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Developing a neuro-fuzzy based framework for labour productivity assessment

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ABSTRACT

Labour productivity assessment is the key to optimal planning and allocation of resources for a construction project. In this study, a detailed questionnaire covering major factors influencing work productivity has been identified by surveying the labourers and their supervisors. The relative importance index (RII) has been used to consolidate the responses and identify the key factors. Based on the factors identified a field study is conducted to develop an automatic productivity assessment tool. The worker performance is estimated using data collected from wearable devices. The data is calibrated against the site supervisor estimated labour performance by training a neuro-fuzzy interference system. The developed model can serve as a framework for the automatic assessment of labour performance in a construction site. This can find extensive applications in making the resource allocation process in major construction sites more rational.

Keywords— *Labour productivity, Neuro-fuzzy system, Activity study, Expert system, Resource optimization*

1. INTRODUCTION

Research has shown that 20% of the construction projects fail to achieve their goal as a result of delays, or cost overruns that can put any construction project at risk. One of the important parts of these construction projects are labour's productivity, since labour wages account for 30-50% of the construction budget it is important to study what are the factors that influence labour's productivity in the Construction projects [3] Labor productivity usually relates manpower in terms of labour cost to the number of outputs produced. [1]

In the context of the construction industry, the work scheduling practices are generally carried out using past experience and there is a bit of vagueness involved in determining the work completion timeline and accountability of stakeholders in its completion. In this study, a questionnaire has been developed to infer the critical factors that have an influencing role in determining work productivity at the site. The identified critical factors are then used for developing an expert system that can predict the out-turn of work based on the data from fitness trackers worn by the labour. This proposed framework can throw better insights into resource allocation and improve the productivity of construction projects.

2. QUESTIONNAIRE SURVEY FROM STAKEHOLDERS

In order to get a better perspective from the Indian context, a tailor-made questionnaire relevant to the context of labours and supervisors has been developed from a review of previous literature. Care has been taken to ensure that the questions are not open-ended and no bias of conformity is developed while answering the questions. A total of 11 contractors and 60 workers were surveyed in and around Madurai region. The scope of this data collection was restricted to small scale residential projects.

2.1 Factors considered for developing the questionnaire

The questions were framed to infer the following parameters that were inferred to have a high correlation to productivity based on the review of the literature. The list of factors considered is broadly summarized in Table 1.

Table 1: Parameters considered in labour productivity study

Factor	Correlation to productivity
Job availability for labours	High demand for labours may render them lethargic at work and lower the productivity on the contrary desperate job seekers in the job market will improve productivity due to the increased commitment level of workers to sustain the available job.

Overtime work	The overtime work may indicate a resource allocation problem or lack of efficiency of labours. In either case, the work turnout during overtime may not be as productive as work extracted during regular work hours due to employee fatigue.
Cause-effect analysis	The deviation from expected timelines was reasoned and rated in the order of importance both from the viewpoint of labours and supervisors.
Nature of activity	The difficulty perceived by workers for various nature of activities were collected to rate the activity's importance from the viewpoint of regular tracking and monitoring.
Job satisfaction	The worker's morale and attitude were analyzed to infer the level of commitment that can be expected out of them at the work site.

2.2 Analysis of stakeholder responses

The responses collected were carefully screened and graded to arrive at meaningful conclusions from the data using the Relative Importance Index (RII) method. The varied responses in order to be collated into a single perspective were graded by assigning weights to the respondents. The weight was assigned for experience and the job role of the labourers.

2.3 Inferences from the questionnaire report

The data collected from the labours and contractors clearly showed a good demand in the job market for construction workers. Almost 75% of the labours surveyed indicated that they were employed for more than 15 days a month. Working overtime was also observed as a common practice with over 50% of construction workers indicating that they do overtime tasks as summarized in figure 1.

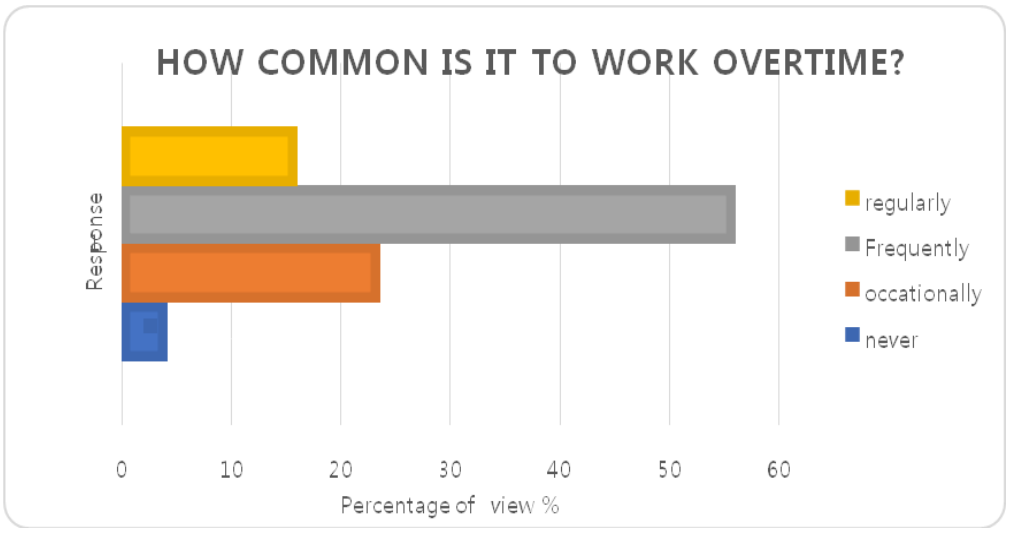

Fig. 1: Frequency of overtime work reported by construction workers

In order to gain better insight into what led to the overtime work, both labours and their supervisors were queried. The supervisors revealed that work allotment and time scheduling of projects were carried out only using experience and no systematic approach was in place. Similarly, workers also indicated that onus of allotted job completion was not fully vested on them and hence skipping deadlines did not have major implications on the workers. Therefore working overtime has almost been accepted as a normal process.

The workers were asked to rate their job difficulty for various commonly carried out activities to infer the physical exertion required at work and the results of difficulty level graded using RII method is as shown in Table 2.

Table 2: RII of activity difficulty level assessed by construction workers

Activity	RII
Earthwork excavation	0.945817
Transport of bricks	0.850455
Beam concreting	0.602081
Column concreting	0.595579
Brickwork (ground level)	0.574339
Roof concrete (first floor)	0.536628
Wall plastering (internal)	0.476376
Floor tiles laying	0.452969

The findings from these outcomes can help the contractors to proportionately give incentives to the workers based on difficulty experienced in performing the activity. The workers were also surveyed to understand what leads to breaching of deadlines at work and their responses are given in table 3.

Table 3: RII of activity delay contributing factors

Factor	RII
Rework	0.82358
Slow helpers	0.816645
Unreasonable work allotment	0.814911
Delay in work arrangement	0.785869
Unclear instructions	0.770264
Fatigue in work	0.657564
Material handling	0.563936

As seen from table 3, resource allocation issues and project planning errors had a major influence in the overall work productivity. The job satisfaction level experienced at the site were also ranked using RII as shown in table 4.

Table 4: RII of job satisfaction experienced by workers

Component	RII
Supervisor control	0.891634
Salary	0.806675
Job role	0.802341
Perks	0.632423
Rest and break	0.61205

3. NEURO-FUZZY BASED PRODUCTIVITY MANAGEMENT SYSTEM

The results of the questionnaire study have set an outline on what key factors needs to be controlled in order to improve the productivity at the site. Accordingly, the following core objectives were devised for developing a productivity monitoring framework.

Table 5: Defining the objectives of the proposed productivity enhancement framework

Problems identified using questionnaire	Action plan devised
Resource allocation issues	To develop a neural network that can predict the expected productivity and thereby recommend ideal workforce requirements
Project planning issues	To collect the site activity data autonomously and remotely and make it centralized for accessibility to all stakeholders.
Labour engagement and delay accountability issues	To monitor the cardio data of employees such as heart activity, a number of steps and calories burnt etc. and correlate it with their effort and performance. To adopt an outcome-based remuneration system to award employees based on their work out-turn following the carrot-stick managerial approach.

3.1 Framework developed for fulfilling the action plan

In order to offset the limitations identified in the current system of productivity measurement monitoring and control the framework is developed as an autonomous system that uses artificial intelligence to replicate the role of a real-time site supervisor. The outline of the framework is as shown in figure 2. Works involving video image processing and accelerometer-based worker idle time detection have been reported in the literature. This study extends those findings into a more comprehensive framework.

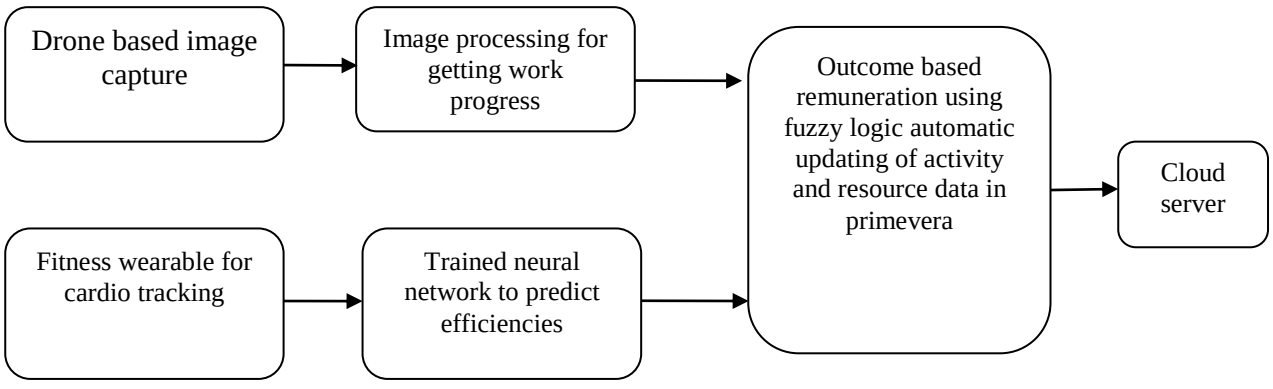

Fig. 2: Framework proposed for productivity enhancement in site

Drone or vehicle mounted cameras serve as the image acquisition system which forms the source for raw site data. Such drones shall be operated on a pre-programmed path around the construction site just like a site supervisor would go around a site. The images captured by these drones shall be centrally transmitted to a cloud platform for image processing. An image processing algorithm shall be developed to detect the type of activity and its extent of completion. The conceptual framework for image processing is as shown in figure 3.

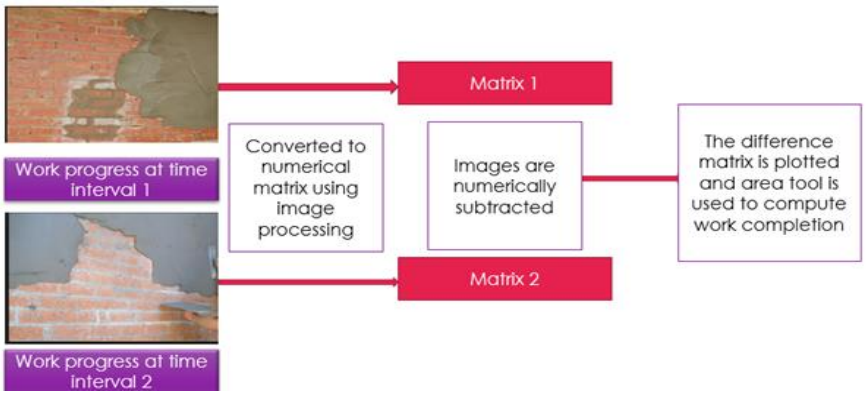

Fig. 3: Conceptual framework for image processing for activity progress tracking

An Artificially intelligent system based on image processing algorithm is developed to interpret site information as much as a site Engineer would do and the data is made centrally accessible in the cloud to all the project stakeholders.

In addition to capturing the overall work progress, the labour management framework will also include a module for promoting employee work accountability. Instead of considering the labours as mere resources they can be made tiny stakeholders to the project thereby ensuring more accountability and fairness of operations. In this context, an outcome based remuneration system is proposed as a paradigm change in labour management.

Each employee shall be fitted with a fitness tracking device. The cardio data measured from the employees can be used as a measure of physical exertion in work. These values when aggregated and meaningfully correlated can give a clear picture of employee work outturn and this, in turn, can be used to remunerate them in a more systematic way instead of fixed daily wages.

A vast data of labour performances monitored using reliable site supervisors have been used to develop a Neural Network that can correlate the cardio level of employees with his/her work efficiency. The input and output structure of the neural network is as shown in figure 4.

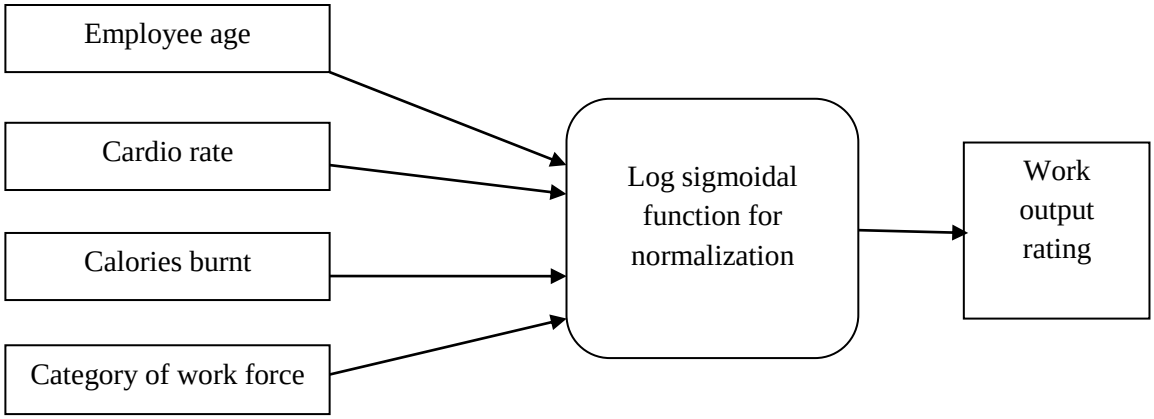

Fig. 4: Neural network for workforce engagement estimate

The data from the image processing algorithm indicating the percentage of work completed for a given time and the corresponding values of work output rating obtained using the fitness trackers are taken as fuzzy variables and a fuzzy logic based rule system is created to remunerate the employees for their performance as shown in figure 5.

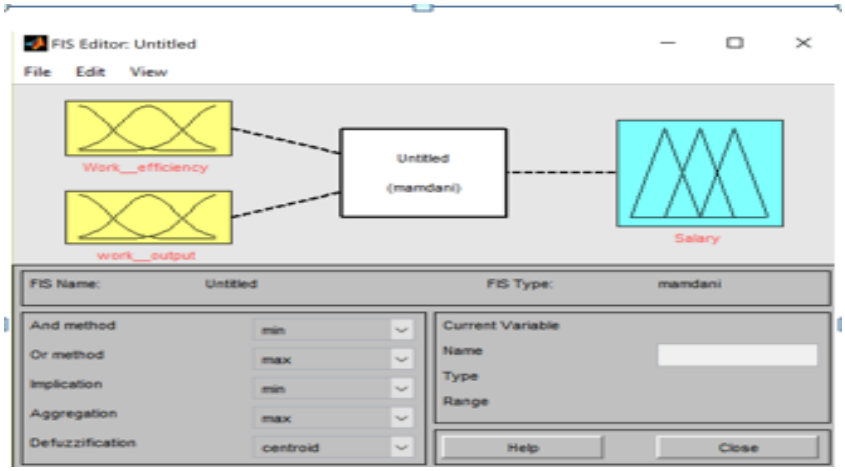

Fig. 5: Fuzzy logic-based decision support system for estimating labour productivity and remuneration

4. SUMMARY

This study is a pilot work to propose a framework for effectively allocating and utilizing the resources in construction sites for productivity enhancement.

- The parameters requiring attention for monitoring and controlling productivity were identified using a stakeholder survey.
- The findings indicated that non-adherence to a standardized system for resource allocation and lack of centralized coordination of work progress led to major deviations in work timelines. The lack of adequate standardization in measuring employee work progress further led to a decreased lack of accountability of the labours in keeping up a time commitment.
- The proposed framework addresses these shortcomings by autonomously tracking the project progress at the site. Image processing technique was adopted to capture the extent of work completion and fitness trackers deployed with the labours were used to identify their contribution and efforts towards the work accomplished.
- A neuro-fuzzy system was able to train itself on the expected work output from the employees based on the fitness tracker readings and fuzzy based rule system was adopted as a decision support tool for estimating the ideal remuneration of the labours based on their contribution to work.
- This framework if deployed can lead to more systematic allocation of resources and can extract more productivity from the labours as their contribution to work is accurately accounted and appraised.

Each employee shall be fitted with a fitness tracking device. The cardio data measured from the employees can be used as a measure of physical exertion in work. These values when aggregated and meaningfully correlated can give a clear picture of employee work outturn and this, in turn, can be used to remunerate them in a more systematic way instead of fixed daily wages.

A vast data of labour performances monitored using reliable site supervisors have been used to develop a Neural Network that can correlate the cardio level of employees with his/her work efficiency. The input and output structure of the neural network is as shown in figure 4.

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