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Productivity Monitoring of Construction Activities Using Digital Technologies: A Literature Review

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INTRODUCTION

Construction is one of the biggest industries in the world

13% of the global Gross Domestic Product

Even when outside of crises, it does not perform well

In lean construction, production activities are improved continuously with respect to waste and value

This study aims to identify and analyze the main existing methods for measuring, analyzing, and improving productivity on construction sites using digital technologies for automated data collection

Systematic literature review

PRODUCTIVITY MONITORING IN CONSTRUCTION

LABOR PRODUCTIVITY

$$\frac{\text{Output (specific physical units)}}{\text{Input (man-hours)}}$$

WORK SAMPLING

Used to indirectly assess productivity

Observing the activities at regular intervals

Categorizing them into different work categories

Direct work	Transport	Travel	Idle

Evaluate how time is utilized

ACTIVITY ANALYSIS

Includes more detailed observations

Provides a more descriptive assessment of the utilization of workers' time

Can continuously identify the areas for productivity improvements

RESEARCH METHOD

SYSTEMATIC LITERATURE REVIEW

Research questions:

- What are the most used digital technologies for productivity monitoring in construction sites?
- How can these technologies help to monitor the productivity of construction activities?
- What are the main advantages and limitations of the technologies used?

Database used: Scopus, ASCE Library, and Web of Science

RESEARCH METHOD

SYSTEMATIC LITERATURE REVIEW

Inclusion criteria: (1) Papers that have search terms at least in the title, abstract, or keywords; (2) Publications between 2010 and 2021; and (3) Articles published in journals.

Exclusion criteria: (1) Papers not focused on the engineering and construction area, and (2) Publications unrelated to the theme.

Search terms:
Construction AND (productivity OR “work sampling” OR “activity analysis” OR “value-adding time”) AND (RFID OR UWB OR bluetooth OR sensors OR accelerometer OR “computer vision” OR “machine learning” OR “deep learning” OR “image processing” OR audio OR microphones).

RESULTS

16 PAPERS IN THE SAMPLE USE METHODS BASED ON COMPUTER VISION

Video-based activity analysis requires methods for detecting and tracking resources, and procedures for activity recognition

Detection algorithms, usually relying on machine learning techniques, involve training to learn the unique signature of a given object

To estimate target trajectories from target detections, additional processing is required to keep track of the detected objects over time

Further analysis of the object's visual stream provides information regarding the contribution of the resource to the construction process

CHALLENGES	Authors pointed out challenges with gesture recognition on computer-based approaches. Training and testing models used in computer-vision methods requires a large amount of empirical data

RESULTS

16 PAPERS IN THE SAMPLE USE METHODS BASED ON COMPUTER VISION

Pose estimation techniques, commonly used in research on construction worker ergonomics, have also gained prominence among productivity studies

- Use of visual data to detect and track workers' skeleton features to interpret and analyze their activities
- Train and perform vision-based activity analysis of equipment

Roberts et al. (2020)

RESULTS

16 PAPERS IN THE SAMPLE USE METHODS BASED ON COMPUTER VISION

ADVANTAGES	DISADVANTAGES
Videos are understandable by any visually able person, provide detailed information, and allow reviews by managers away from the work sites	Computer vision algorithms are sensitive to environmental factors such as occlusions, lighting, and illumination conditions
Visual data contains information about not only the physical movements of workers and equipment, but also their visual features and spatial-contextual natures	A single camera can only cover a limited field of view. To fully cover a large construction job site, it would be necessary to install multiple cameras in various locations

RESULTS

16 PAPERS IN THE SAMPLE USE METHODS BASED ON SENSORS

Body-worn sensors:

- Accelerometer
- Gyroscope
- Magnetometer

- Measurement of workers' posture and motions
- Construction activity monitoring

- Investigation of work techniques that are safer and more efficient
- Measurement of the operational efficiency of excavators
- Detection of the proportion of time spent in each activity by workers

Resilient and robust in difficult conditions, small size, good accuracy, reasonable power consumption.
Can be embedded in wristbands to classify activities performed with hands

Ryu et al. (2019)

RESULTS

16 PAPERS IN THE SAMPLE USE METHODS BASED ON SENSORS

Real-Time Location Sensors (RTLS)

- Radio Frequency Identification (RFID)
- Ultra-Wideband (UWB)
- Bluetooth Low Energy (BLE)

  - Technological maturity
  - Cost-efficient infrastructure
  - Ability to operate without line of sight

- Analyze the time trajectories of workers and perform automated work sampling
- Track the efficiency of a material lift system for transportation
- Analyze the share of uninterrupted presence of workers in work locations, a necessary condition for value-added time

CHALLENGES	Although RTLS sensors can be useful for a variety of applications, without interpreting the activities and purely based on location information, deriving workface data is challenging

RESULTS

16 PAPERS IN THE SAMPLE USE METHODS BASED ON SENSORS

Use of biosensors in wearable devices to analyze factors that affect the productivity of construction workers

Physiological signals:

Heart rate (HR)
Blood volume pulse
Respiration rate
Galvanic skin response
Skin temperature

Study of the influence of physical strain, emotional status, and psychological stress on productivity and safety performance

Despite being promising, the use of too many sensors may be uncomfortable for the subject and can interfere with normal or spontaneous activity

RESULTS

3 PAPERS IN THE SAMPLE USE METHODS BASED ON AUDIO

Audio has been investigated by researchers as input data for recognizing activities of construction heavy equipment that generate distinct acoustic patterns while performing routine tasks.

ADVANTAGES	DISADVANTAGES
A single microphone can cover larger areas without the need to be directly attached to a machine	The existence of background noise might be a negative factor for the algorithms
The processing of audio files is computationally less expensive compared to processing images and video files.	Certain types of construction machinery do not generate distinct sound patterns during operation

DISCUSSION AND CONCLUSIONS

Technologies based on computer vision and sensors

The most used for productivity monitoring on construction sites

- Automate data collection for work sampling and activity analysis
- Measure inputs and outputs
- Monitor physical and emotional factors that can influence workers' productivity

Vision-based methods

Have made great advances in recent years

Detection of fine movements is still a challenge

Pose estimation techniques can analyze movements in a more detailed way

- Potential for studies of productivity monitoring integrated with ergonomics analysis

Sensor-based methods

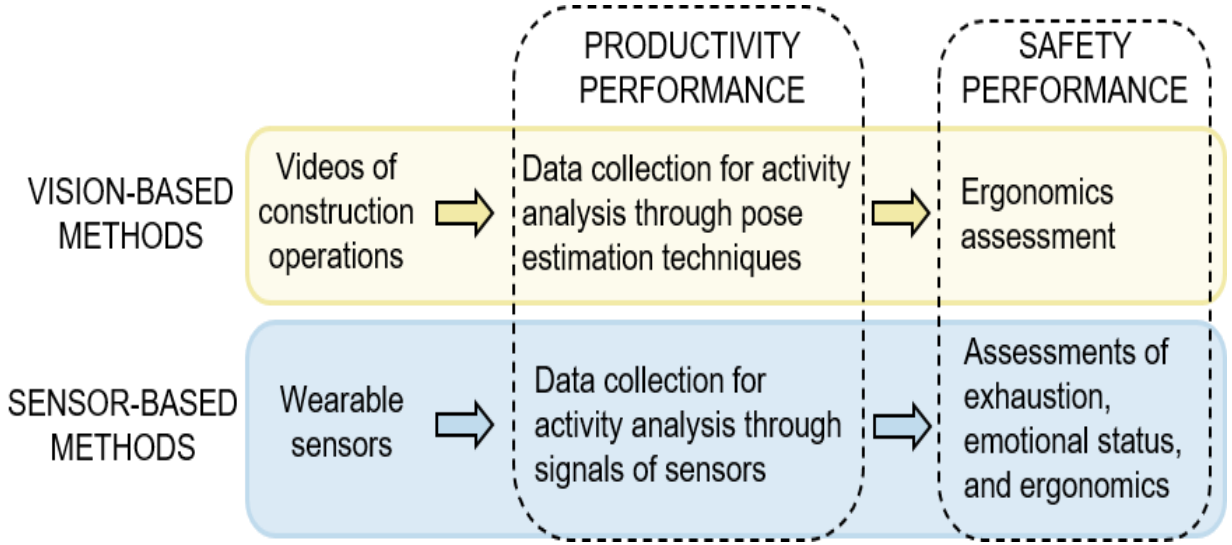
Further studies are needed to overcome the challenge of relating the worker's location to the type of work being performed

Studies using physiological signals have great potential to demonstrate the influence of stress and physical demand on workers' productivity

DISCUSSION AND CONCLUSIONS

There is an opportunity to combine the technologies of computer vision-based and sensor-based methods to provide evidence regarding the integrated management of productivity and safety and their impacts on the production process.

This integration, despite being of great value, has been little explored in the literature.



THANK YOU!

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