics (ISL 2007), Hungary

Vigtil, A., 2006. Exchange of advance demand information in Vendor Managed Inventory. In Proceedings of NOFOMA 2006.