An object recognition, tracking, and contextual reasoning-based video interpretation method for rapid productivity analysis of construction operations

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ABSTRACT

Measuring the process of construction operations for productivity improvement remains a difficult task for most construction companies due to the manual effort required in most activity measurement methods. This paper proposes and describes the elements, processes, and algorithms that comprise a computational and intelligent construction video interpretation method. A number of vision-based construction object recognition and tracking methods were evaluated to provide guidance for algorithm selection. A prototype system was developed to integrate the proposed video analysis processes and selected computer vision algorithms. Videos of construction operations were analyzed to validate the proposed method. Comparing to the traditional manual construction video analysis method, the proposed method provided a semi-automated video interpretation method. The new method enabled the interpretation of these videos into productivity information, such as working processes, cycle times, and delays, with an accuracy that was comparable to manual analysis, without the limitations of on-site human observation.

1. Introduction

In construction projects, daily site operations often suffer from inefficiencies caused by a variety of incidents such as interruptions and waiting [1]. Our recent analysis of craft time utilization based on the data from a long-term work sampling study indicated that only 45.5% of craft time is devoted to value-adding activities, and this percentage shows no sign of improvement over the last forty years [2]. Systematic measurement and analysis of construction operations constitute a foundational block of productivity improvement initiatives. To ensure the efficiency of construction processes, the waste, manifesting itself in the form of waiting, idle, excessive travel and transporting time, etc., has to be measured. Traditional methods, such as work sampling, time studies, activity rating, and crew balance chart, are effective means to measure the process of construction operations [3]. But, the significant manual efforts required in these methods often make them cost prohibitive for most contractors [4,5].

Recently, considerable research in the construction domain has been centered on information and sensing systems for automated onsite productivity data collection. These studies fall in two broad areas: (1) automated project progress tracking for measuring construction output [6–8]; and (2) automated resource utilization tracking for measuring construction input [9–12]. These studies demonstrated that it is now technologically feasible to gather a great volume and variety of ever-changing data during construction to support project managers on decision making. Also, these studies, by focusing on measuring either input or output quantities, have implicitly adopted the concept that construction production is a conversion process rather than a flow process. Recent studies have argued that the industry's excessive focus on the conversion model is not favorable for productivity improvement [13]. Therefore, two pertinent issues with automated productivity data collection are the potential overflow of low-level data or information that can place extra burden on project managers [14] and the lack of focus on the measurement of workflow in construction operations [13]. These issues present two major challenges to current sensor-based productivity data collection methods. First, the methods need to be intelligent at reasoning low-level data, such as sensor readings, into information relevant to productivity. The information can be time utilization, work sequences, and so on. Second, the methods should be capable of measuring key parameters about operation processes, such as working sequence and cycle time. To meet these challenges, intelligent sensor-enabled productivity data collection methods that can gather, process, and reason about productivity data in dynamic construction operation processes are of great need.

In this paper, we proposed and validated a computational method that can interpret construction videos into productivity information as an important step towards developing field deployable intelligent vision systems for autonomous productivity assessment. The following sections of this paper outline the background of this research,