

Tracking of Humans in Industrial Environments

Student name: Shehbaz Rafiq Patel

Date: 19/07/2018

Table of Contents

Introduction.....	3
-------------------	---

Hardware acceleration for computer intelligence.....	3
Previous Application of Artificial Intelligence.....	4
Use of FPGAs.....	5
Use of Video Surveillance Systems.....	8
Analysis of Research Trends.....	9
Use of hardware acceleration for image processing algorithms (FPGAs vs. ASICs).....	9
Use of Visual hull and Articulated ICP.....	10
Customized vision system.....	11
Heterogeneous computing.....	13
People Detection Process through Algorithms.....	14
YouTube Videos.....	19
Video clip 1.....	19
Video clip 2.....	19
Conclusion.....	19
References.....	20

Introduction

In the modern industrial environments, according to Mosberger and Andreasson (2013), many position systems have been structured within such environments. Such systems possess a long-term stable macro-structure possessing possible small-scale dynamic structure. It is as a

result of these assumptions where industries attempt to enable the previous positioning designs to offer and apply stabilized maps. Nevertheless, high levels of dynamic industrial contexts may result in challenges when tracking humans. The use of a variety of hardware acceleration helps in computer intelligence and the role it plays in dynamic industrial environments (Mosberger & Andreasson, 2013). This paper seeks to present a novel allocation structure for tracking individuals in industrial situations. It will show how hardware acceleration for computer intelligence can be employed in dynamic industrial environments. It will also illustrate the element of Field Programmable Gate Arrays (FPGAs) as part of hardware acceleration for image processing algorithms in industrial applications. The paper will also present the aspect of fast 3D reconstruction techniques for industrial applications including the profiling of people. It will also demonstrate a clear understanding of face recognition for lateral faces.

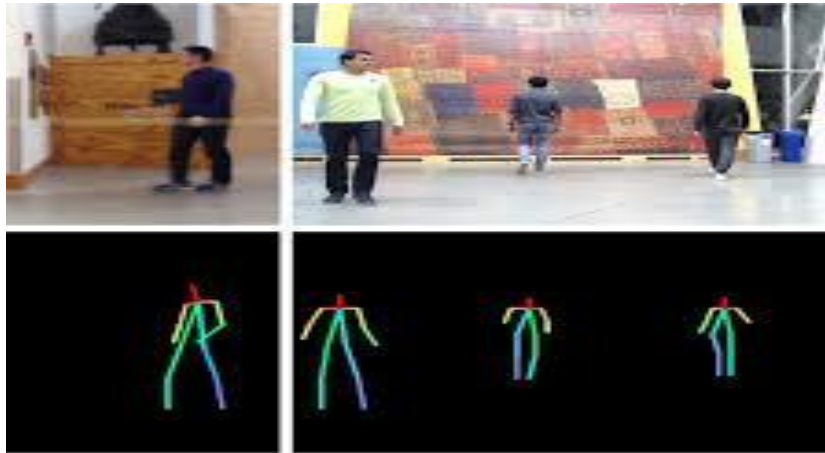
Hardware acceleration for computer intelligence

The use of hardware acceleration for computer intelligence would undertake a significant role in the tracking of humans in industrial environments. Hardware acceleration enhances artificial intelligence (AI) applications. Consequently, AI algorithms exert a lot of evolutionary impact on human societies. They also cover a broad spectrum of applications include image recognition frameworks, robots intelligence, control of traffic, speech understanding structures, and data analytics. The improved performance of AI algorithms requires high-level performance memory as well as computation resources. Through the use of AI accelerator, industries would be able to design the acceleration of artificial neural networks, machine-learning algorithms, and machine vision. These designs are vital in that they are capable of improving the tracking of human beings in dynamic industrial contexts. As supported by Schwabe (2014), the application of Graphics Processing Units (GPUs) is vital for the manipulation of images. The mathematical

perspective of neural networks is similar to the manipulation of pictures aimed at tracking humans. Even though GPUs are popular in how they work to enhance artificial intelligence, they continue evolving in a direction to facilitate deep learning and training needs.

Previous Application of Artificial Intelligence

Da Xu et al. (2014) illustrate that the application of artificial intelligence in the industrial conditions is used to track individuals through identifying risk and their levels of emotional responses. The detection of emotions takes place through various streams of documents and texts and has been available in the last decade. The identification of mood in a written document is one element, but detecting the emotions or mood in a human is an ultimately different component. Based on this, it is possible for machines in dynamic industrial to determine the attitude of a person. This element encourages tracking of human beings through machine algorithms and calculating probabilities regarding core emotions including sadness, joy, and anger. It is through an attempt to identify people's emotional responses in the workplace through which humans are tracked in the industry. For instance, through a firm known as Affectiva, automotive artificial intelligence is given the appropriate consideration (Bond & Gasser, 2014). The automation AI enables manufacturers of driverless vehicles to efficiently undertake tracking of the human drivers' various emotional responses. This helps in the detection of emotions including anger, fear, joy, or surprise.



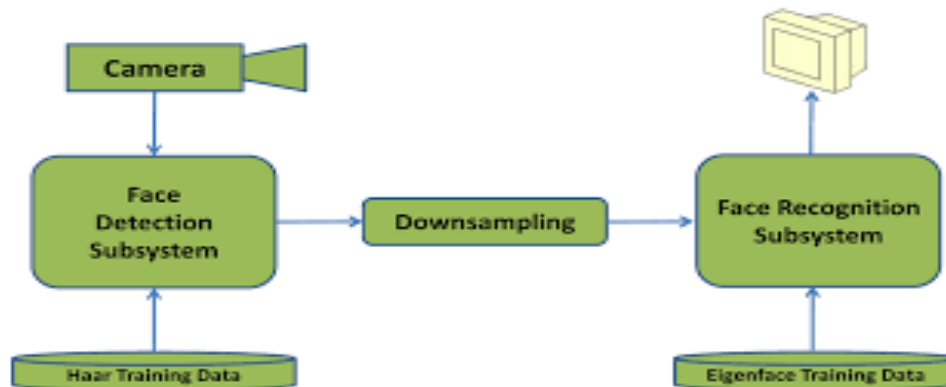
The automation artificial intelligence enhances innovative application of the RGB cameras and infrared cameras. These types of cameras are applied in arriving at confidence scores and identification things such as drowsiness, yawning, and other signs of the individuals' fatigue. The ability to identify these signals in humans, aligned with artificial intelligence, helps to reduce accidents in the industrial settings. The use of automotive AI would also be used in the identification of humans who are working under the influence of alcohol, drugs, or related-substances (Munaro et al., 2016). In history, BMW partnered with Allianz Insurance Group to identify artificial intelligence-based items to enhance safety in its industry. Through the use of technology and leveraging on the firms' artificial intelligence platforms, solutions were created to track the humans' alertness levels and unsafe work habits.

Use of FPGAs

The FPGAs are used to track humans in various industrial control applications. Tavana and Dinavahi (2015) show that to make the noticeable difference in the industrial settings; the control systems should be significantly performing, flexible, and reliable. The rationale for using FPGAs in the industries is that the revolution of automation in industries is a core driver for the insatiable demand for increased productivity, low costs of ownership, and enhanced safety for

the humans. Hence, the use of FPGAs as industrial applications would appropriately track humans and create the insatiable demand for increased system-based performance (Tavana & Dinavahi, 2015). The use of FPGAs is justified in that they meet vital timing and performance needs with parallel processing and real-time industrial applications for their performance. FPGAs also facilitate a greater level of integrated connectivity because of existing easy integration of third-party IP for industrial-related networks.

The FPGAs provide extraordinarily powerful and significant solutions to meet different machine visions, high levels of industrial networking, control of the motor, and video surveillance requirements (Irwansyah et al., 2017). As part of human tracking in dynamic industrial contexts, the reliable and flexible nature of FPGAs enables designers to promptly respond to changes in image sensor interfaces (Rodríguez-Andina et al., 2015). It also allows prompt responses to image processing needs and encourages the evolution of analysis capabilities to align with requirements in the industry.



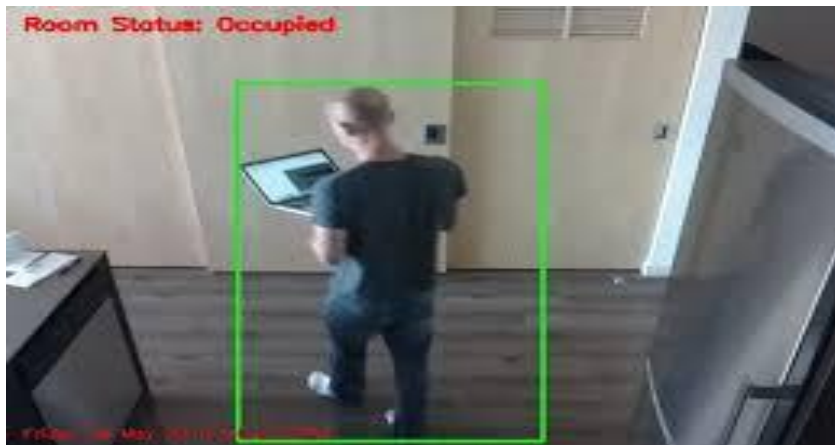
There are certain benefits of the use of FPGAs in industries to track humans. This is based on the assertion that the factory ecosystem is a profoundly improving workplace which requires interfaces to cross a broad range of applications including motors, sensors, and Programmable Logic Controllers (PLCs). The existing industrial networking protocols offer

seamless, effective communication between the modules. This is relevant in that it allows elements from various manufacturers who are linked with the industry. The use of FPGAs in industries takes the form of three categories. The device category offers communication between the modules within short periods (Rodríguez-Andina et al., 2015). The process category enables peers within the industrial contexts to communicate with each other and allows a greater latency than the device category communication. The highest category of communication is the utilization of Ethernet which offers the biggest data bandwidth and distance. This assists in tracking humans in various sites within an industry.

The FPGAs are utilized to track humans in dynamic industrial contexts through video surveillance. Xu et al. (2015) propose that the application of the high-level definition, Internet Protocol-related video cameras is efficient in tracking humans in the industries. As a result of the rapid creation of broadcast markets, there have been numerous ASIC and ASSP video solutions for industrial processes. The FPGAs encourage greater product differentiation because of high levels of flexibility when implementing the individual sensors and customer-related IP and image processing roles (Xu et al., 2015). This way, FPGAs helps in tracking humans in the industries by encouraging the use of special sensors for the individuals within the industry environment. It also offers the night-vision cameras which would monitor the movement of the individuals and eliminate intruders into the industrial sites. The modern use of video surveillance systems is improved because in the past, limited processing was undertaken at the relevant camera nodes (Munaro et al., 2016). However, modern-day intelligent cameras are used for capturing and analyzing data in real-time, compressing the collected data, and process it for use in analyzing tracking processes.

Use of Video Surveillance Systems

Nevertheless, the modern application of video surveillance systems in industrial systems has eradicated the use of traditional standards of tracking humans (Michel et al., 2015). In this case, the coax cables are used alongside the Cat-5 Ethernet cables. The effectiveness of the Coax is that it provides bandwidth to other elements which cannot support the high-level resolution in new IP sensors for tracking purpose (Gajjar et al., 2017). As a result, in this execution, FPGAs are employed as companion devices to existing systems. The benefits of such alignment are the addition of high-image processing capabilities which improve and extend the ability of the system process, the capacity to offload processing from the primary system processors and adapt to the contemporary sensors for tracking purposes in the industrial environments. Some FPGAs exist in the form of Spartan-6 SPGAs which are built and maintained on the 45nm architecture (Gajjar et al., 2017). This enables appropriate tracking of humans in the industrial contexts through vital systems in the factory ecosystems.



Analysis of Research Trends

Use of hardware acceleration for image processing algorithms (FPGAs vs. ASICs)

The FPGAs are composed of interconnected logic blocks in the form of bi-dimensional arrays. The logic blocks entail look-up tables (LUTs) formulated using simple memories. The LUTs have fixed amounts of inputs and are characterized by multiplexors and Flip-Flop to express circuits in a sequential manner (Nurvitadhi et al., 2016). The architecture of FPGAs necessitates the implementation of subsequent as well as combination circuit, which ranges from simple logic functions to high-end soft processes. Designs such as Hardware Description Languages (HDL) and Verilog HDL are applied to decrease the complexity of formulating the FDGA systems. From a traditional perspective, FPGAs were majorly employed for signal processing and analysis of network packets (Nurvitadhi et al., 2016). However, as a result of the embedment of high-speed resources in the FPGA designs, the FPGAs are applied to trigger the algorithm as independent systems or coprocessors in human tracking. Apart from the reprogramming tasks, the utilization of the FPGA systems has various benefits which cannot be provided by the ASIC in tracking humans in the dynamic industrial systems (Andina et al., 2017).



Modern Systems

Use of Visual hull and Articulated ICP

Michel et al. (2015) assert that visual hull and articulated ICP are applied in capturing markerless human motion. The markerless system refers to a marker-free techniques which capture various human motions. The use of articulated iterative closest point (ICP) algorithm alongside soft joint constraints proves to be a vital design. The visual hull series necessitates application of standard 3D depiction of dynamic sequences obtained from many pictures (Milano, 2015). The quality and outcomes of visual hull systems is based on various elements such as calibration of the cameras, number of cameras, configuration of the cameras, resolution of the images, and appropriate and suitable segmentation of the cameras (Tagliasacchi et al., 2015). The rationale for these requirements is that the use of grayscale cameras such as BW4 and BW1 hinder accurate use of the cameras and result to inappropriate outcomes for the visual hulls. This way, industries attempt to consider the application of five cameras including the BW2, BW3, C3, C2, and C1 to enhance results of the visual hulls rather than using mere estimates.



Proper articulation of the body results to successful tracking via specific video sequencing. These aspects show that there are feasibility and viability of assessing 3D human body kinematics through the markerless motion capture designs depending on visual hulls

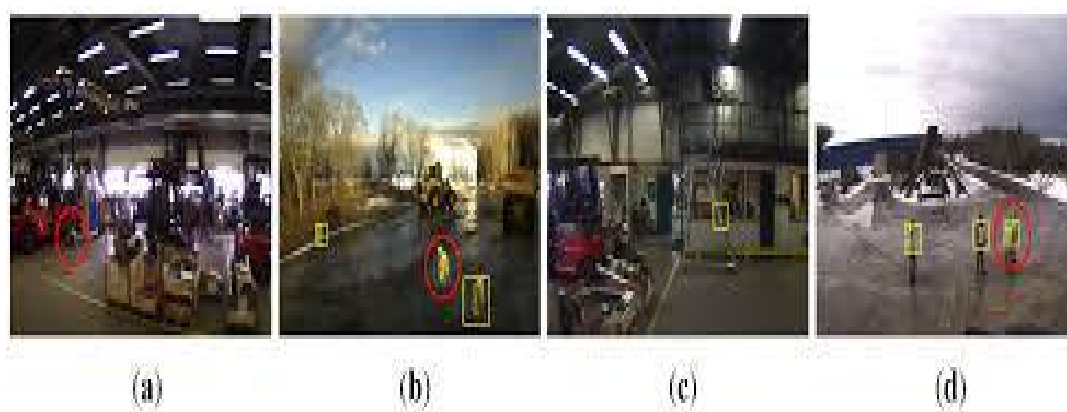
(Cadavid & Selbie, 2018). The use of such algorithms facilitates appropriate tracking of human body segments in industrial contexts. However, the algorithm does not facilitate enforcement of hard constraints to track articulated schemes. The used cost function encompasses two elements that ensure that suitable relevant points match. The application of different cameras to enhance the quality of the visual hulls and an improved knowledge helps industries to track human figures in different sites.

Customized vision system

Tracking industrial workers used observations on reflective patterns on their safety clothing is an appropriate mechanism. This also takes into perspective the element of color vision. In this context, color vision entails the application of different tracking algorithms for tracking and monitoring construction workers from both dynamic and static cameras (Aydalot & Keeble, 2018). For instance, this can be facilitated through the use of a pedestrian detection design which is specifically created for underground mining sites. Thermal vision would then be an appropriate strategy in this context due to the existence of lack of sensitivity to illumination shifts and the frequent dust occurring in underground mining sites (Tagliasacchi et al., 2015). This issue can be solved through the provision of a modular design which enables individuals to combine various responses from a variety of human detectors. It would be vital in improving the strength and reliability of the system. This way, it would necessitate the use of Radio-frequency identification (RFID) system to enhance robust proximity warning systems (Amendola et al., 2015). It would help in detecting humans in the sites of heavy industrial machinery.

The precise technique of applying the properties of high-level visibility clothing and related gear is to ensure that the detection of industrial workers is effective. The algorithm in use would identify the fluorescent color of safety clothing (Andina et al., 2017). This would be

possible through processing locally-existing color histograms obtained from the sections of interest. Although the reflective nature of the vests may not be exploited wholly, the distinctive color of safety clothing would contribute significantly toward a more efficient detection and tracking of human beings in the site of heavy industrial machinery and relevant operation (Munaro et al., 2016). Nevertheless, the operational contexts that industrial vehicles encounter a lot of challenges are based on various perspectives. This is because they engage in their activities differently in bright outdoor and inadequately illuminated indoor sections. This results to a wide range of varied light situations, a perspective which hinders the involvement of purely visible-light vision depending on detectors which use appropriate contrast and texture regarding the image (Aydalot & Keeble, 2018). In the outdoor uses, they are usually faced with the challenge of the rough terrain.



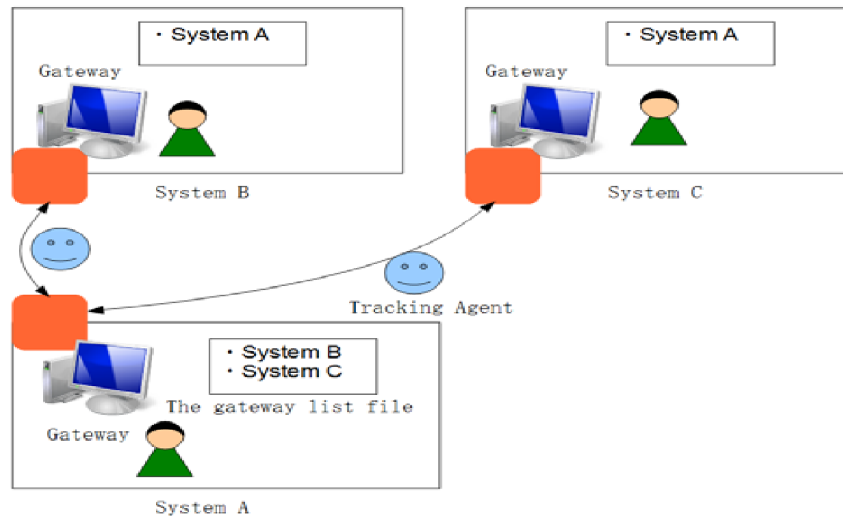
When operating alongside thermal vision sensors, the availability of different heat sources in industry-based working site may make the attainment of background areas more challenging than in road traffic (Irwansyah et al., 2017). Additional issues when using high-visibility clothing in tracking humans in industrial sites is that there is numerous human body poses experienced in the industrial workplace. Rather than looking at upright pedestrians as in the context of road traffic experiences, industrial workers may end up appearing in various

body positions based on the activities performed (Munaro et al., 2016). Also, the typical motion conditions of industrial vehicles encompass a lot of acceleration and deceleration, making sharp turns and reverses.

Heterogeneous computing

Heterogeneous computing are designs that utilize more than one form of cores or processor. As supported by Yotsumoto et al. (2014), it is applied in industries because heterogeneous computing obtain energy efficiency as well as performance through addition of dissimilar coprocessors. The extent of using heterogeneous computing in industrial environments fits well toward the tracking of humans. The systems are capable of performing mathematically intensive computations on very large data-sets. It is also capable of undertaking operations on different industrial operating systems and carry out traditional serial activities. In this context, a monitoring range which is present for tracking is restricted to a specific level. The monitoring range is evaluated by the volume and the region of cameras in a certain building (Sapiezynski et al., 2015).

Through the use of heterogeneous computing designs, feature data collected from cameras are applied to detect a target. It is also utilized to keep tracking a particular target. This form of computing also puts into consideration the IP address of every gateway to keep tracking across heterogeneous designs (Haque et al., 2016). The gateway serve has a gateway list which lists the necessary gateway serve of other systems used to transmitting tracking request to other suitable systems.



People Detection Process through Algorithms

The detection process can be formulated as a cascade of various algorithms to preserve accuracy. In such specific cascade of classifier modularity, detection approaches are presenting in declining order of speed and rising levels of categorizing accuracy (Andina et al., 2017). This results to an application of simplified and immediate verification processes when multiple detection windows are processed. There are also algorithms that are formulated for composing the single phases of the cascade. They can be categorized into color-related, consistency, and depth-related algorithms. The consistency constraints present the ability to determine if a detection window depicts compatibility with individuals on the ground plane. The initial constraint is a height in the image against disparity constraint (Stahlschmidt et al., 2016). The rationale behind the consistency constraints is that individuals of specific height in images, presented in pixels, require to have disparities which place the individuals at reasonable distances. The other constraint forces items to be placed on the ground plan. The thresholds for the two constraints are based on evaluating how the individuals can be detected using cameras placed 1.8 meters from the ground. Afterward, there is a need to eliminate high-level overlapping

detection windows emanating from the consistency module. The activity enables to significantly decrease the number of detection windows that need to be evaluated through various phases of the detection cascade.



The depth-related algorithms are used to identify few number of detection windows which can appropriately be evaluated using different phases of the cascade (Stewart et al., 2016). However, this is different from the consistency method in that it needs a point cloud rather than a disparity-based image. With the use of the point cloud, this approach eliminates the ground plane points and undertakes a categorizing of the other elements. Through the tracking algorithm, it is possible to exploit the outcomes of the individuals' detection cascade to carry out data connection between previous designs and new potential detections (Andina et al., 2017). It is alignment is depended on assessing color histograms of individuals from respective color-based images.

In case detection is not linked with previous tracks, a current design is formulated using other threads. The threads are focused on certain particle filters on the x-y planes. It ends up exploiting detections and the relevant color histograms in determination of the specific individual within the specified image. This technique enables detecting individuals despite the detection cascades offering “no valid” outcomes (Stewart et al., 2016). Also, the applications of particle filters allow the recovery from errors presented by the tracker including an identity switch.

Hence, in such a data association scheme, different detections might be attributed to a similar scheme, with the aim of avoiding different generation of tracks from the same individual.

In this context, the algorithm needs a separate thread for each track, hence the volume of tracks that can be facilitated is restricted through the numerous threading abilities of the computer-based gadget. About the RGB-D human detection approaches, it is evident that there are favorable outcomes (Stahlschmidt et al., 2016). The safety approaches dictate that no individual can be missed in the industrial applications of tracking people. Hence, there is a need to undertake further envisioning and improvement of the process of detecting people. Also, the approaches used should focus on the need for ensuring that the tracking algorithms are more scalable regarding the volume of tracked individuals.

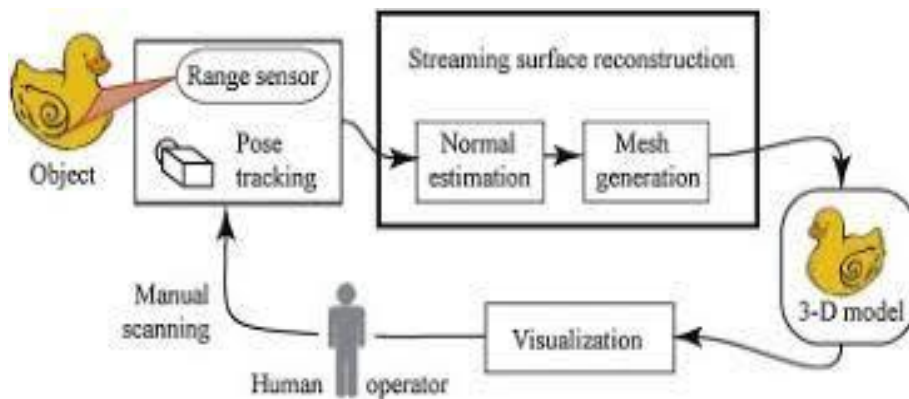
Three dimensional (3D) image reconstruction is a modern process of formulating a mathematical representation of 3D objects. There are various techniques which can be incorporated in 3D reconstruction system. The approach is commonly used to track people in dynamic industrial operations. For instance, one of the approaches is structured illumination. The possession of a calibrated projector-camera is appropriate in that it projects light patterns and images through specific cameras (Liu et al., 2015). In case the surface in the background scene does not have a 3D surface deviation, the pattern illustrated in the relevant image is similar to one of the projected light patterns. In other situations, if the scene's surface is non-planar, the presented light patterns in the corresponding images are distorted because of the existence of surface geometry. The structured illumination is appropriate for industrial tracking of humans because it utilizes the information provided by distorted projected light patterns.

The 3D reconstruction system may also employ the technique of stereo vision (stereopsis). This technique ends up reconstructing a 3D object through the deduction of spatial

shapes and positioning of objects through parallaxes between the relevant pixels from a variety of images (Milano, 2015). The policy of traditionally-based stereopsis technique is triangulation. Through triangulation, the distinct contours of objects are vital in how they determine the images collected from the two unparallel cameras used in the various sites in industrial settings. The other technique used in the 3D reconstruction systems is the photometric stereo. This technique has improved in recent times. It is a strategy in computer vision for determining the surface normal of items by observing the objects through various lighting situations. It is based on the assertion that the volume of light reflected by a surface is based on the surface's orientation in association with the observer and the light sources (Liu et al., 2015). The space of potential surface orientations is restricted through assessing the amount of light reflected into the camera in the industrial settings. The photometric stereo is utilized in industrial contexts to track humans because it entails the analysis of multiple images of various objects under distinct lighting situations (Antonimuthu, 2016). This estimates the direction of employees and other attendants by estimating the normal direction for each generated pixel.

The basis for using the photometric stereo to track humans is based on various regulations and assertions. For instance, it needs some form of control of the lighting environment in the industrial sites, without inappropriate changing of the cameras or the individuals' work sites. Three illumination directions are adequate to achieve the surface normal (Aggarwal & Xia, 2014). However, for effective and efficient use of photometric stereo in tracking individuals in industrial settings, there is a need to use four illumination directions. This ensures that the imaging system is appropriately applied to track humans. The setback of using the photometric stereo to track humans in industrial sites is that there might be increased errors at sections with large gradients. This occurs when the surface normal attempt to approach a

direction which is perpendicularly-related to the cameras. Improvements could be made to the photometric stereo through optimization of the reconstruction algorithm (Aggarwal & Xia, 2014). It helps to offer enhanced height estimates at sections with sharp edges in the industrial sites.



The other modern approach which can be applied to track humans in industrial contexts includes the element of face segmentation for lateral faces. Face detection represents a crucial fundamental in enhancing safety and smooth operations in different industrial settings. The formulation of face segmentation triggers the capability to recognize faces in the visual working environment. Faces are incorporated in selected target-present conditions in frontal, mid-profile, or profile view of the head. Hence, detection performance is assessed as a function of face view. From different experiments, the detection outcome of face segmentation in lateral approaches illustrated that view is a central element in face detection (Munaro et al., 2016). It can influence the speed as well as credibility with which the social stimuli are depicted in visual surroundings in industries. In lateral faces, the eyes establish a vital pattern for distinguishing faces from other items. This is relevant with the evidence that eyes decrease visual elimination in the spatial identification of humans in construction sites.

YouTube Videos

Video clip 1

In the video, Milano shows how the map-based particle filtering approach is used to detect, track, and predict human motion inside an industrial environment. The video shows how people in the industry can be tracked when they walk into defined as well as undefined destinations (Milano, 2015). (<https://www.youtube.com/watch?v=gRQpYLbQpRQ>)

Video clip 2

The video begins by demonstrating how the industrial revolution used steam engines. It then illustrates the current fourth stage of the industrial revolution and how it influences both physical and biological systems. Hence, in the industrial environment, the element of the fourth industrial revolution is used to track people and promote their well-being in the industry (Antonimuthu, 2016). (https://www.youtube.com/watch?v=1K_ATYqvHTs)

Conclusion

In conclusion, based on the discussion above, it is evident that there is need to utilize human tracking in industrial environments. This would ensure that operations are undertaken smoothly and appropriately. Human tracking in such industrial settings would also facilitate safety for the individuals involved in industrial operations. It is also clear that traditional human tracking systems are faced by various setbacks which are resolved through the modern systems. Therefore, with regard to efficiency and safety in industrial activities, there is need for human tracking through the use of different systems and designs.

References

- Aggarwal, J. K., & Xia, L. (2014). Human activity recognition from 3D Data: A review. *Pattern Recognition Letters*, 48, 70-80.
- Amendola, S., Bianchi, L., & Marrocco, G. (2015). Movement Detection of Human Body Segments: Passive radio-frequency identification and machine-learning technologies. *IEEE Antennas and Propagation Magazine*, 57(3), 23-37.
- Andina, J. J. R., De la Torre Arnanz, E., & Valdes, M. D. (2017). *FPGAs: Fundamentals, Advanced Features, and Applications in Industrial Electronics*. CRC Press.
- Antonimuthu, R. (2016). The Fourth Industrial Revolution. How Industry 4.0 is going to impact Human Life? Retrieved from https://www.youtube.com/watch?v=1K_ATYqvHTs
- Aydalot, P., & Keeble, D. (2018). *High technology industry and innovative environments: the European experience*. Routledge.
- Bond, A. H., & Gasser, L. (Eds.). (2014). *Readings in distributed artificial intelligence*. Morgan Kaufmann.
- Cadavid, S., & Selbie, W. S. (2018). 3D Dynamic Pose Estimation from Markerless Optical Data. *Handbook of Human Motion*, 197-219.
- Da Xu, L., He, W., & Li, S. (2014). Internet of things in industries: A survey. *IEEE Transactions on industrial informatics*, 10(4), 2233-2243.
- Gajjar, V., Khandhediya, Y., & Gurnani, A. (2017, September). Human Detection and Tracking for Video Surveillance: A Cognitive Science Approach. In *ICCV Workshops* (pp. 2805-2809).

- Haque, A., Peng, B., Luo, Z., Alahi, A., Yeung, S., & Fei-Fei, L. (2016, October). Towards viewpoint invariant 3d human pose estimation. In *European Conference on Computer Vision* (pp. 160-177). Springer, Cham.
- Irwansyah, A., Ibraheem, O. W., Hagemeyer, J., Pormann, M., & Rueckert, U. (2017). FPGA-based multi-robot tracking. *Journal of Parallel and Distributed Computing*, 107, 146-161.
- Liu, Z., Qin, H., Bu, S., Yan, M., Huang, J., Tang, X., & Han, J. (2015). 3D real human reconstruction via multiple low-cost depth cameras. *Signal Processing*, 112, 162-179.
- Michel, D., Panagiotakis, C., & Argyros, A. A. (2015). Tracking the articulated motion of the human body with two RGBD cameras. *Machine Vision and Applications*, 26(1), 41-54.
- Milano, P. (2015). Detecting, tracking and predicting human motion inside an industrial robotic cell. Retrieved from <https://www.youtube.com/watch?v=gRQpYLbQpRQ>
- Mosberger, R., & Andreasson, H. (2013, May). An inexpensive monocular vision system for tracking humans in industrial environments. In *ICRA*.
- Munaro, M., Lewis, C., Chambers, D., Hvass, P., & Menegatti, E. (2016). RGB-D human detection and tracking for industrial environments. In *Intelligent Autonomous Systems 13* (pp. 1655-1668). Springer, Cham.
- Nurvitadhi, E., Sheffield, D., Sim, J., Mishra, A., Venkatesh, G., & Marr, D. (2016, December). Accelerating binarized neural networks: comparison of FPGA, CPU, GPU, and ASIC. In *Field-Programmable Technology (FPT), 2016 International Conference on* (pp. 77-84). IEEE.

- Prankl, J., Aldoma, A., Svejda, A., & Vincze, M. (2015, September). RGB-D object modelling for object recognition and tracking. In *Intelligent Robots and Systems (IROS), 2015 IEEE/RSJ International Conference on* (pp. 96-103). IEEE.
- Rodríguez-Andina, J. J., Valdes-Pena, M. D., & Moure, M. J. (2015). Advanced features and industrial applications of FPGAs—A review. *IEEE Transactions on Industrial Informatics*, 11(4), 853-864.
- Sapiezynski, P., Stopczynski, A., Gatej, R., & Lehmann, S. (2015). Tracking human mobility using wifi signals. *PloS one*, 10(7), e0130824.
- Schwabe, P. (2014). Graphics processing units. In *Secure Smart Embedded Devices, Platforms and Applications* (pp. 179-200). Springer, New York, NY.
- Stahlschmidt, C., Gavrilidis, A., Velten, J., & Kummert, A. (2016). Applications for a people detection and tracking algorithm using a time-of-flight camera. *Multimedia Tools and Applications*, 75(17), 10769-10786.
- Stewart, R., Andriluka, M., & Ng, A. Y. (2016). End-to-end people detection in crowded scenes. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 2325-2333).
- Tagliasacchi, A., Schröder, M., Tkach, A., Bouaziz, S., Botsch, M., & Pauly, M. (2015, August). Robust articulated-ICP for real-time hand tracking. In *Computer Graphics Forum* (Vol. 34, No. 5, pp. 101-114).
- Tavana, N. R., & Dinavahi, V. (2015). A general framework for FPGA-based real-time emulation of electrical machines for HIL applications. *IEEE Transactions on Industrial Electronics*, 62(4), 2041-2053.

- Xu, R., Guan, Y., & Huang, Y. (2015). Multiple human detection and tracking based on head detection for real-time video surveillance. *Multimedia Tools and Applications*, 74(3), 729-742.
- Yotsumoto, T., Nomura, A., Tanigawa, K., Takahashi, K., Kawamura, T., & Sugahara, K. (2014). Human Tracking across Heterogeneous Systems Based On Mobile Agent Technologies. *World Academy of Science, Engineering and Technology, International Journal of Computer, Electrical, Automation, Control and Information Engineering*, 8(8), 1351-1355.