THE MAXIMUM TIME INTERVAL OF TIME-LAPSE PHOTOGRAPHY FOR MONITORING CONSTRUCTION OPERATIONS

A Thesis

by

JI WON CHOI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2004

Major Subject: Construction Management

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Approved as to style and content by:

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ABSTRACT

The Maximum Time Interval of Time-Lapse Photography

for Monitoring Construction Operations. (August 2004)

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Dr. Nancy L. Holland

Many construction companies today utilize webcams on their jobsites to monitor and record construction operations. Jobsite monitoring is often limited to outdoor construction operations due to lack of mobility of wired webcams. A wireless webcam may help monitor indoor construction operations with enhanced mobility. The transfer time of sending a photograph from the wireless webcam, however, is slower than that of a wired webcam. It is expected that professionals may have to analyze indoor construction operations with longer interval time-lapse photographs if they want to use a wireless webcam. This research aimed to determine the maximum time interval for time-lapse photos that enables professionals to interpret construction operations and productivity.

In order to accomplish the research goal, brickwork of five different construction sites was videotaped. Various interval time-lapse photographs were generated from each video. Worker's activity in these photographs was examined and graded. The grades in one-second interval photographs were compared with the grades of the same in longer time interval photographs. Error rates in observing longer time-lapse photographs were then obtained and analyzed to find the maximum time interval of time-lapse photography for monitoring construction operations.

Research has discovered that the observation error rate increased rapidly until the 60-second interval and its increasing ratio remained constant. This finding can be used to predict a reasonable amount of error rate when observing time-lapse photographs less than 60-second interval. The observation error rate with longer than 60-second interval did not show a constant trend. Thus, the 60-second interval could be considered as the maximum time interval for professionals to interpret construction operations and productivity.

DEDICATION

To God the Almighty the Heavenly Father who has given me the Knowledge to do this and showed me so much Love. All Glory be to God on High.

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First of all, I would like to thank God, my Lord and Savior, for giving me Knowledge, Strength, and Perseverance in my studies. Without Him none of this would be possible.

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CHAPTER I

INTRODUCTION

1.1 Introduction

1.1.1 Background

A web-based camera (referred to as a webcam) is one of the new tools used to monitor construction operations at a jobsite. Use of the webcam is expected to enhance site monitoring, which may result in better project control (McCormack 2002). The use of webcams for site operation monitoring, therefore, is expected to increase. In most cases, webcams are located on the outside of a building, thus occasionally the view of the camera is blocked as the project develops (Everett, Halkali, and Schlaff 1998). In addition, webcams are usually connected with web servers through cables that limit the mobility of the webcams. Considering that more than 50% of construction operations are implemented inside a building and the interior activities are dynamic, wired webcams can hardly be utilized for monitoring interior construction operations. Limited mobility, therefore, makes it difficult to use wired webcams for monitoring interior construction operations.

New attempts have been made to avoid wiring cables on a congested jobsite by using wireless technology. Recently two new wireless technologies, IEEE 802.11b and CDPD (Cellular Digital Packet Data), were introduced to the construction industry. If a webcam uses the IEEE 802.11b technology, it can transmit images to the server at a

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speed of 11 megabytes per second. However, a webcam using the IEEE 802.11b technology must be located within a specified distance from an access point connected to a host computer on site by a wired connection. Wiring to an access point may still be cumbersome. A webcam with the CDPD technology can be used on any site where cellular phone service is available. No previous network setup and special education for site personnel are necessary.

1.1.2 Problem

The CDPD technology based wireless webcam (referred to as a cellular-webcam) is expected to help professionals enhance their ability to monitor interior construction operations or operations in an area congested by many obstacles. The CDPD technology is believed to provide a raw data rate of up to 19.2Kbps (CDPD Technology Overview 2001). However, because some of this capacity is used for error correction and system overhead, the actual data rate is in the range of 10 to 15Kbps, which transmits a 450Kb (medium quality one mega pixel) photograph at least for 30 to 45 seconds. Is it possible for construction professionals to use this interval for monitoring construction operations? What interval of time-lapse photos would satisfy construction professionals' expectations? The investigation of an appropriate interval of time-lapse photos to monitor construction operations may provide us some answers to these questions.

1.2 Problem Statement

To what extent can the frame rate of a webcam be lowered for monitoring construction operations at a jobsite?

1.3 Objectives

The primary goal of this research is to determine the maximum time interval for time-lapse photos that enables professionals to optimally interpret construction operations and productivity.

1.4 Hypothesis

The error in interpreting construction operations using time-lapse photography will be affected by increasing the interval between the time-lapse photographs.

1.5 Definition of Terms

Access point:

A device that transports data between a wireless network and a wired network infrastructure

Bandwidth:

The range of frequencies, expressed in Kilobits per second, that can pass over a given data transmission channel within a frame relay network. The bandwidth determines the rate at which information can be sent through a channel - the greater the bandwidth, the more information can be sent in a given amount of time.

CDPD:

Short for Cellular Digital Packet Data - a data transmission technology developed for use on cellular phone frequencies. CDPD uses unused cellular channels (in the 800- to 900-MHz range) to transmit data in packets. This technology offers data transfer rates of up to 19.2 Kbps, quicker call set up, and better error correction than using modems on an analog cellular channel.

IEEE 802.11b:

The first industry standard specification for wireless networks operating in the 2.4 GHz frequency spectrum. It enables devices to link to a network at speeds of up to 11Mb per second.

Real time:

A transmission or transaction that occurs immediately or in an extremely short period of time. A telephone conversation occurs in real time - correspondence through mail does not.

Real-time recording:

The actual passage of time. Any event that occurs in real time indicates that the event is happening as we would see it - in actual time. Recording video in real time would require approximately 30 frames per second.

Time-lapse photography:

A cinematic technique defined as taking moving pictures at any rate slower than 24 frames per second.

Webcam:

A digital camera designed to take digital photographs and transmit them over the Internet.

1.6 Limitations

This research is limited to outer-wall bricklaying on residential construction sites in the Bryan/College Station area. Instead of using a webcam, a video camera was used to generate time-lapse photos of jobsites. Because the maximum recording time of a normal digital video tape is one hour, the length of videotaping time is limited to one hour.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

A review of related literature has been performed to establish a body of knowledge with regard to the recording and monitoring of construction activities. This review includes the following subjects: a description of the trend of recording construction activities, use of webcams, time-lapse photography, cameras and locations, and the use of wireless technology in recording construction activities.

2.2 Recording Construction Operations

2.2.1 The Beginning of Recording Construction Operations

Recording construction activities or projects using a camera was performed for the first time in the early 1900's. In 1902, Frank Gilbreth (1868~1924), who was a bricklayer, a building contractor, and a management engineer, photographed the progress of work on the Augustus Lowell Laboratory of Electrical Engineering for the Massachusetts Institute of Technology. He used these photographs in order to explain the detail work procedure of the project in his book, "Bricklaying System" (Gilbreth 1909). Surprisingly, there was virtually no difference between today and 100 years before in using photographs for a construction project.

He was interested in standardization and method study. As a bricklayer, he observed bricklayers and found individuals did not always use the same motions in the course of their work (Gilbreth 1909). After the motion study of bricklayers, he developed many improvements in bricklaying and explained those improvements with specific photographs in “Bricklaying System”. Frank and Lillian Gilbreth continued their motion study and analysis in other fields and pioneered in the use of motion pictures for studying worker activities. They broke down a work into fundamental elements and studied by means of a movie camera and a timing film that indicates time interval on it. This study was to find the shortest path of body movement or to remove waste motions (Gilbreth F. and Gilbreth L. 1973). Although their study was limited to short time movement of a worker, applying their method to investigate long time movement of workers could be possible.

2.2.1 The Purpose of Recording Construction Operations

Since early 1900’s, construction professionals have used construction photographs or movies for documentation and analysis of construction activities (Everett, Halkali, and Schlaff 1998). To be more specific, time-lapse film and time-lapse video have both been used mainly for productivity analysis and for the improvement of construction operations (Oglesby, Parker, and Howell 1989). The motion study of bricklayers by Gilbreth is a good example.

Through experience gained and experimentation performed in the 90’s, Everett et al. (1998) found that time-lapse video could be of significant benefit in documenting actual project progress, in resolving claims and disputes, for providing education, and in public relations, fund raising, and media applications. It could be used to provide project managers with a live image of remote projects, as well. As has been noted, the use of construction activity recordings has diversified over time.

2.3 Webcams

According to Soldatini, Mähönen, Saaranen, and Regazzoni (2000), the video camera systems that include webcams have started to substitute for Closed Circuit Television (referred to as CCTV) systems. Thus, the function of webcams and CCTV systems will be identified in this review of literature.

2.3.1 Conventional Use of Webcams

The most common purpose of using webcams or CCTV systems today is to keep surveillance on people and objects. In New York City, for instance, there are more than two thousand private surveillance cameras taping citizens in public (Staples 2000). Likewise, in the UK, many cities applied CCTV systems to create safe, secure, and attractive places for consumption, entertainment, and tourism (Lyon 2001).

Due to the development of technology in 1992, the CCTV systems were applied to traffic surveillance systems for the first time (Moran 1998). Since then, the use of CCTV systems has been diversified. The cameras, today, not only provide views, but also perceive objects, and, therefore, some traffic cameras can monitor the speed and detect speeding cars (Norris and Armstrong 1998). Besides, some more advanced cameras can observe a moving object without missing it wherever it goes, constantly monitoring sites (Kumar 2002).

However, the most significant changes of using these cameras happened after a video camera was connected to the Internet in 1991 to check the level of coffee in Trojan Room coffee pot (Stafford-Fraser 1995). The examples below show the diversity of using webcams.

Buckman Elementary School, Room 100, Portland, Oregon

Bus stop, wilshire Boulevard, Beverly Hills, California

Cambridge panorama, Cambridge, UK

Kessell's Webcam, shots of a car dealership in cornwall, England

Hauptbahnof train/bus terminal, Berlin, Germany

NASA Cams and Mission Displays from Kennedy Space Center

SBT Accounting Systems, visitors' lobby, San Rafael, California

Street corner (9th & Pearl), Boulder, Colorado (Staples 2000)

2.3.2 Current Issues of Using Webcams

There are two major issues, privacy and technology, in using webcams. The privacy issue is one of the most common issues. Although a CCTV system has played an important role in reducing crime rates, people have begun to worry about being monitored by someone. For instance, a survey regarding surveillance on people by cameras was performed and the extent of concern was highlighted by the outcome that 72 per cent agreed the use of these cameras could easily be abused and used by the wrong people; 39 per cent felt that people who are in control of these systems could not be completely trusted to use them only for the public good; 37 per cent felt that in the future, cameras will be used by the government to control people (Davies 1998). Finally, the concern about privacy was expressed as a form of citizen action, throwing blankets over cameras, in London 1995 (Davies 1998).

Ironically, the other issue is how to enhance the surveillance ability of cameras. Recently, many researches concerning technical matters of camera systems have been done. These are, for instance, detecting and tracking humans and other moving objects automatically in complex scenes and setting up various sensors in the systems, in order to counteract the limitation of monitoring by humans. It is clear that the financial cost associated with human monitoring of webcams or CCTV is already considerable and continues to grow. Here is a good example, “The Glasgow system, for example, has 12 screens displaying images from 32 cameras watched by only two operatives. These 32 cameras produce 768 hours of tape per day” (Norris et al. 1998). This kind of situation is common today and, therefore, to promote efficiency, automatic surveillance systems that are operated by sensors are highly requested.

2.3.3 Use of Webcams in Other Industries

2.3.3.1 Public Use of Webcam

The public use of webcams is almost like the conventional use of webcams or CCTV systems. First, government uses webcams for surveillance on people or objects on a public area in order to prevent crimes. Second, webcams are used for monitoring weather conditions. Third, webcams are used for monitoring traffic conditions.

2.3.3.2 Private Use of Webcam

The private use of webcams is related to business activities. One of the good examples is that about 80%of all webcams are used in the sex industry (Timothy and Gloves 2001). Other than this industry, the industries that most actively use webcams are the construction industry and the tourism industry. The tourism industry uses webcams to show the view of tourist attractions to the potential customers (Timothy and Gloves 2001). Webcams are also used in the retail industry mainly for surveillance on customers.

Recently, day care centers have begun to use webcams giving parents to view their children from wherever the Internet is accessible. Besides, there are some people who want show what they are doing and sometimes even their private lives on the Internet by using a webcam.

2.3.4 Use of Webcams in the Construction Industry

Unfortunately, due to the lack of study in this area, it was not easy to find books or articles that are directly related to the use of webcams in the construction industry. As noted above, webcams had been used for many purposes in various places but it took times to use them on construction sites, because the construction industry was too conservative to accept new technologies. However the advance in information technology and the availability of construction management related software have brought many changes in this industry (Deng, Li, Tam, Shen, and Love 2001). In 1996, the first webcam was available on the market (What is a Network Camera 2002). At first construction professionals conjectured the potential usefulness of webcams but could not go beyond that boundary due to some technical problems such as difficulty of getting high-speed network connection on site. After couple of years, the use of webcams on site began to increase.

Following is a good example of using a webcam in the construction industry. "Construction workers at the WorldCom Corporation headquarters that was being built in Kansas City were monitored by a video camera mounted on poles overlooking the construction site. Here the project manager could zoom in on any worker or any place. Every hour, a picture is taken from the video and posted on the company internal

Intranet allowing thousands of employees to check construction progress regularly". (Staple 2000)

2.4 Time-Lapse Photography

2.4.1 Recording Methods

There are two major methods of recording construction activities using either time-lapse or real-time recordings. Although the real-time recording of a project provides a thorough recording of the entire process, the major disadvantage is that the time required to view the film or video is equal to the time required to perform the original operation (Abeid and Arditi 2002). On the other hand, time-lapse recording has the advantage of greatly reducing the amount of time spent viewing, while allowing viewers the opportunity to accurately interpret various construction operations (Everett et al. 1998). Consequently, time-lapse recording techniques have been used in many cases for recording construction activities.

2.4.2 Time-lapse Interval

At this point, one might ask what time-lapse interval would be appropriate for recording construction activities. Abeid and Arditi (2002) have investigated the appropriate time-lapse interval for efficient handling of construction management issues such as delays, accidents, and claims. They videotaped activities on a small bridge construction site, and then generated clips (each of which had a different time-lapse interval) from the video. Analyzing worker movement in each clip, they determined that the predicted man-hours for the activity of placing form-panels could best be reviewed at less than a 10-second interval, and accidents required less than a 4-second interval to be accurately recorded. Overall, one-second intervals between frames was found to be the most appropriate frame rate for multipurpose use when recording construction operations (Abeid and Arditi 2002).

However, there is room to reconsider this suggestion, since the researchers mentioned that a time-lapse interval should be less than a few seconds in order to accurately record the moment of an accident that usually occurs within a few seconds. Generally, if there is an accident, it will be reported immediately. Therefore, it is reasonable to record activities with one-second intervals and then store the video temporarily for a number of days. As long as no accident is reported during that set number of days, it is wise to restore the video with an interval much longer than one-second. Converting one-second interval time-lapse photograph into longer time-lapse interval photograph may help construction professionals save time in reviewing construction operations.

2.5 Cameras and Locations

2.5.1 Cameras

Thus far, three types of cameras have been used to record construction activities. The oldest is the movie camera, which was used to record construction activities in the past. Once video cameras became less expensive and easier to operate than movie cameras, they replaced movie cameras (Everett et al. 1998). Recently, most construction companies have turned to webcams rather than video cameras for recording activities, because webcams provide construction professionals not only with a record of work, but also with real time visual information from the site through the Internet (McCormack 2002).

2.5.2 Camera with Features

Some webcams come with advanced features such as panning, tilting and zooming functions, all of which can be controlled remotely through the Internet. With the use of these functions now available, the monitoring of construction activities is enhanced (Everett et al. 1998). However, not all of these added features for webcams are needed because merely pointing a camera in the same direction at all times is the essential function for recording specific activities. On the other hand, if the camera motion is programmed to take pictures of a certain angle at a certain time interval, it could substitute for several fixed cameras providing time-lapse pictures from several different views.

2.5.3 Location

The location of a camera should be carefully considered, especially at the beginning of a construction project. Everett et al. (1998) stated, “in the early stages of most building projects, the entire site and all of the work can be seen from one location. As the project develops, the building itself may obstruct the view of the side(s) away from the camera.” Since this situation could happen frequently, the placing of multiple cameras is worth considering, especially for very large or complex projects (Everett et al. 1998).

2.6 Wireless Technology

Occasionally, there are still sites where cabling is not possible or phone lines are not available (McComick 2002). In those cases, using wireless cameras should be considered. In addition, there is frequently a problem with recording interior work after a building's envelope has been installed (Everett et al. 1998). Since most webcams currently being used on sites are wired webcams and most interior work moves quickly from place to place, wiring through ceilings, walls, and from floor to floor proves difficult. Following are currently available wireless technologies that could be used on construction sites.

2.6.1 IEEE 802.11 Technology

Regarding an IEEE 802.11b network, several wireless webcams are already available on the market today. The advantage of using this technology is the following: it is relatively inexpensive and has a high-speed data transfer rate (up to 11 Megabytes, depending on the distance from an access point) (Wireless 2.4GHz Internet Camera 2002). On the other hand, there are some disadvantages such as a limited operations range and the necessity of setting up a wireless network on site. In order to use the IEEE 802.11b network, the use of access points is indispensable, and the distance between a camera and an access point should be less than 300 feet, with no intervening obstacles, for stable communication. However, ordinary site conditions are not favorable for using this network due to numerous obstacles such as walls and steel structures. Furthermore, establishing a wireless network on a jobsite requires setting up access points on the site.

This means wiring from a host computer to each access point should be carried out—a situation unfit for most jobsites, as mentioned in the introduction.

Besides, there are 802.11a and 802.11g technologies. Although the data transfer rate of 802.11a technology is much higher (up to 54 Megabytes) than that of 802.11b, the operation range of 802.11a is at least 60 feet, which is one fifth of the operation range of 802.11b technology (Geier 2002). Thus the use of 802.11a technology for a wireless webcam is incongruent due to the small operation range. On the other hand, 802.11g technology has advantages of each 802.11a and 802.11b technologies having the same data transfer rate as 802.11a and the same operation range as 802.11b technology (Marks 2003). Despite of the superior data transfer rate, the limited operation range of the 802.11g technology is still not favorable to use on a construction site.

2.6.2 CDPD (Cellular Digital Packet Data) Technology

CDPD technology is similar to using a cell phone camera that takes photos at regular intervals and sends those photos continuously to a webserver. This camera is also currently available on the market. There are two major advantages to using this technology. First, there is no limited range to monitoring construction sites with this camera. Secondly, there is no need to establish a wireless network on site. These two merits should offer construction professionals substantial flexibility in recording and monitoring activities. However, there is a bandwidth issue to be solved. Because CDPD technology offers only a raw bit rate of 19.2 Kbps (CDPD Technology Overview 2001), the quality of image must be lowered or the time-lapse interval lengthened for greater image clarity.

2.7 Summary

As construction professionals become aware of the importance of recording construction activities, more construction movies will be made adopting this time-lapse technique. To record and monitor activities in further detail, the use of wireless cameras will increase. Although the bandwidth of CDPD technology is much smaller than IEEE 802.11b technology, CDPD technology seems to be more practical and easy to use than IEEE 802.11b. To use CDPD technology for recording and monitoring construction activities, researchers must investigate how low the rate of time-lapse photos can be to properly analyze productivity at a job site.

CHAPTER III

METHODOLOGY

3.1 Introduction

To achieve the research goal, brickwork on five different construction sites were videotaped. Because human subjects were used in this research, IRB approval was obtained before videotaping. Nine different intervals for time-lapse photography (excluding one-second interval) were chosen. Each worker in a photograph was examined and graded according to predefined guidelines. The grade of a worker at every second in one-second interval photo set was compared to the grade of the same worker in other interval photo sets. Nine observation error rates per worker were obtained from the comparison of grades. Finally the observation error rate lines of workers were drawn and analyzed.

3.2 Videotaping Construction Sites

3.2.1 Operations to be monitored

Five residential construction sites in the Bryan/College Station area were selected for this research. Outer-wall brickwork was chosen because the operation was relatively simple and the workflow was easy to understand. To find residential construction sites where bricklayer works were being performed, homebuilders in the Bryan/College Station area were contacted. The size of the projects was limited to one story, single-family home building sites.

3.2.2 Videotaping

A digital video camera was used to videotape the operation. The camera was set up at a location where the majority of bricklayers could be monitored. The distance between the workplace and the camera was at least 50 feet in order to not disturb the work. The camera lens was kept at a height of 5 to10 feet above the working level. Each bricklaying work site was videotaped for one hour.

3.3 Analysis of Time-Lapse Photos

3.3.1 Making Time-Lapse Photos

3.3.1.1 Equipment & Software

A desktop computer equipped with a Pentium IV processor of 2.53GHz, 512 megabytes of RAM, 80 gigabytes of hard drive, an IEEE 1394 video capture card, and an IEEE 1394 6-pin to 4-pin cable were used for this research.

3.3.1.2 Making Time-Lapse Photos

The Adobe Premiere 6.0 video editing program was used to make the time-lapse photos. One-second interval time-lapse photo set, which has a total of 3600 photos, was created as a control template for this research.

3.3.1.3 Intervals for Time-Lapse Photograph

In order to compare the differences in monitoring construction operations at different intervals, potential intervals that construction professionals may want to use in monitoring their projects were considered. Nine intervals: 3, 5, 10, 30, 40, 60, 180, 300, and 600-second were selected and divided into three groups: short, mid, and long. The short interval group consisted of 3, 5 and 10-second; the mid interval group consisted of 30, 40, and 60-second; the long interval group consisted of 3, 5, and 10-minute.

3.3.2 Analyzing Time-Lapse Photos

3.3.2.1 Classifying Sites and Workers

To classify each worker, a symbol was assigned to each worker. The symbol was an alphanumeric designation indicating a site and a role in the brickwork. Five residential construction sites were classified as A, B, C, D, and E and workers on them classified as bricklayers (initialed as “B”) or helpers (initialed as “H”). For instance, worker A-B2 is the second bricklayer at site-A and C-H1 is the first helper at site-C.

3.3.2.2 Classifying Worker Activities

Worker activity in each time-lapse photo was examined and classified into three categories: effective work, contributory work, and ineffective work according to pre-defined guidelines (Oglesby et al. 1989). The guidelines were as follows:

Effective work:

- The actual process of adding to the unit being constructed.
    1. Measuring, laying out bricks.
    2. Carrying or holding bricks or mortar.
    3. Setting up or dismantling a scaffold

Contributory work:

- Work not directly adding to, but (through associated processes) essential to finishing the unit.
    1. Discussing the work

2. Giving or receiving instruction
3. Reading plans.

Ineffective work:

- Doing nothing or doing something that is in no way necessary to complete the end product.
  1. Talking while not actively working.
  2. Walking around empty-handed.
  3. Unable to find the worker in the frame.

3.3.3 Observation and Grading

In each photo, there were generally three or four workers visible and each worker was examined individually. If a worker was defined as doing effective work in the photo, the worker would be assigned a grade of two for that time-frame. For contributory work, the grade would be one. For ineffective work, the worker would be graded zero. Additionally, if a rework occurred, the worker involved in the rework (including demolition) would be assigned a grade of three. In this research, two different methods of observation, full-observation and partial-observation were used.

3.3.3.1 Full-Observation

The full-observation method is observing and grading all workers in nine different interval photo sets. First of all, to perform the full-observation method, it is necessary to make nine interval photo sets out of one-second interval photo set. In order to make nine different interval photo sets, specific photographs (including the 1^{st} photograph) from one-second interval photo set were collected. For instance, in order to make 5-second interval photo set, the 1st, the 6th, the 11th… and the 3596th photographs (a total of 720 photographs) were collected from one-second interval photo set.

The numbers of photos in each interval photo set were as follows.

1-second interval photo set (3,600 photos)

3-second interval photo set (1,200 photos)

5-second interval photo set (720 photos)

10-second interval photo set (360 photos)

30-second interval photo set (120 photos)

40-second interval photo set (90 photos)

60-second interval photo set (60 photos)

3-minute (180-second) interval photo set (20 photos)

5-minute (300-second) interval photo set (12 photos)

10-minute (600-second) interval photo set (6 photos)

Full-observation was implemented by observing and grading all workers in every photo of ten different interval photo sets. All 10 different interval photo sets of sites A, D, and E, were observed in order from the 10-minute interval photo set to the 1-second interval photo set. By observing in descending order from the 10-minute interval photo set, the observer limits bias in grading because the observer does not know what happened in previous frames. However, if the observer grades in ascending order from the 1-second interval photo set, he/she may be biased in grading the next interval photo set because the observer would already know what had happened and he/she would grade based on knowledge rather than inspection.

3.3.3.2 Partial-Observation

The partial-observation method is observing and grading all workers only in the 1-second interval photo set. Based on grades assigned in the 1-second interval photo set, grades for the workers in nine different interval photo sets were given. In detail, after the observation of the 1-second interval photo set, each worker was graded per one-second time-frame. The same worker in the other interval photo sets automatically had his/her own grade from the predefined grade. Figure 1 shows how a worker in 5-second and 10-second interval photo sets was given a grade from the 1-second interval photo set.

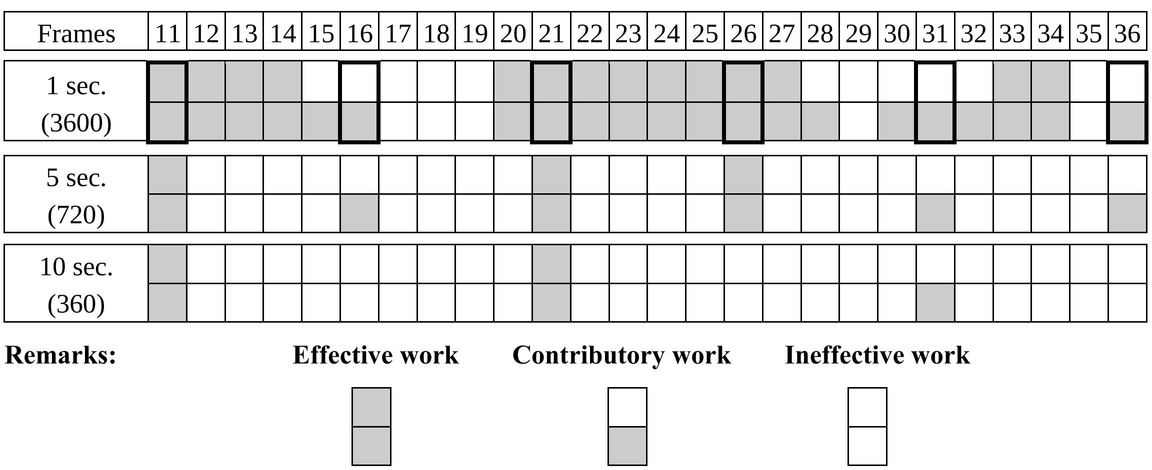

Fig. 1. Obtaining grades from the one-second interval photo set

3.3.4 Observation Errors

Observation error is the difference between evaluation of the activities of a worker at the 1-second interval photo set and other photo sets. The basic method for obtaining observation error is comparing each frame grade of a worker in the 1-second interval photo set with the same frame grade of the worker in different photo set.

3.3.4.1 Distributing Grades for Comparison

However, the numbers of grades for a worker in other interval photo sets are less than 3600. For example, the 5-second interval photo set has 720 grades specifically at the 1, 6, 11, ··· 3586, 3591, and 3596 frames. To compare this with the one-second interval photo set, 3600 grades should be inferred from 720 grades. A grade in the 5-second interval photo set should cover five frames, assuming that once the worker is assigned a certain grade at a frame, the grade will remain the same before and after two frames. Figure 2 shows a grade of “1” at the 16th frame in the 5-second interval photo set, and this grade will be distributed to five frames-- the 14th to the 18th frames. In this manner, all interval photo sets contained 3600 grades.

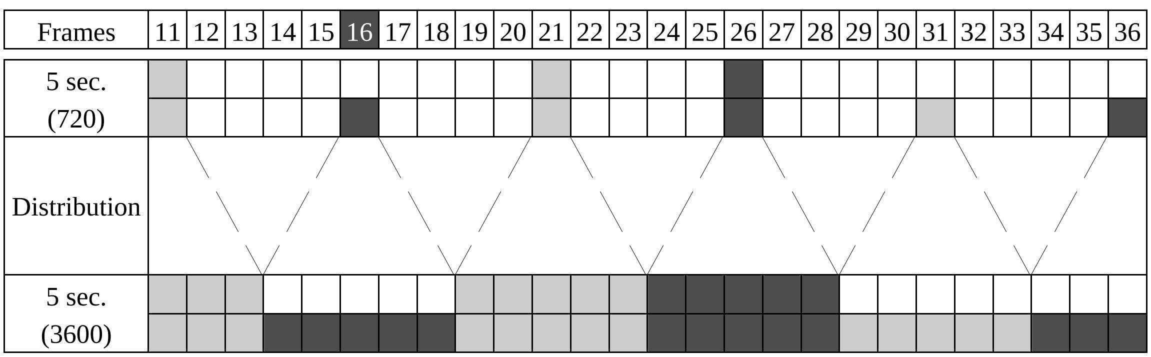

Fig. 2. Distributing grades

3.3.4.2 Calculating Observation Error Rates

The next step compared all 3600 frames of the one second interval photo set with other interval photo sets one by one; if both grades were the same at a frame then the frame was marked 0, and if both grades were different at a frame, marked 1. The sum of marked numbers (errors) divided by 3600 frames represented the observation error rate of the worker. The same routine was continued with other workers. Figure 3 shows the observation errors at the 5-second interval. After that one observation error rates table per jobsite was made.

Frames	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 sec.																										
Comparison	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕
5 sec.																										
Same (S) or Different (D)	S	S	S	D	S	S	D	D	D	S	S	S	S	S	S	S	S	D	D	S	S	S	D	D	D	S
Error	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	0

Fig. 3. Finding observation error

Table 1 shows a sample observation error rates table for a site. From the figure 3, for instance, suppose the error rate of the worker at 5-second interval is 34.62%, which is 9 errors divided by total 26 frames. This error rate is highlighted on the sample observation error rates table below. The others are arbitrary error rates.

Table 1. Sample observation error rates table for a site

Items	3 sec.	5 sec.	10 sec.	30 sec.	40 sec.	60 sec	3 min.	5 min.	10 min.
Worker	10.00%	34.62%	25.00%	35.00%	40.00%	50.00%	55.00%	50.00%	60.00%
-	- %	- %	- %	- %	- %	- %	- %	- %	- %
-	- %	- %	- %	- %	- %	- %	- %	- %	- %

3.3.5 Developing Graphs

According to the observation error rates on an error rates table, the graphs of observation error rates were drawn. The graphs showed observation error rates from 0 % to 100 % on the Y-axis and time-frames from 0 second to 600 seconds on the X-axis. Each worker had his/her own error-rate line. One line contained 10 error-rates, each of which corresponds to certain intervals. Figure 4 shows a sample graph of observation error rates of the worker on the table 1.

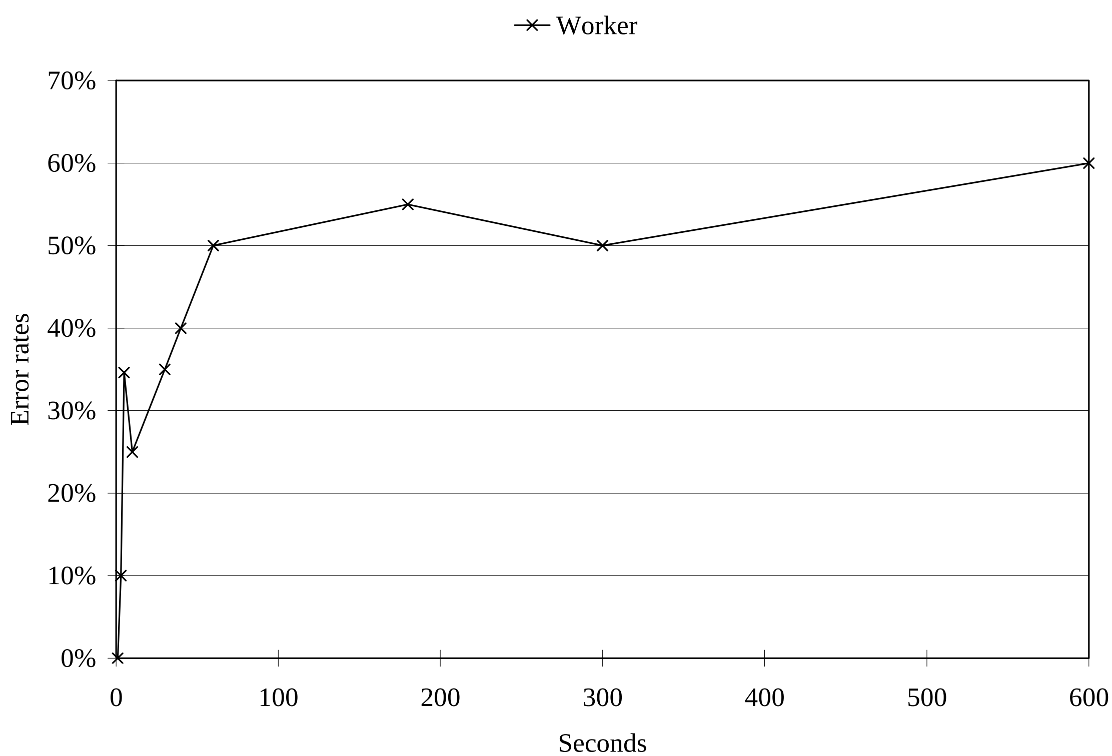

Fig. 4. Sample graph of observation error rates

CHAPTER IV

RESULTS

4.1 Introduction

Error-rates of observing outer-wall brickworks were obtained, with the error-rates increasing as the time interval lengthened. Therefore, the hypothesis was supported by the results. Observation error rates by full-observation were obtained from sites A, D, and E, while observation error rates by partial-observation were obtained from all sites.

4.2 Error Rates by Full-Observation

Three sites--site-A, site-D, and site-E--were selected for full-observation (the other two sites were excluded because worker activities were already observed while recording the sites). As specified in the methodology, all 10 different interval photo sets of each site were observed by the researcher in order from the 10-minute interval photo set to the 1-second interval photo set. Finally, observation error rates were obtained.

4.2.1 Observation Error Rates of Site-A

There were three workers, two bricklayers and one helper. Table 2 shows observation error rates of each worker in each time interval.

Table 2. Observation error rates of site-A from full-observation

Items	3 sec.	5 sec.	10 sec.	30 sec.	40 sec.	60 sec	3 min.	5 min.	10 min.
A-B1	6.92%	11.67%	13.36%	22.11%	28.61%	30.72%	40.44%	59.36%	71.42%
A-B2	11.06%	22.72%	19.17%	25.61%	28.69%	37.44%	44.31%	57.28%	69.47%
A-H1	3.86%	7.19%	8.92%	15.50%	21.67%	22.75%	28.31%	53.61%	58.92%

4.2.2 Observation Error Rates of Site-D

Among several workers, two bricklayers and one helper were observed. Table 3 shows observation error rates of each worker in each time interval.

Table 3. Observation error rates of site-D from full-observation

Items	3 sec.	5 sec.	10 sec.	30 sec.	40 sec.	60 sec	3 min.	5 min.	10 min.
D-B1	12.75%	14.58%	18.14%	22.36%	26.69%	30.61%	34.72%	39.72%	40.39%
D-B2	9.33%	9.86%	14.81%	15.92%	12.86%	14.78%	28.47%	10.17%	11.08%
D-H1	12.81%	14.81%	21.78%	29.11%	30.64%	33.03%	32.78%	44.92%	51.44%

4.2.3 Observation Error Rates of Site-E

Among several workers, two bricklayers and two helpers were observed. Table 4 shows observation error rates of each worker in each time interval.

Table 4. Observation error rates of site-E from full-observation

Items	3 sec.	5 sec.	10 sec.	30 sec.	40 sec.	60 sec	3 min.	5 min.	10 min.
E-B1	10.42%	11.47%	13.08%	17.00%	18.78%	18.75%	32.50%	47.03%	49.67%
E-B2	5.36%	6.58%	12.14%	16.19%	12.69%	30.17%	27.97%	44.81%	35.97%
E-H1	6.83%	12.08%	16.28%	19.92%	31.33%	25.22%	30.50%	39.64%	20.81%
E-H2	7.78%	10.92%	10.89%	31.06%	29.86%	29.81%	36.39%	40.61%	43.17%

4.3 Error-rates by Partial-Observation

Observation error rates by partial-observation were obtained from all sites by observing and grading all workers in the 1-second interval photo set. Based on the grades of workers in the 1-second interval photo set, the grade of the worker in other interval photo sets was given as specified in the methodology. Observation error rates of each worker were obtained using the same method that was used for obtaining the full-observation error rates.

4.3.1 Observation Error Rates of Site-A

There were three workers, two bricklayers and one helper. Table 5 shows observation error rates of each worker in each time interval.

Table 5. Observation error rates of site-A from partial-observation

Items	3 sec.	5 sec.	10 sec.	30 sec.	40 sec.	60 sec	3 min.	5 min.	10 min.
A-B1	1.61%	3.17%	6.25%	13.44%	17.78%	20.17%	40.03%	50.28%	50.94%
A-B2	1.25%	2.17%	4.64%	9.64%	12.61%	20.14%	26.94%	39.31%	35.17%
A-H1	1.75%	2.83%	5.50%	10.83%	12.47%	21.86%	25.33%	43.75%	53.89%

4.3.2 Observation error rates of Site-B

There were three workers, two bricklayers and one helper. Table 6 shows observation error rates of each worker in each time interval.

Table 6. Observation error rates of site-B from partial-observation

Items	3 sec.	5 sec.	10 sec.	30 sec.	40 sec.	60 sec	3 min.	5 min.	10 min.
B-B1	0.86%	1.50%	2.78%	7.94%	9.58%	13.67%	16.39%	20.47%	31.58%
B-B2	0.72%	1.11%	2.33%	6.11%	8.14%	11.53%	20.17%	23.81%	26.56%
B-H1	1.22%	2.08%	3.72%	9.19%	10.72%	15.58%	20.17%	21.61%	35.19%

4.3.3 Observation error rates of Site-C

Among several workers, three bricklayers and one helper were observed. Table 7 shows observation error rates of each worker in each time interval.

Table 7. Observation error rates of site-C from partial-observation

Items	3 sec.	5 sec.	10 sec.	30 sec.	40 sec.	60 sec	3 min.	5 min.	10 min.
C-B1	0.89%	1.50%	3.92%	9.86%	10.42%	16.89%	23.36%	31.14%	21.44%
C-B2	2.61%	4.36%	9.03%	18.97%	18.97%	26.47%	30.31%	31.39%	46.42%
C-B3	2.67%	4.39%	7.47%	15.22%	16.83%	18.67%	29.19%	31.67%	28.17%
C-H1	5.92%	9.50%	17.22%	29.67%	33.92%	34.61%	35.58%	44.67%	53.17%

4.3.4 Observation error rates of Site-D

Among several workers, two bricklayers and one helper observed. Table 8 shows observation error rates of each worker in each time interval.

Table 8. Observation error rates of site-D from partial-observation

Items	3 sec.	5 sec.	10 sec.	30 sec.	40 sec.	60 sec	3 min.	5 min.	10 min.
D-B1	1.56%	2.42%	5.64%	12.50%	14.58%	17.42%	26.83%	26.69%	33.06%
D-B2	0.50%	0.86%	2.11%	5.19%	6.36%	9.06%	15.42%	9.19%	11.08%
D-H1	3.06%	5.72%	9.64%	18.67%	20.58%	24.14%	31.69%	41.17%	41.28%

4.3.5 Observation error rates of Site-E

Among several workers, two bricklayers and two helpers were observed. Table 9 shows observation error rates of each worker in each time interval.

Table 9. Observation error rates of site-E from partial-observation

Items	3 sec.	5 sec.	10 sec.	30 sec.	40 sec.	60 sec	3 min.	5 min.	10 min.
E-B1	1.28%	2.50%	5.19%	9.47%	13.67%	14.00%	25.58%	31.67%	34.00%
E-B2	0.39%	0.67%	1.28%	4.11%	4.83%	7.58%	14.11%	19.83%	16.08%
E-H1	1.22%	2.39%	4.97%	9.89%	15.19%	13.97%	20.67%	21.06%	21.92%
E-H2	1.78%	3.50%	6.22%	13.67%	17.56%	19.67%	28.78%	33.94%	43.17%

CHAPTER V

DISCUSSION & ANALYSIS

5.1 Introduction

With the obtained error-rates, graphs of broken lines showing errors along the time-frames were drawn. The trend of the error-rate-lines was examined to determine whether or not the lines decrease or increase markedly at a certain interval, form any specific curve, fluctuate more as the interval increases, etc. The graph was subdivided by observation types, sites, and worker activity types.

The average observation error-rate of each site at each interval and the average of each worker activity type was obtained, compared and interpreted. The observation error rates of each worker from both full and partial-observations were examined. The trend of the error-rate-lines and average difference between observation error rates of full and partial-observations interval were compared and analyzed. Specifically, the average error rate differences of the short interval group, mid interval group, and long interval group were compared. In order to tell full-observation from partial-observation, letter “F” was used right after the site name.

5.2 Analysis from Full-observation

5.2.1 Analysis by Sites

5.2.1.1 Site-A

All three workers showed similar trends, but the error rates differed from each other. The observation error rates of B1 and H1 increased rapidly until the 40-second interval while the observation error rates of B2 increased rapidly until the 60-second interval. After that, error rates increased slowly. Figure 5 shows error rate graphs of site-A from full-observation.

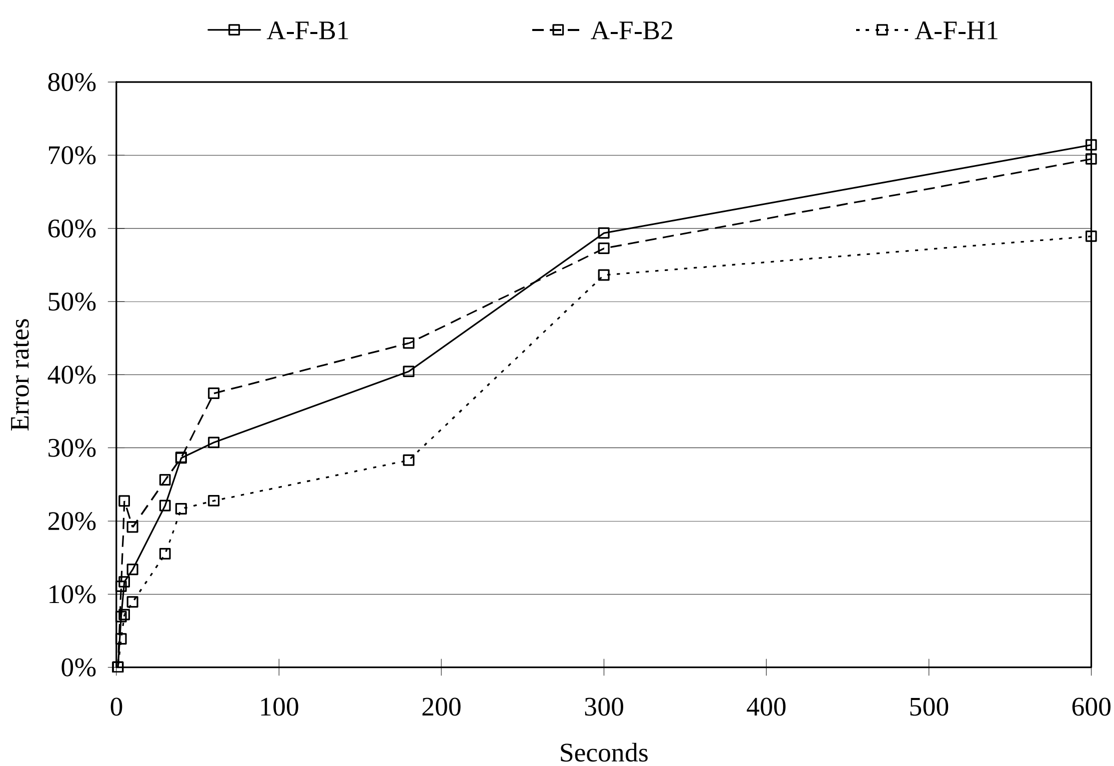

Fig. 5. Graphs of observation error rates of site-A from full-observation

5.2.1.2 Site-D

Workers B1 and H1 showed similar trends, but B2 reflected a totally different trend from that of the other workers. The observation error rates of B1 and H1 increased rapidly until the 60-second interval; after that, error rates increased slowly. However, the observation error rates of B2, who worked most of the time, increased rapidly until the 10-second interval; after that, the error rates fluctuated until the 600-second interval. Even the observation error rates of the 300 and 600-second intervals were almost 10% which was similar to the error rate of the 5-second interval. Figure 6 shows observation error rate graphs of site-D from full-observation.

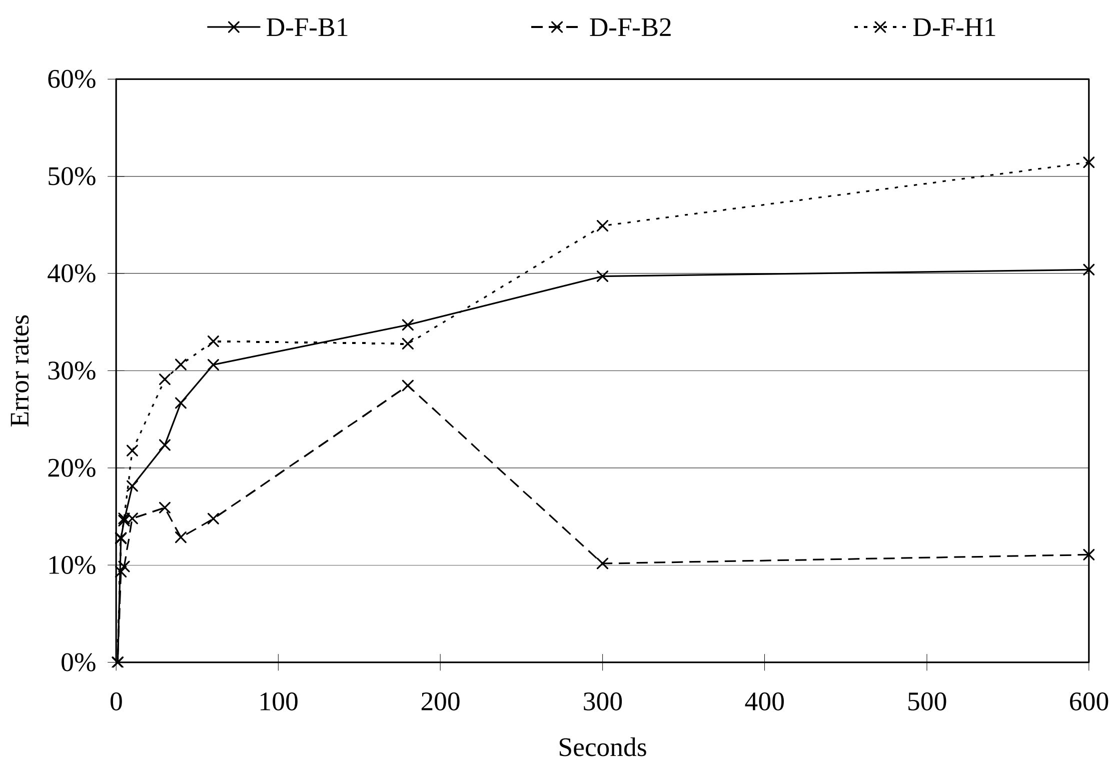

Fig. 6. Graphs of observation error rates of site-D from full-observation

5.2.1.3 Site-E

The observation error rate graphs of workers on site-E provided a good example of the difficulty of monitoring worker productivity with time lapse photos occasionally. Worker B1 showed a different trend from others, but looked normal in comparison with other site workers. Observation error rates of B1 increased until the 40-second interval; then the error rates increased slowly. However, the observation error rates of B2, H1, and H2 followed similar trends, but different from other site workers. The observation error rates of B2, H1, and H2 increased rapidly until the 30-second interval then began to fluctuate. Figure 7 shows observation error rate graphs of site-E from full-observation.

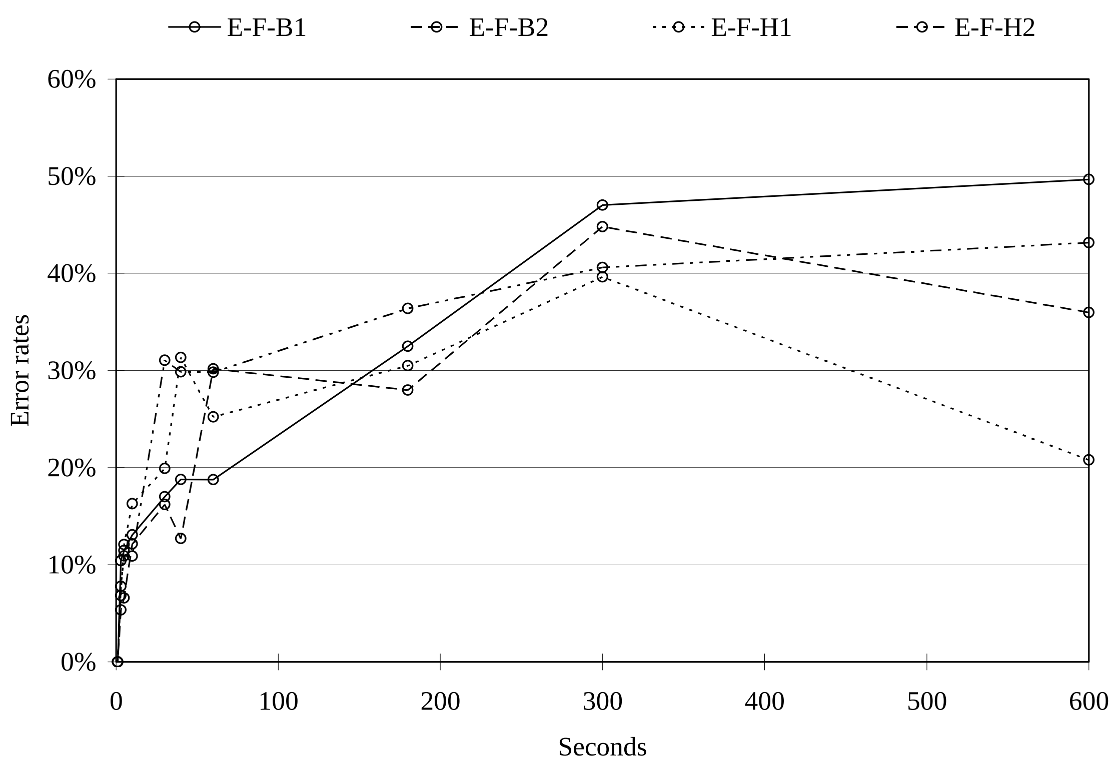

Fig. 7. Graphs of observation error rates of site-E from full-observation

5.2.1.4 Overall Analysis by Sites

The average observation error rate of each of the three sites was calculated and drawn. Up to the 180-second interval, all three sites showed similar trends. The average observation error rates increased rapidly until the 60-second interval, then the error rates increased slowly or remained the same according to sites. Figure 8 shows average observation error rate graphs of site A, D, and E from full-observation.

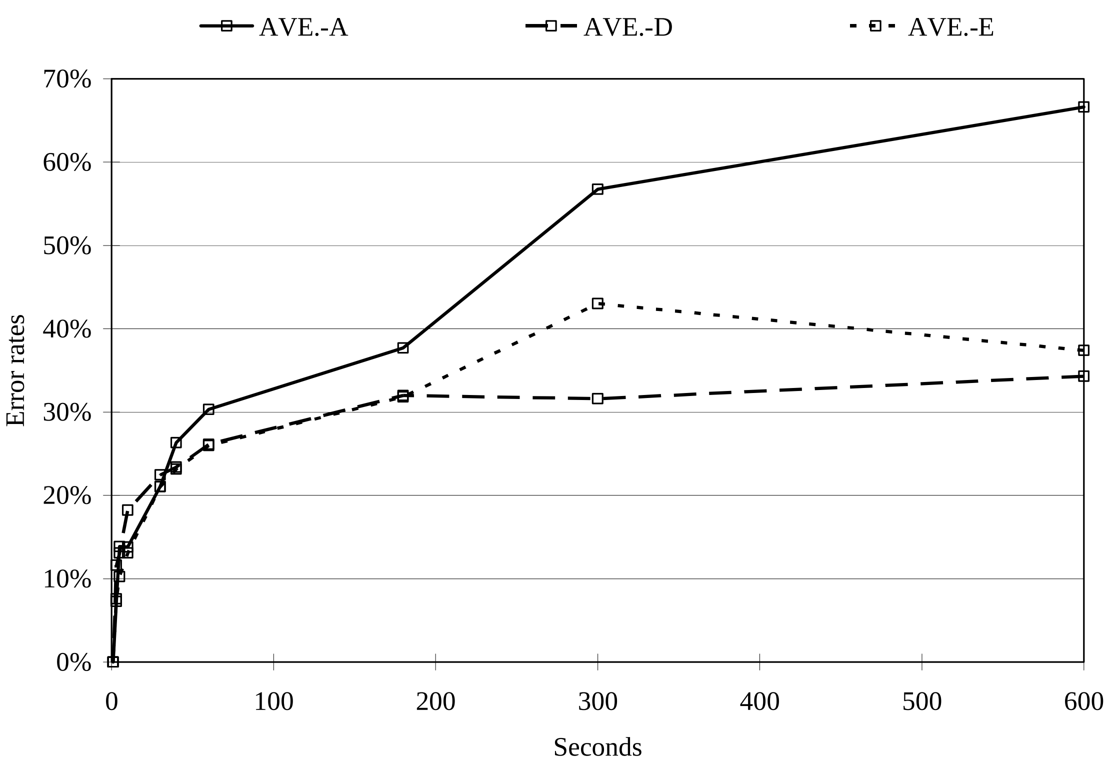

Fig. 8. Graphs of average observation error rates of site A, D, and E from full-observation

5.2.2 Analysis by Activities

5.2.2.1 Bricklayers

The observation error rates of bricklayers were analyzed. Only worker B1 of site A and worker B1 of site E showed similar trends, indicating no specific trend for bricklayers. Overall, the error rate increased rapidly until the 40-second interval; after that it increased slowly, maintained, or even decreased. Figure 9 shows observation error rate graphs of bricklayers from full-observation.

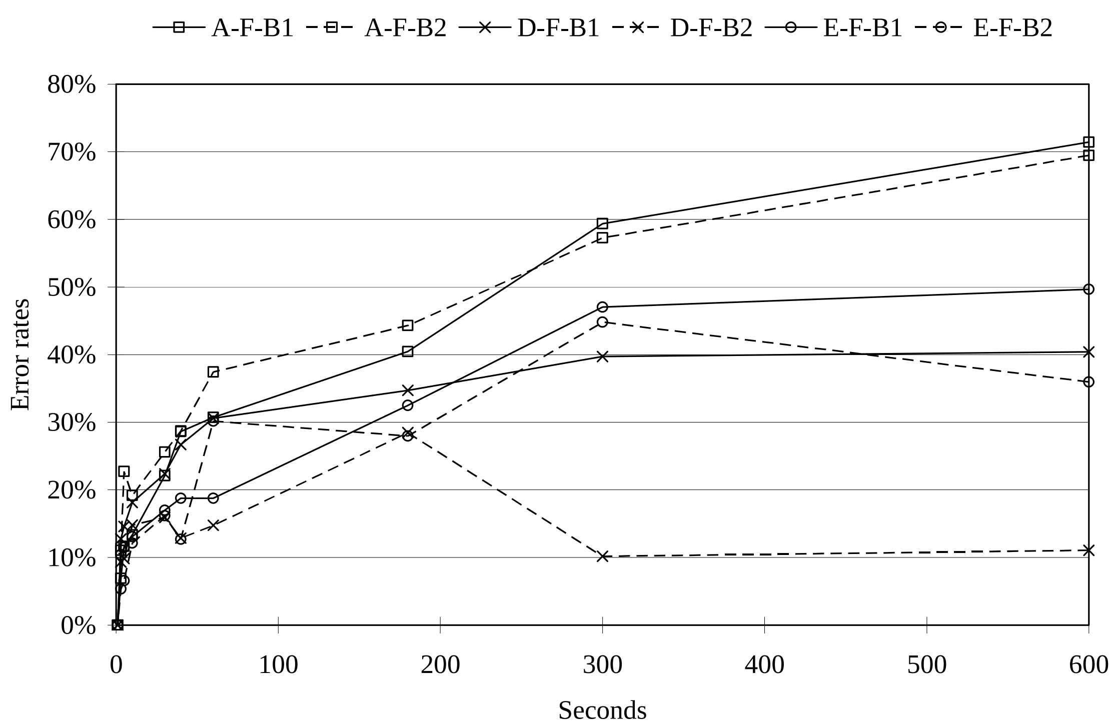

Fig. 9. Graphs of observation error rates of bricklayers from full-observation

5.2.2.2 Helpers

The observation error rates of helpers were analyzed as well, with no helpers showing similar trends. Overall, the error rate increased rapidly until the 40-second interval and after that they increased slowly, remained or even decreased. Figure 10 shows observation error rate graphs of helpers from full-observation.

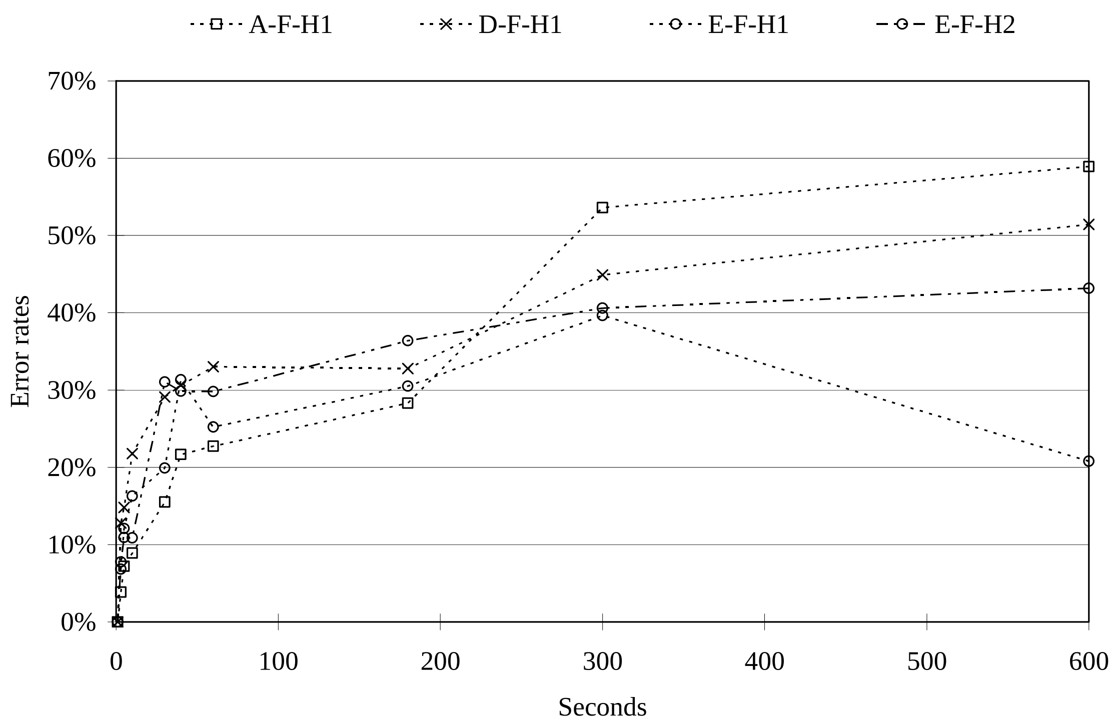

Fig. 10. Graphs of observation error rates of helpers from full-observation

5.2.2.3 Overall Analysis by Activities

The average observation error rates of the two activities (bricklaying and helping) were calculated and drawn. Although observation error rates of certain intervals were different between the two activities, the overall trends of the two activities were fairly identical. The average observation error rate of bricklayers increased rapidly until the 60-second interval while the average observation error rate of helper increased rapidly until the 40-second interval; then they increased slowly until the 600-second interval. Figure 11 shows average observation error rate graphs of bricklayers and helpers from full-observation.

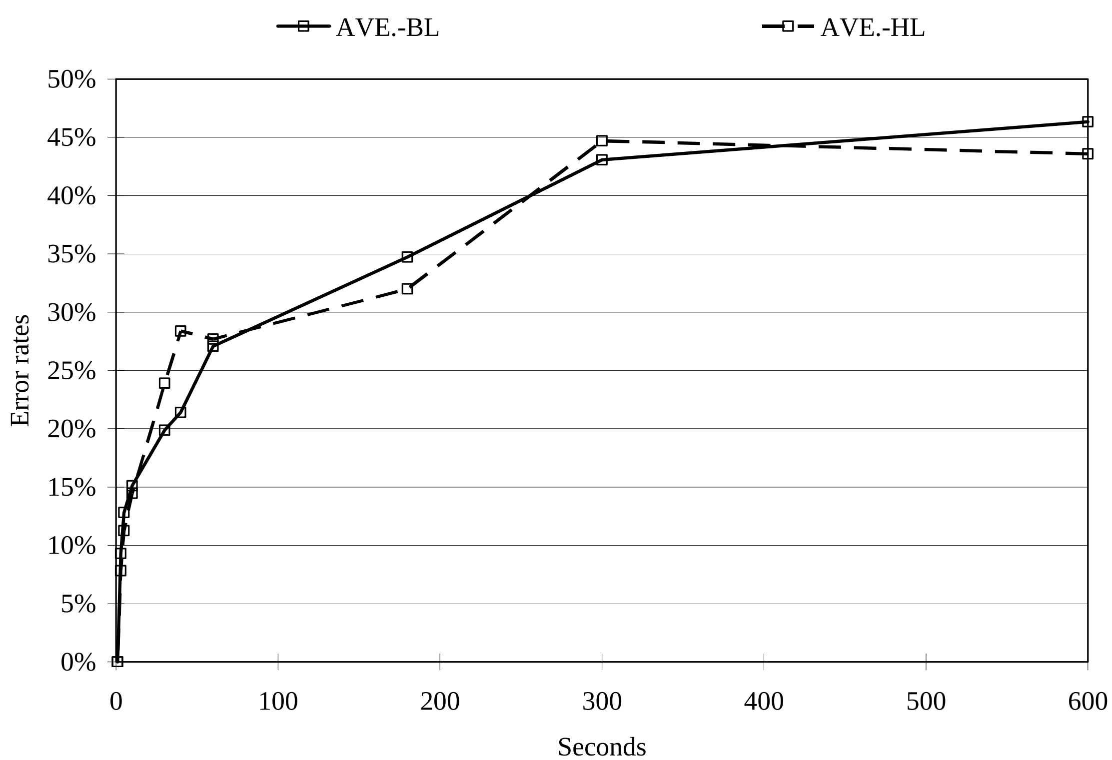

Fig. 11. Graphs of average observation error rates of bricklayers and helpers from full-observation

5.2.3 Summary

The observation error rates of all workers from sites A, D, and E were analyzed. An error rate trend, although not strong, was obtained from Figure 10. In order to identify the trend line, an average observation error rate of all workers at each interval was calculated and drawn. The average observation error rate increased rapidly until the 10-second interval, then increased rapidly (but slower than shorter interval group) until the 60-second interval. After that the average observation error rate increased slowly, maintained, or even decreased until the 600-second interval. Figure 12 shows average observation error rate graphs of all workers from full-observation.

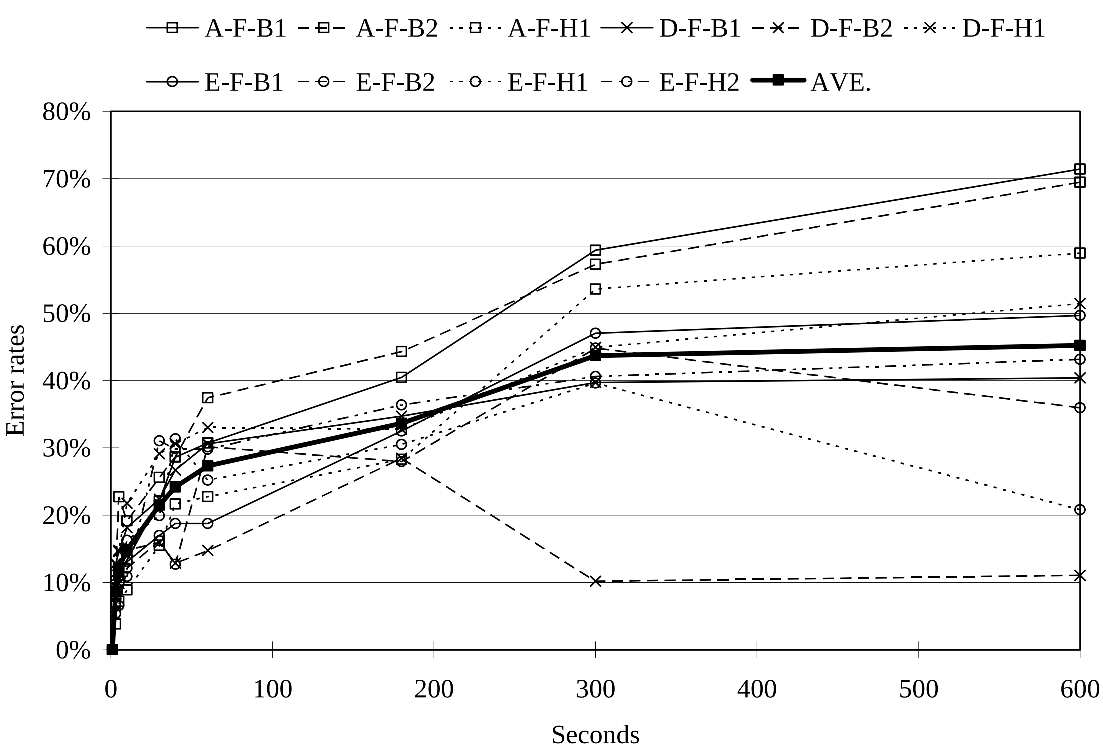

Fig. 12. Graphs of observation error rates of all workers from full-observation

5.3 Analysis from Partial-observation

5.3.1 Analysis by Sites

5.3.1.1 Site-A

Workers B2 and H1 showed fairly similar trends until the 300-second interval. The observation error rates of B2 and H1 increased rapidly until the 60-second interval, while the observation error rate of B1 increased rapidly until the 300-second interval. At that point, observation error rates increased slowly or remained the same according to workers. Figure 13 shows observation error rate graphs of site-A from partial-observation.

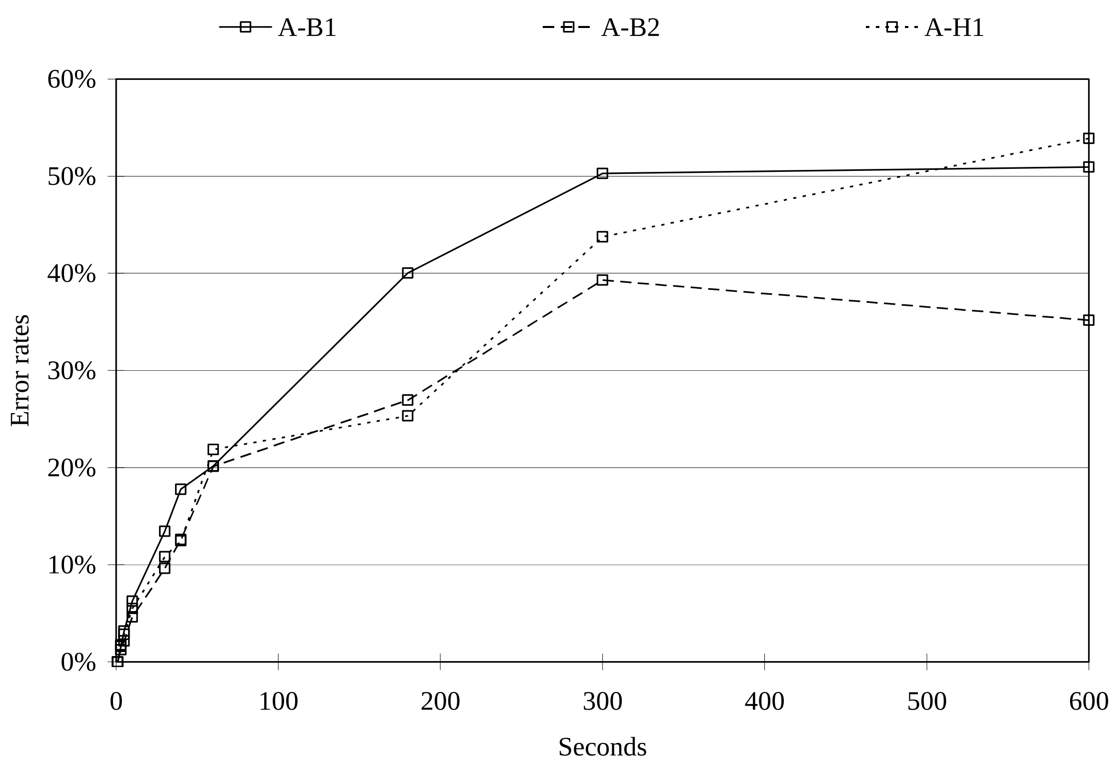

Fig. 13. Graphs of observation error rates of site-A from partial-observation

5.3.1.2 Site-B

All workers showed fairly similar trends, with observation error rates for all workers increasing rapidly until the 60-second interval. After that observation error rates increased slowly. Figure 14 shows observation error rate graphs of site-B from partial-observation.

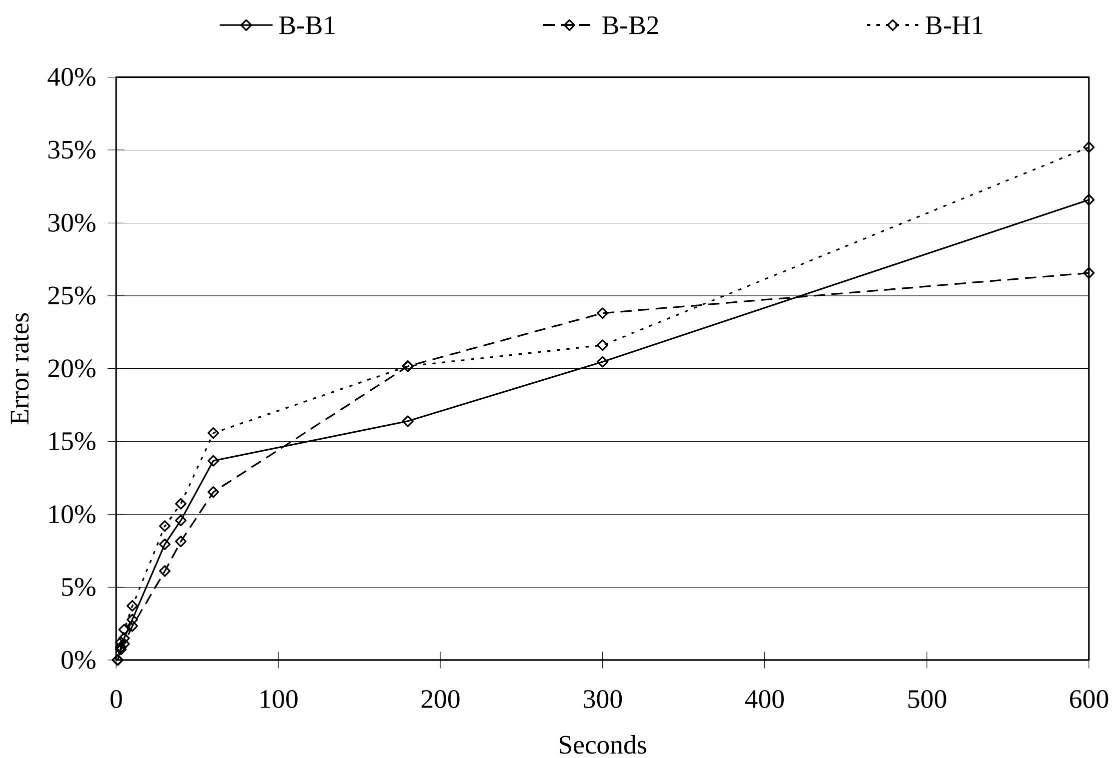

Fig. 14. Graphs of observation error rates of site-B from partial-observation

5.3.1.3 Site-C

Workers B1 and B2 showed fairly similar trends until the 180-second interval. The observation error rates of B1 and B2 increased rapidly until the 60-second interval, while the observation error rate of B3 increased rapidly until the 30-second interval. After that, observation error rates increased slowly, remained, or even decreased, varying by worker. The observation error rate of H1 increased rapidly until the 40-second interval and after that, the observation error rate increased slowly. Figure 15 shows observation error rate graphs of site-C from partial-observation.

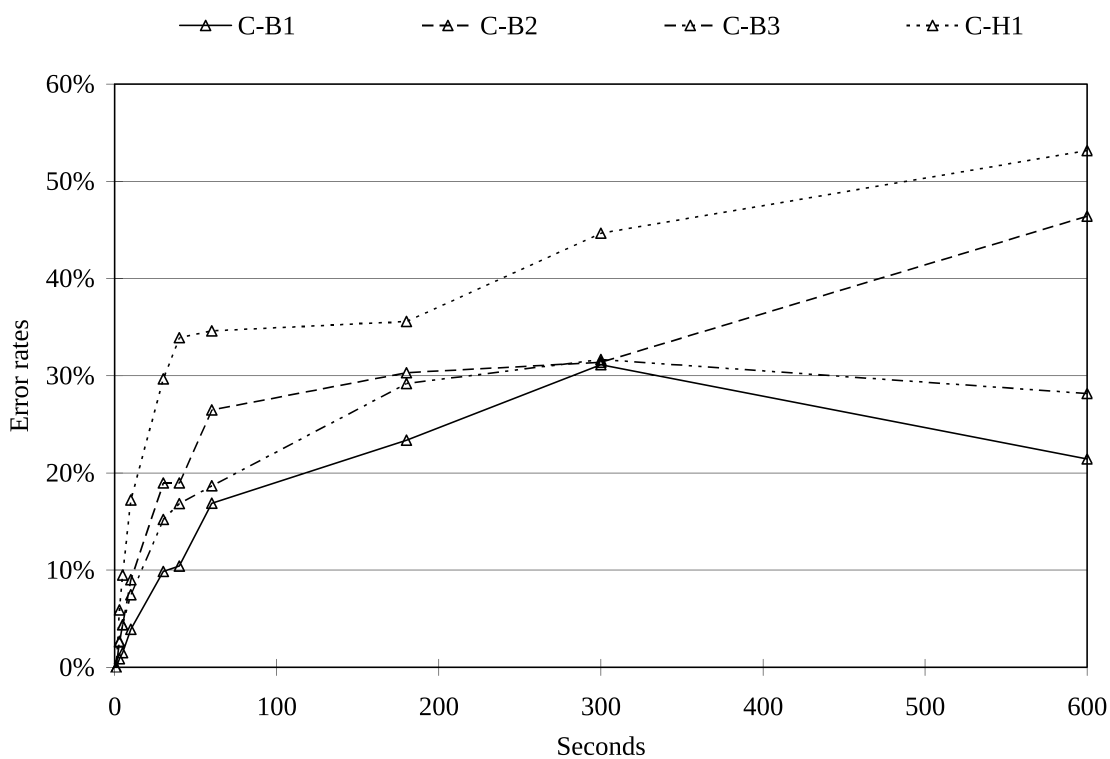

Fig. 15. Graphs of observation error rates of site-C from partial-observation

5.3.1.4 Site-D

Even though the observation error rate of worker B2 was much lower than the others, all workers showed fairly similar trends until the 180-second interval. The observation error rates of all workers increased rapidly until the 60-second interval; after that, error rates increased slowly, remained, or even decreased, according to individual workers. The observation error rate of worker B2 remained around 10% after the 60-second interval, probably because B2 kept working most of the time as previously mentioned. Figure 16 shows observation error rate graphs of site-D from partial-observation.

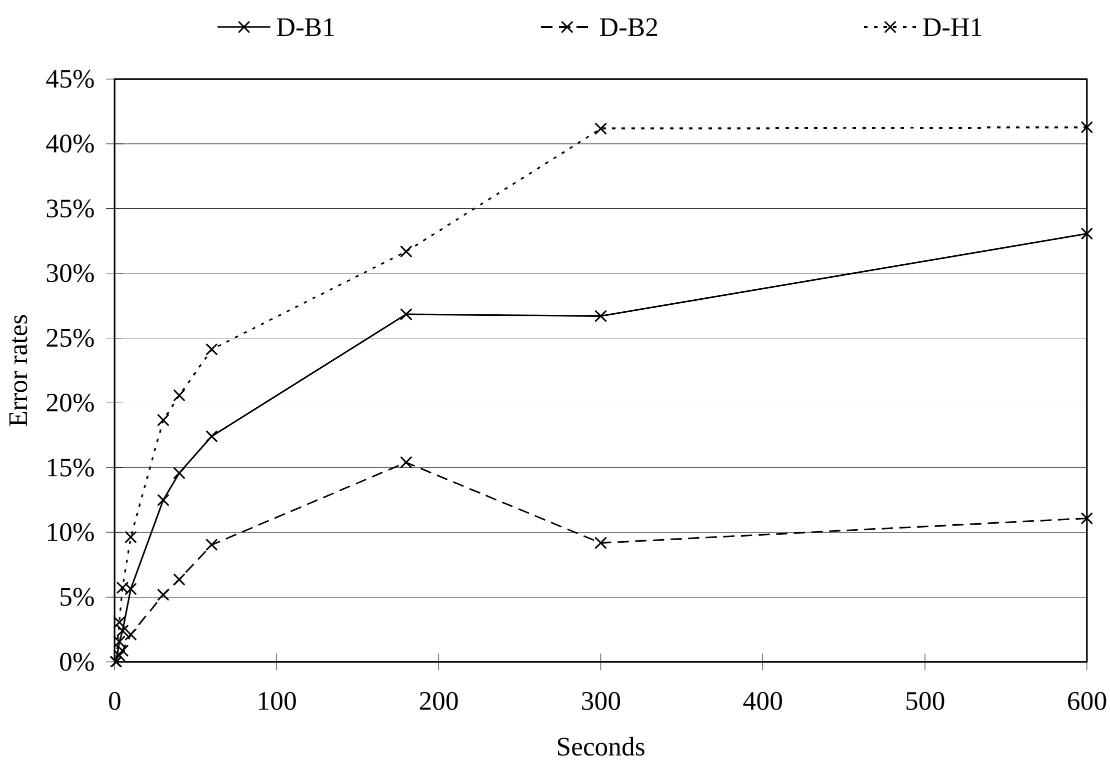

Fig. 16. Graphs of observation error rates of site-D from partial-observation

5.3.1.5 Site-E

Workers B1 and H2 reflected similar trends until the 180-second interval. The observation error rates of B1, H1, and H2 increased rapidly until the 40-second interval; after that error rates increased slowly or remained stable, according to individual workers. The observation error rate of B2 increased steadily until the 300-second interval and after that error rate decreased slowly. Figure 17 shows observation error rate graphs of site-E from partial-observation.

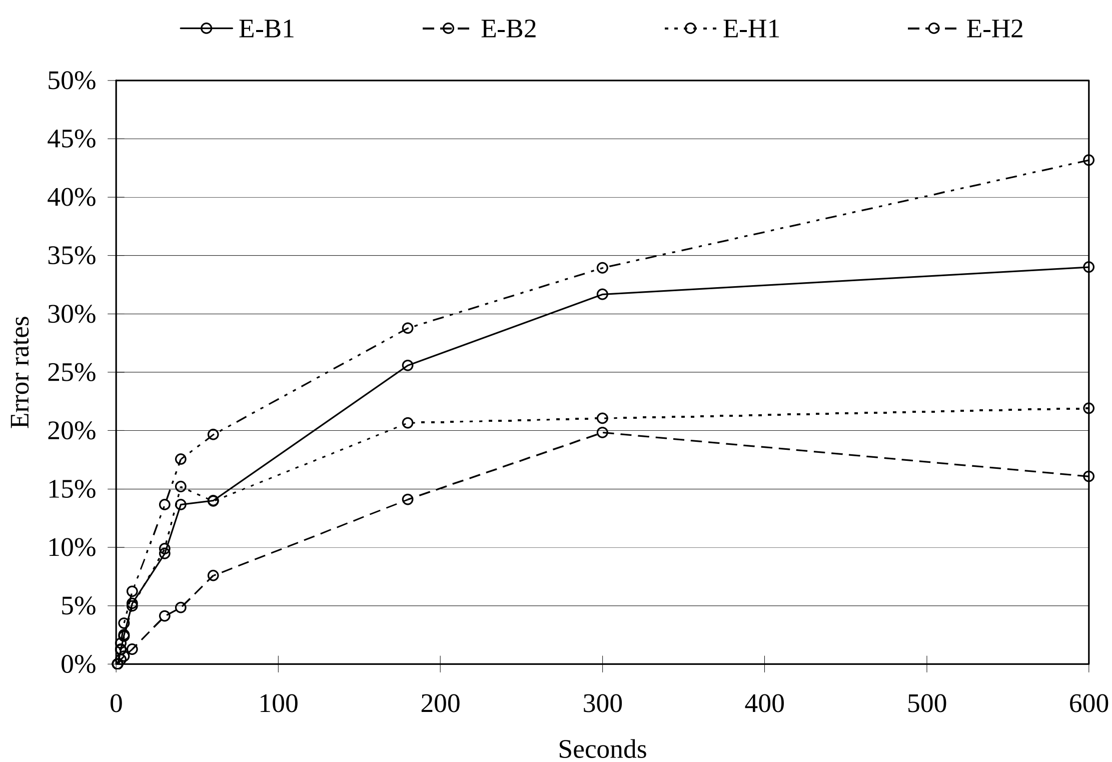

Fig. 17. Graphs of observation error rates of site-E from partial-observation

5.3.1.6 Overall Analysis by Site

The average observation error rates of all sites were calculated and drawn. Until the 300-second interval, sites B, C, and D showed similar trends. The average observation error rates of sites A, B, C, and D increased rapidly until the 60-second interval, while the average observation error rate of site-E increased until the 40-second interval. After that error rates increased slowly or remained stable, according to sites. Figure 18 shows average observation error rate graphs of all sites from partial-observation.

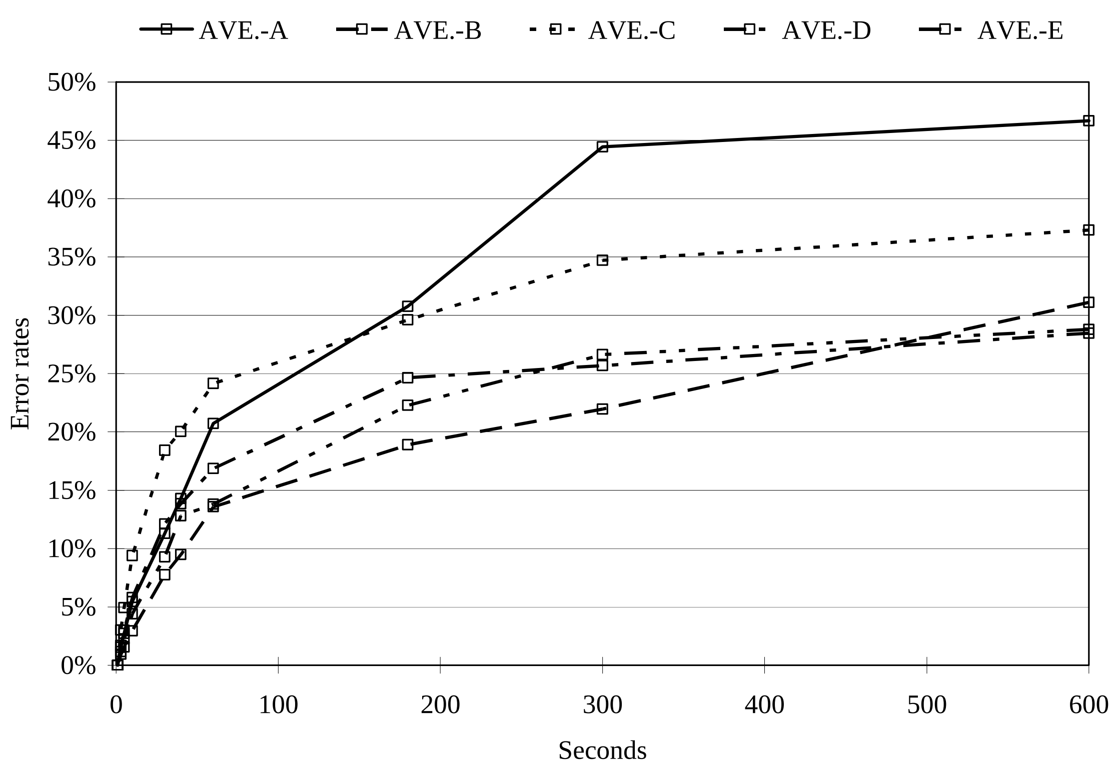

Fig. 18. Graphs of average observation error rates of all sites from partial-observation

5.3.2 Analysis by Activities

5.3.2.1 Bricklayers

The observation error rates of 11 bricklayers were analyzed. Although the observation error rates of workers on each interval varied, most workers showed similar trends. The error rates increased rapidly until the 60-second interval; after that, they increased slowly, maintained, or even decreased according to individual worker. Figure 19 shows observation error rate graphs of all bricklayers from partial-observation.

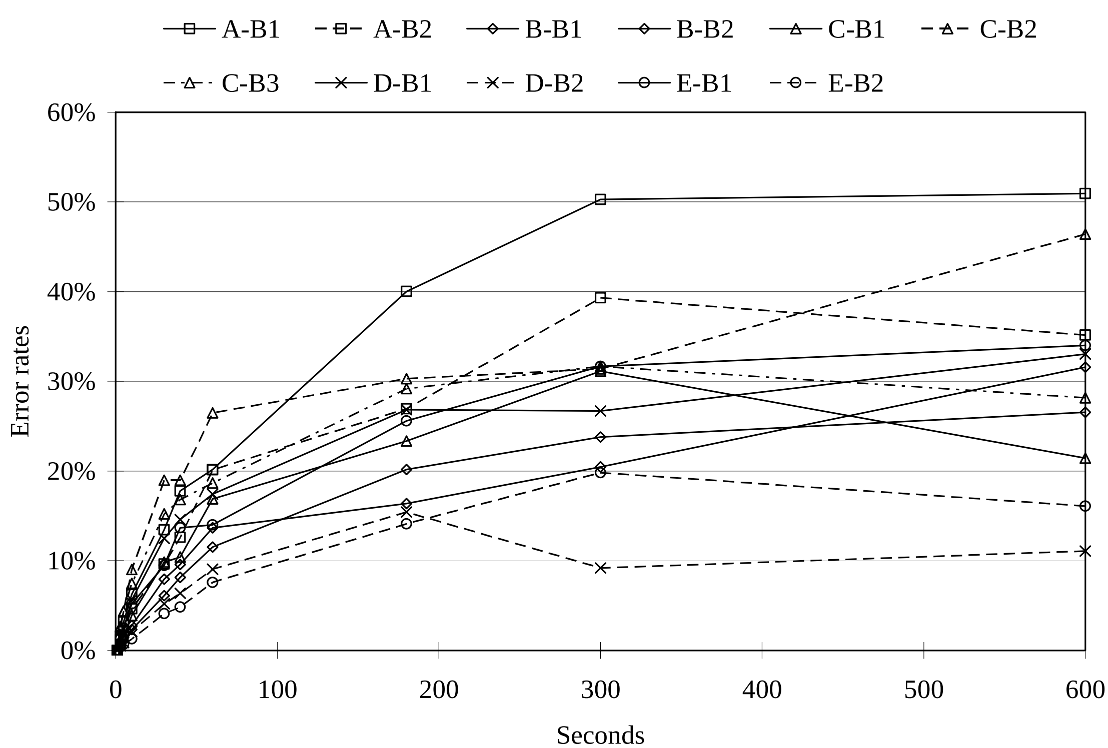

Fig. 19. Graphs of observation error rates of all bricklayers from partial-observation

5.3.2.2 Helpers

The observation error rates of helpers were analyzed as well. Worker H1 of site-D and worker H2 of site-E showed similar trends until the 300-second interval. Overall, the error rates increased rapidly until the 60-second interval; after that, they increased slowly or remained stable. Figure 20 shows observation error rate graphs of all helpers from partial-observation.

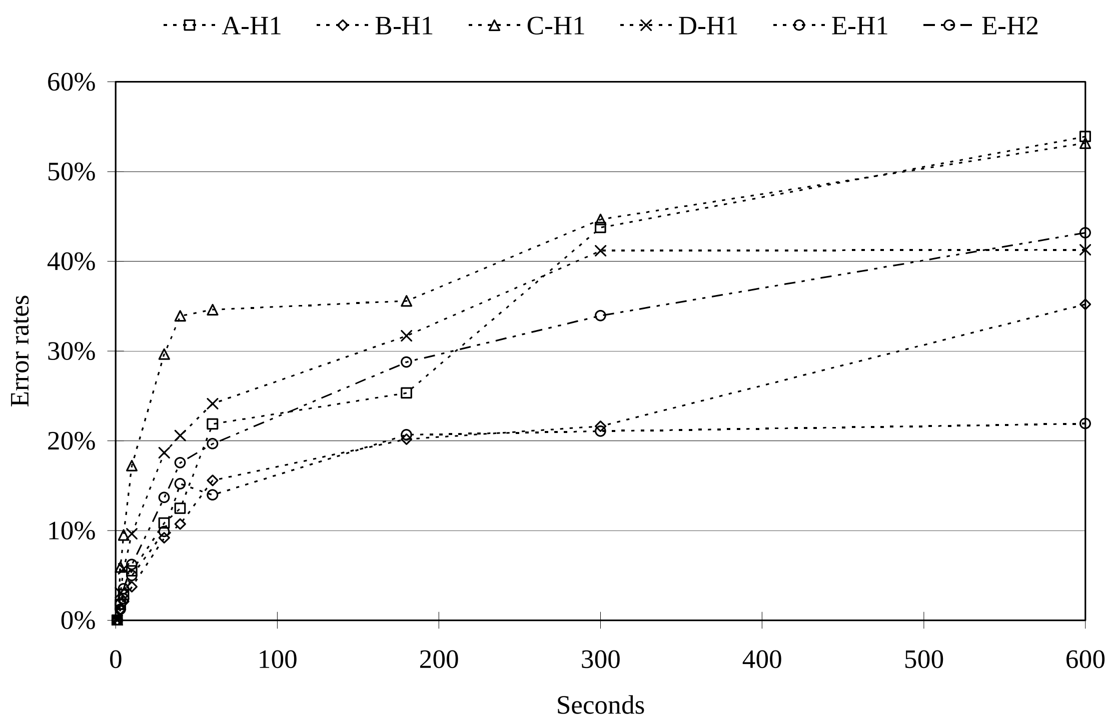

Fig. 20. Graphs of observation error rates of all helpers from partial-observation

5.3.2.3 Overall Analysis by Activities

The average observation error rates of two activities (bricklaying and helping) were calculated and drawn. Although observation error rates at each interval were different between the two activities, the trends of both activities were similar. The average error rates of both activities increased rapidly until the 60-second interval and after that they increased slowly until the 600-second interval. Figure 21 shows average observation error rate graphs of bricklayers and helpers from partial-observation.

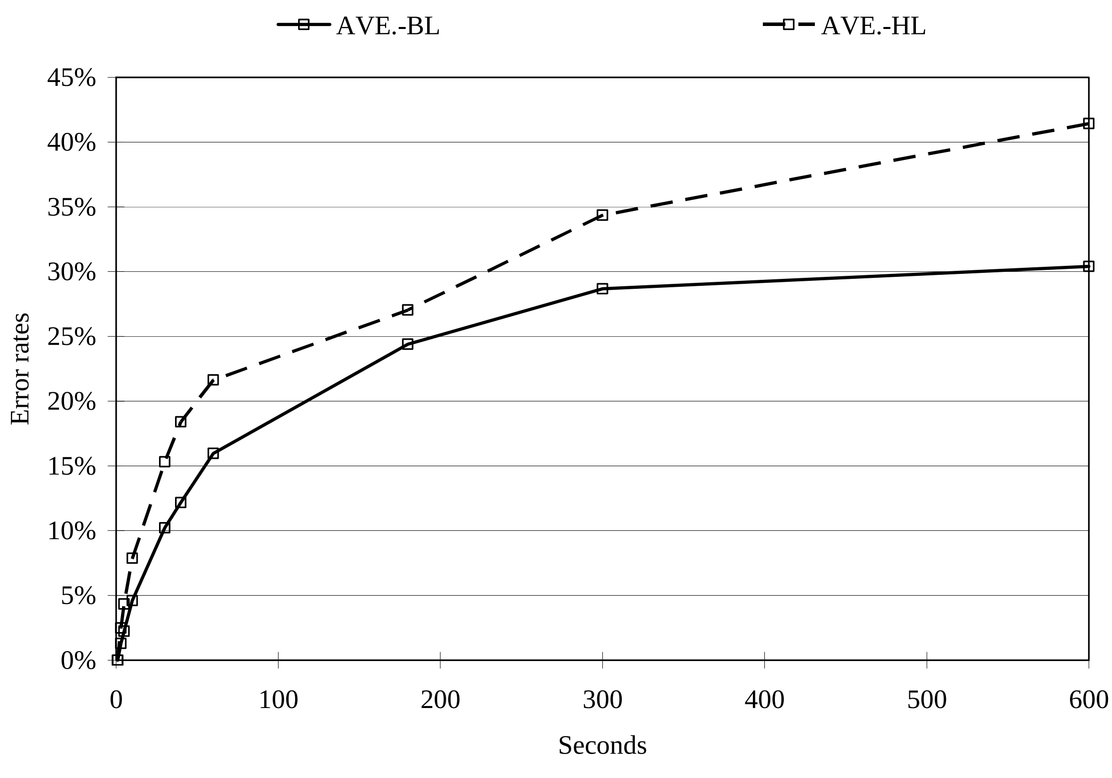

Fig. 21. Graphs of average observation error rates of bricklayers and helpers from partial-observation

5.3.3 Summary

The observation error rates of all workers from all sites were analyzed. A trend of error rates is represented in Figure 19. In order to identify the trend line, an average observation error rate of all workers at each interval was calculated and drawn. The average observation error rate increased rapidly until the 60-second interval and after that the average error rate increased slowly, maintained, or even decreased until the 600-second interval. Figure 22 shows average observation error rate graphs of all workers from partial-observation.

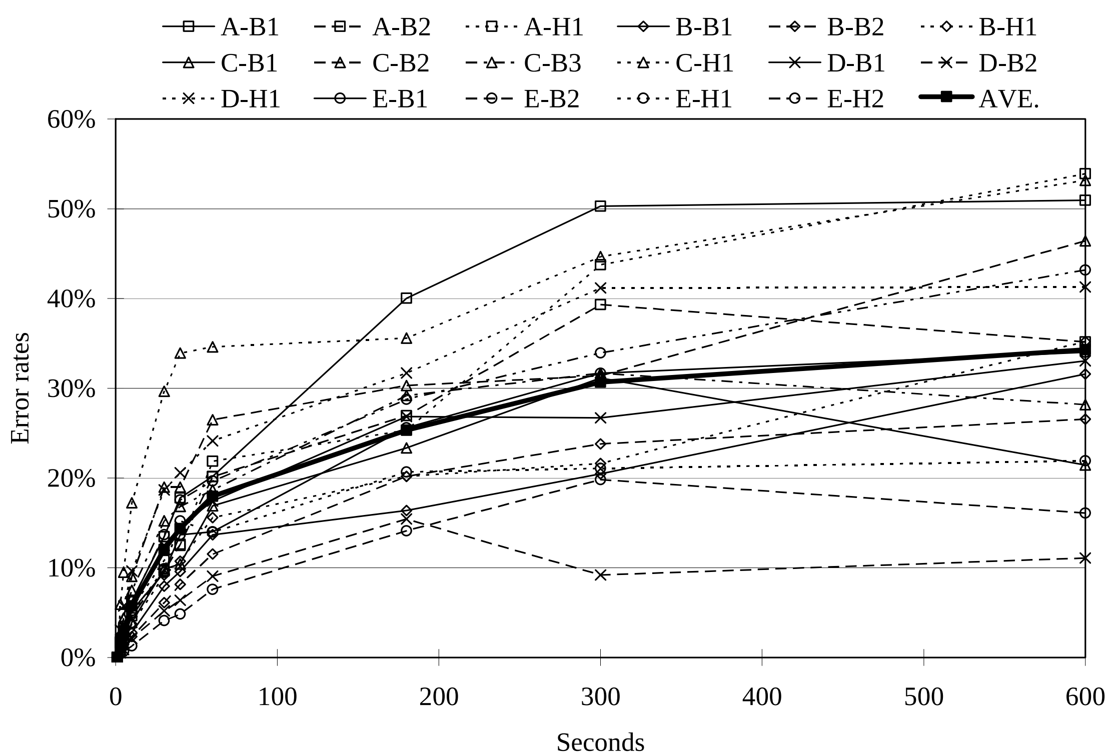

Fig. 22. Graphs of observation error rates of all workers from partial-observation

5.4 Error Rate Difference Between Full and Partial-observations

5.4.1 Site-A

5.4.1.1 Worker B1

Two graphs show similar trends except at the 180-second interval. The overall average observation error rate difference between full-observation and partial-observation was 8.99%. Specifically, the average observation error rate differences of the short interval group, mid interval group, and long interval group were 6.97%, 10.02%, and 9.99%, respectively. Figure 23 illustrates the observation error rate graphs of worker B1 from full and partial-observation.

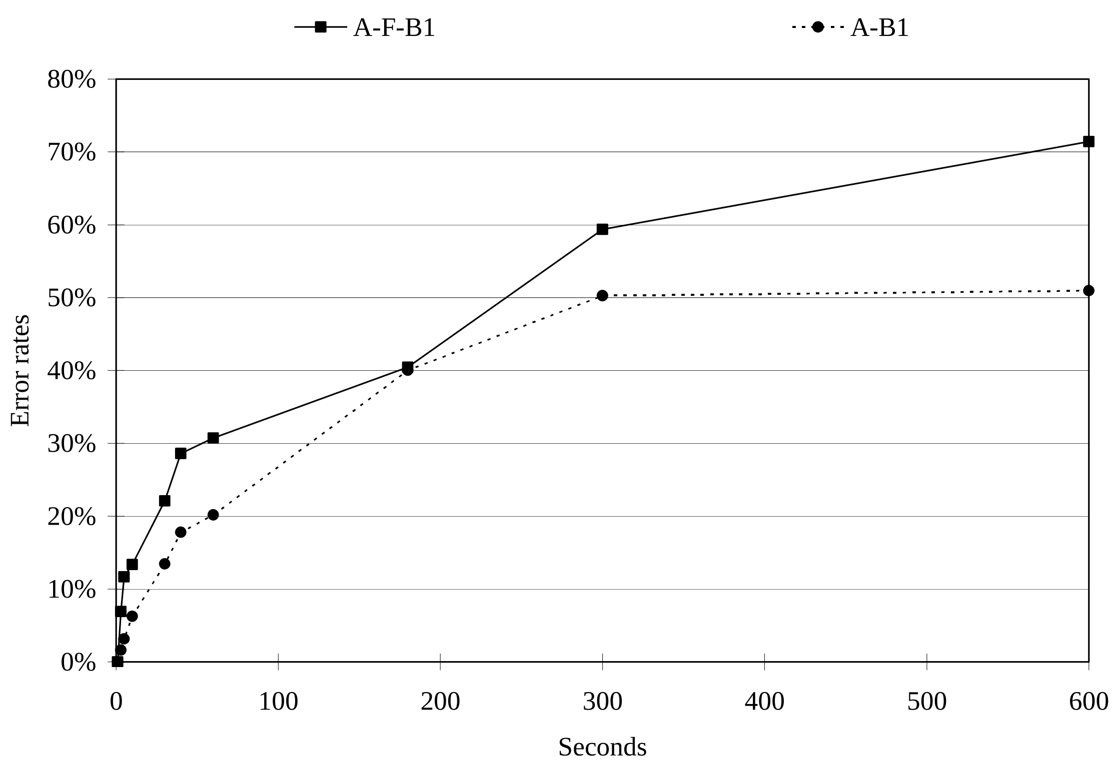

Fig. 23. Graphs of observation error rate of site-A worker B1 from full and partial-observation

5.4.1.2 Worker B2

The two graphs reflect fairly similar trends except at the 5-second interval. The overall average observation error rate difference between full-observation and partial-observation was 18.21%. Specifically, the average observation error rate differences of the short interval group, mid interval group, and long interval group were 14.96%, 16.45%, and 23.21%, respectively. Figure 24 shows the observation error rate graphs of worker B2 from full and partial-observation.

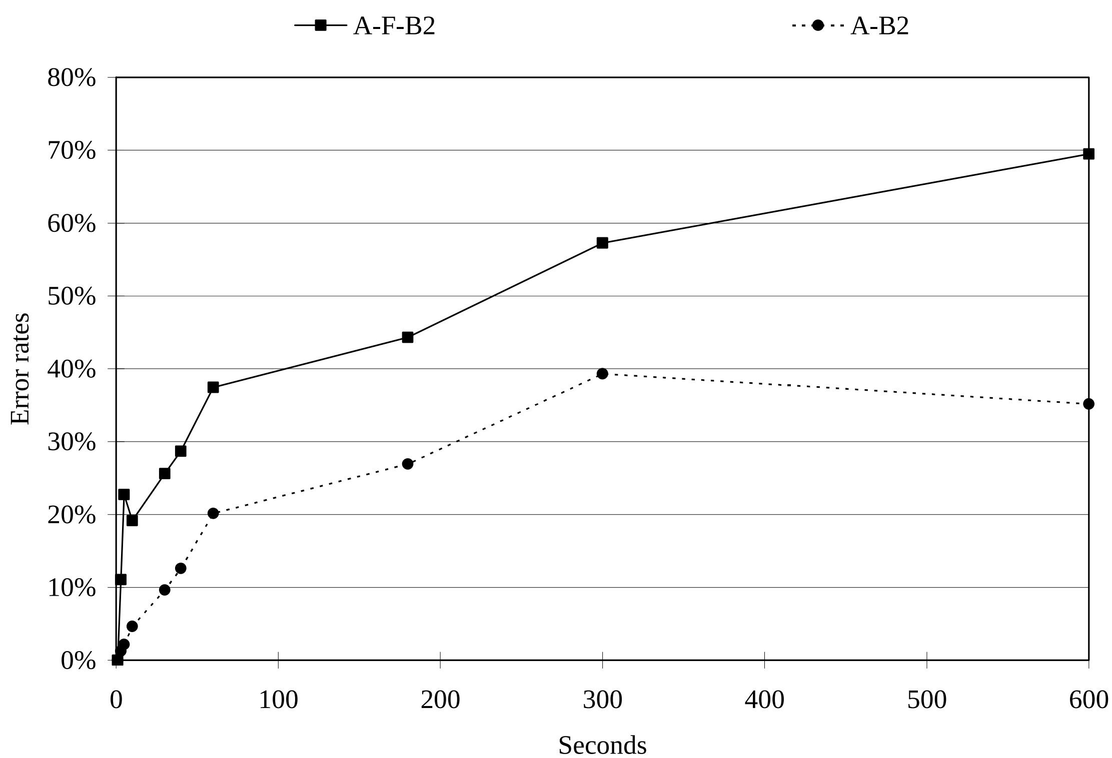

Fig. 24. Graphs of observation error rate of site-A worker B2 from full and partial-observation

5.4.1.3 Worker H1

The two graphs show fairly similar trends. One small difference was that the error rate of full-observation increased rapidly until the 40-second interval, while the error rate of partial-observation increased rapidly until the 60-second interval. The overall average error rate difference between full-observation and partial-observation was 4.72%. Specifically, the average error rate differences of the short interval group, mid interval group, and long interval group were 3.30%, 4.92%, and 5.95%, respectively. Figure 25 shows the observation error rate graphs of worker H1 from full and partial-observation.

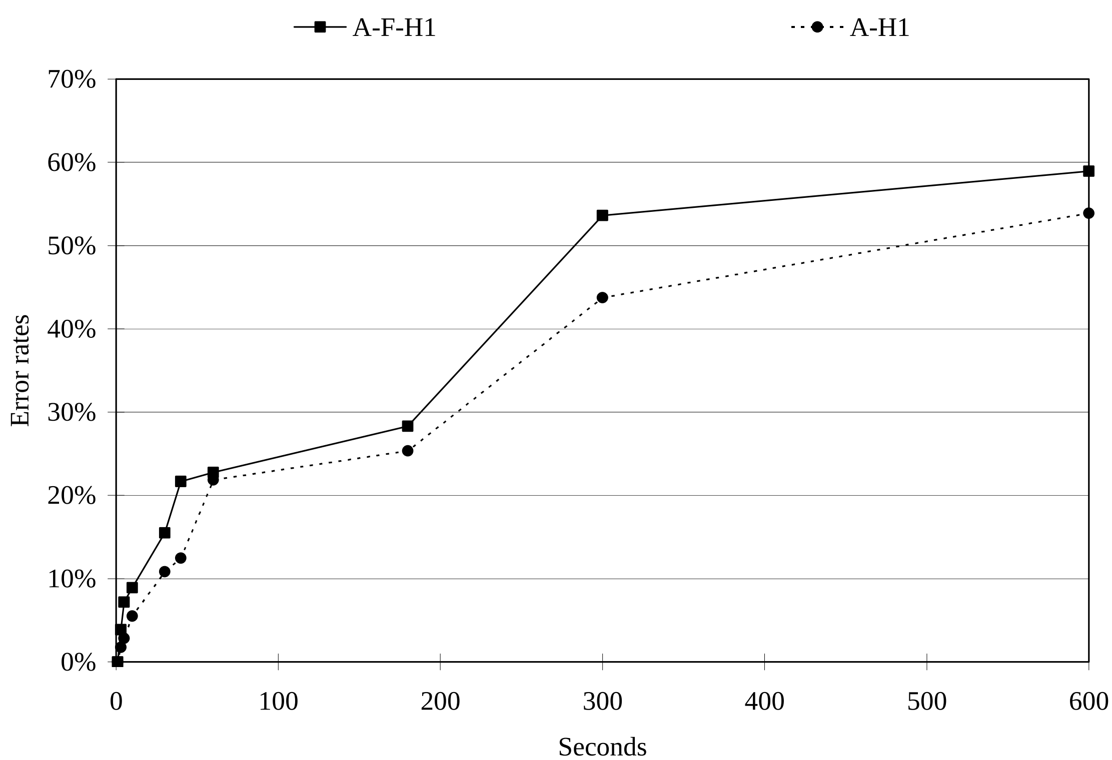

Fig. 25. Graphs of observation error rate of site-A worker H1 from full and partial-observation

5.4.2 Site-D

5.4.2.1 Worker B1

The two graphs indicate similar trends. The overall average error rate difference between full-observation and partial-observation was 11.03%. Specifically, the average error rate differences of the short interval group, mid interval group, and long interval group were 11.95%, 11.72%, and 9.42%, respectively. Figure 26 shows the observation error rate graphs of worker B1 from full and partial-observation.

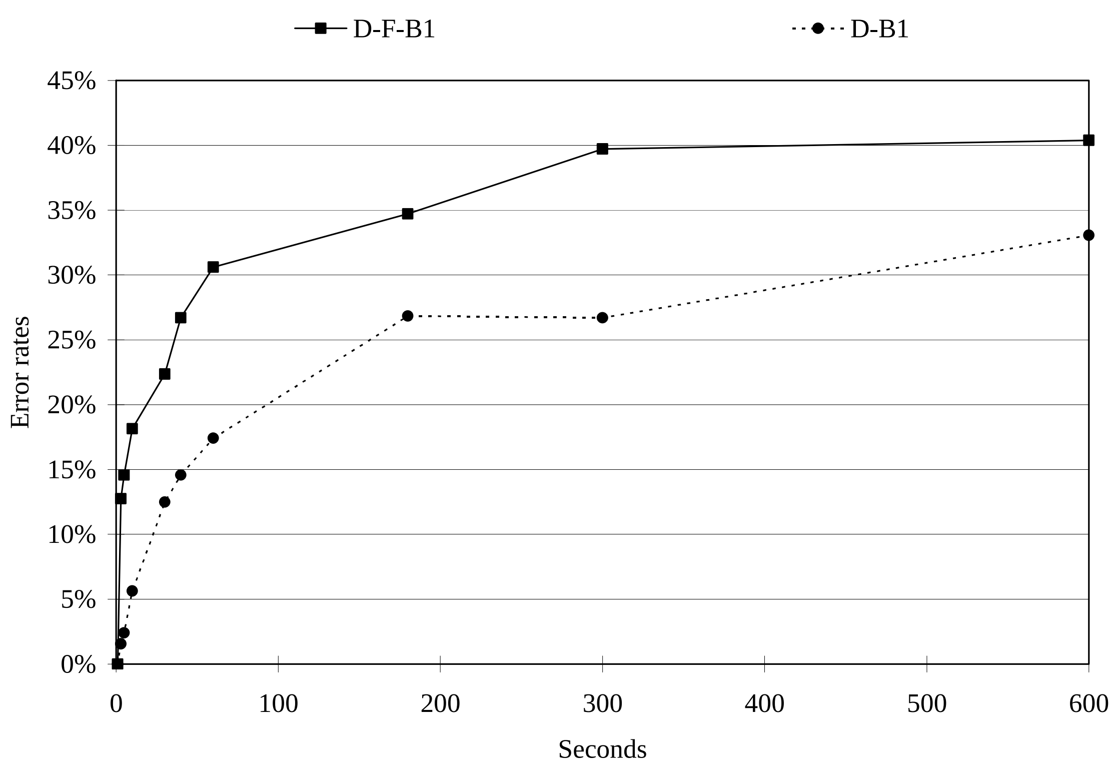

Fig. 26. Graphs of observation error rate of site-D worker B1 from full and partial-observation

5.4.2.2 Worker B2

The two graphs show similar trends after the 40-second interval. The overall average error rate difference between full-observation and partial-observation was 7.50%. Specifically, the average error rate differences for the short interval group, mid interval group, and long interval group were 10.18%, 7.65%, and 4.68%, respectively. Figure 27 shows the observation error rate graphs of worker B2 from full and partial-observation.

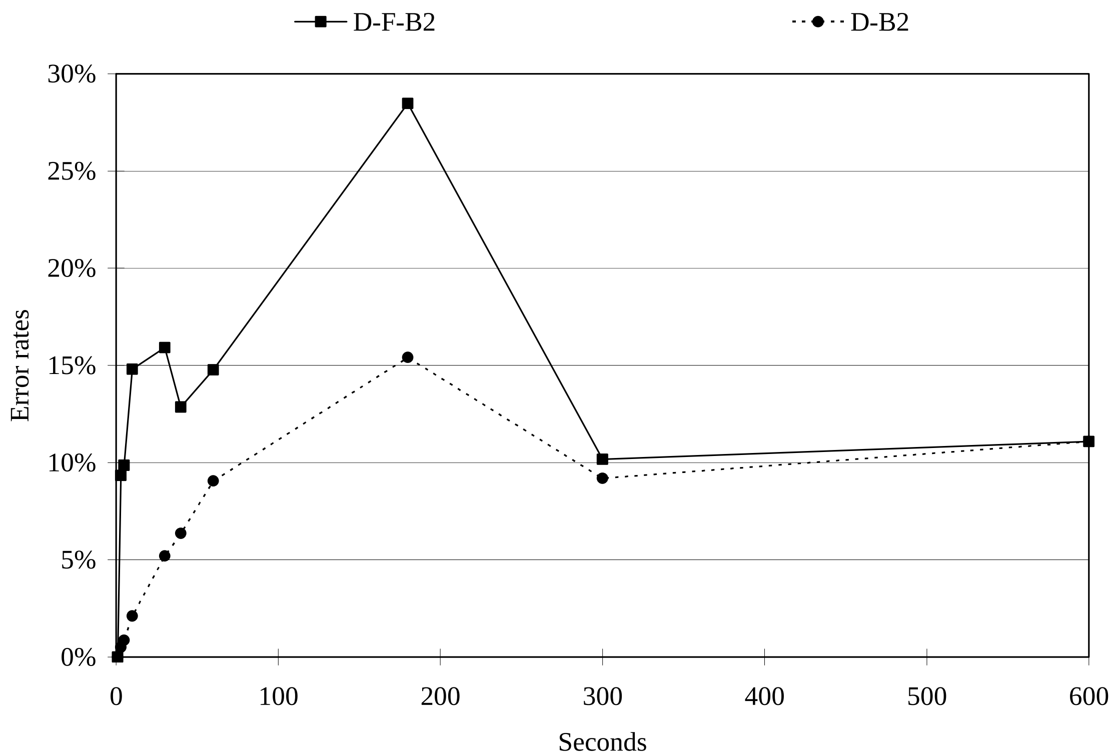

Fig. 27. Graphs of observation error rate of site-D worker B2 from full and partial-observation

5.4.2.3 Worker H1

The two graphs indicate similar trends except at the 180-second interval. The overall average error rate difference between full-observation and partial-observation was 8.37%. Specifically, the average error rate differences of the short interval group, mid interval group, and long interval group were 10.32%, 9.80%, and 5.00%, respectively. Figure 28 shows the observation error rate graphs of worker H1 from full and partial-observation.

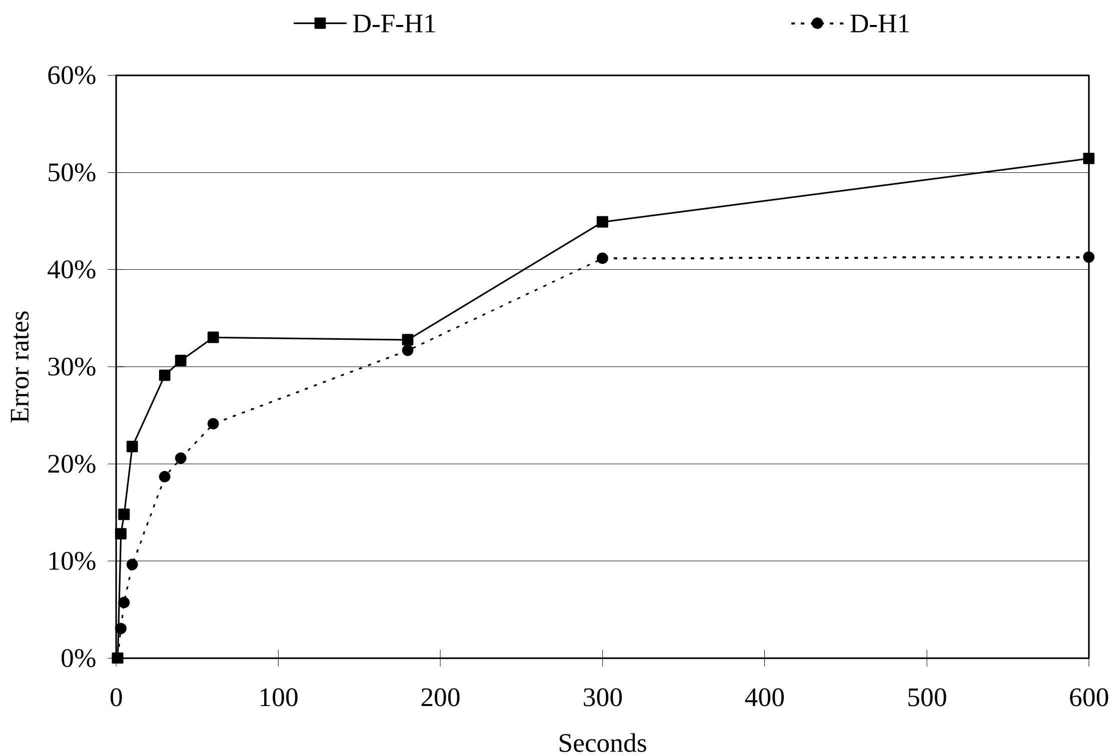

Fig. 28. Graphs of observation error rate of site-D worker H1 from full and partial-observation

5.4.3 Site-E

5.4.3.1 Worker B1

The two graphs indicate similar trends. The overall average error rate difference between full-observation and partial-observation was 9.04%. Specifically, the average error rate differences of the short interval group, mid interval group, and long interval group were 8.67%, 5.80%, and 12.65%, respectively. Figure 29 shows the observation error rate graphs of worker B1 from full and partial-observation.

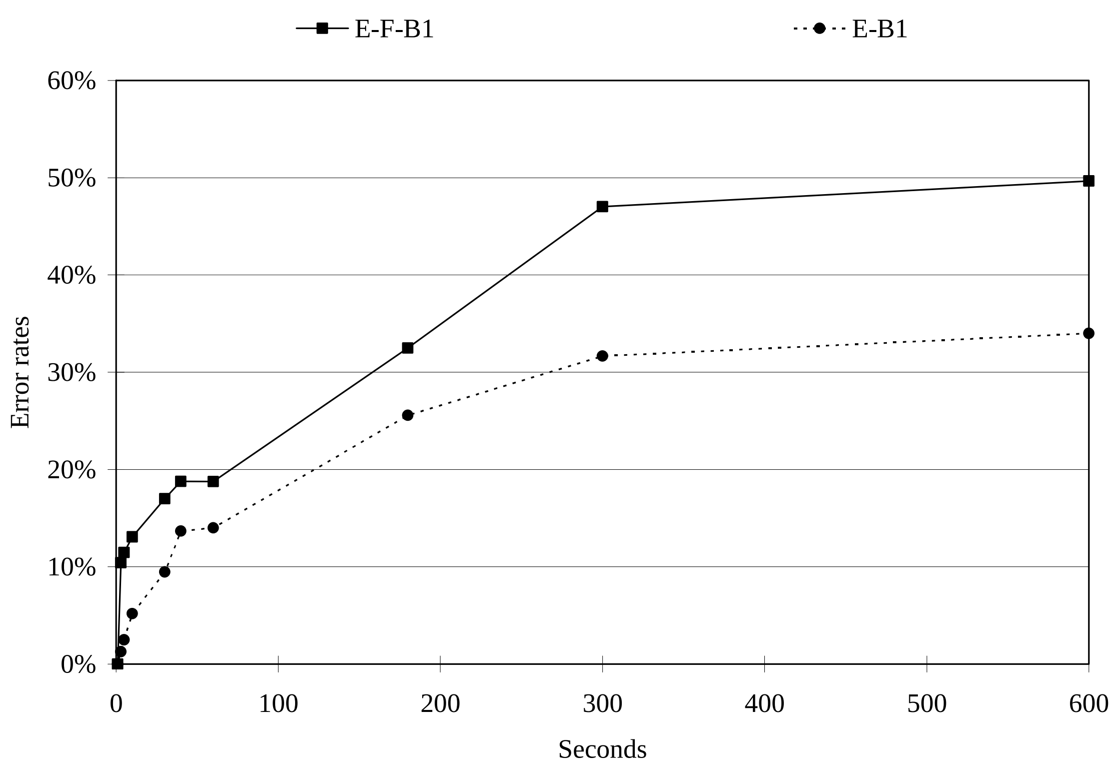

Fig. 29. Graphs of observation error rate of site-E worker B1 from full and partial-observation

5.4.3.2 Worker B2

The two graphs do not show similar trends, probably because worker B2 worked in a dark corner, making it difficult for the observer to recognize whether or not B2 was working. The overall average error rate difference between full-observation and partial-observation was 13.67%. Specifically, the average error rate differences of the short interval group, mid interval group, and long interval group were 7.25%, 14.18%, and 19.57%, respectively. Figure 30 shows the observation error rate graphs of worker B2 from full and partial-observation.

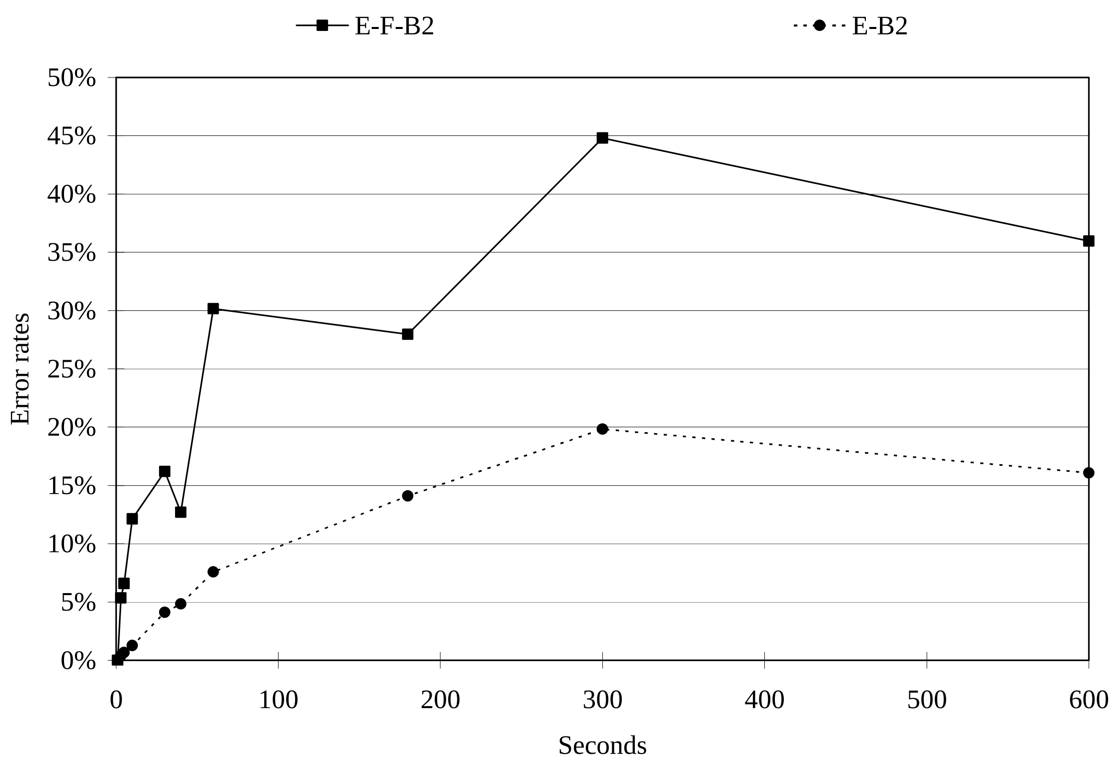

Fig. 30. Graphs of observation error rate of site-E worker B2 from full and partial-observation

5.4.3.3 Worker H1

The two graphs indicate similar trends except at the 600-second interval. The overall average error rate difference between full-observation and partial-observation was 10.40%. Specifically, the average error rate differences of the short interval group, mid interval group, and long interval group were 8.87%, 12.47%, and 9.84%, respectively. Figure 31 shows the observation error rate graphs of worker H1 from full and partial-observation.

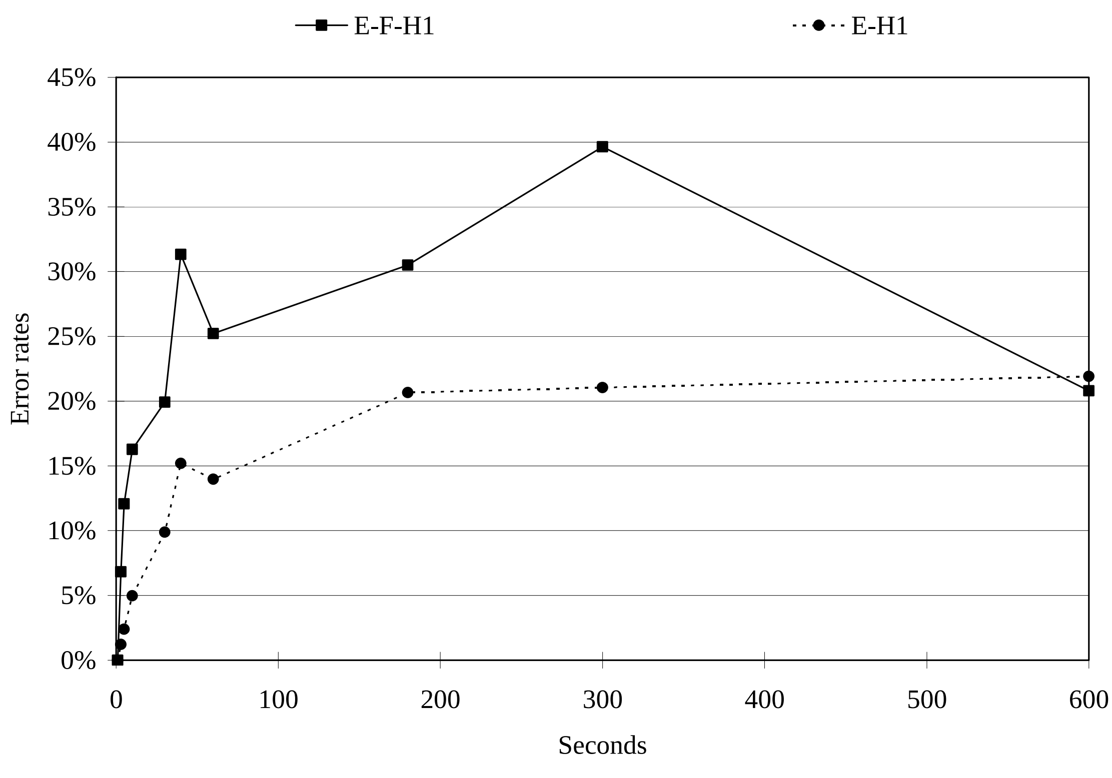

Fig. 31. Graphs of observation error rate of site-E worker H1 from full and partial-observation

5.4.3.4 Worker H2

The two graphs indicate similar trends except at the 30 and 40-second intervals. The overall average error rate difference between full-observation and partial-observation was 8.02%. Specifically, the average error rate differences of the short interval group, mid interval group, and long interval group were 6.03%, 13.28%, and 4.76%, respectively. Figure 32 shows the observation error rate graphs of worker H2 from full and partial-observation.

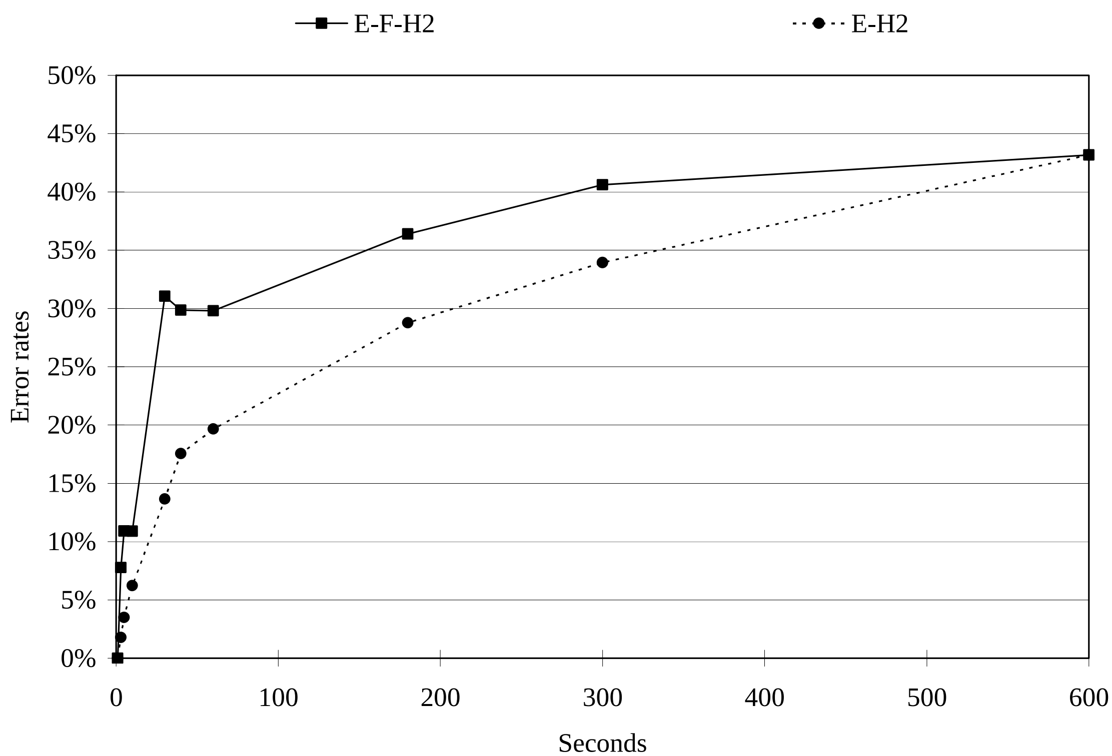

Fig. 32. Graphs of observation error rate of site-E worker H2 from full and partial-observation

5.4.4 Overall Analysis of Error Rate Difference

The error rate differences were synthesized and analyzed according to time interval. First, a correlation between error rate differences and time interval was investigated. After the investigation, a correlation was found between sites A and D; however, the results were contrary to each other. The observation error rate differences of the workers at site-A increased as the time interval lengthened while they decreased for site-D. No correlation was found for workers at site E. Therefore, it is difficult to state that there is a correlation between them. Second, average observation error rate differences by workers and by time interval were calculated. The average error rate differences by time interval remained at approximately 10%, while it varied by worker. Table 10 shows observation error rate differences of workers in each time interval.

Table 10. Observation error rate differences of workers according to time interval

Items		Short Interval	Mid Interval	Long Interval	Average by Workers
Site-A	A-B1	6.97%	10.02%	9.99%	8.99%
	A-B2	14.96%	16.45%	23.21%	18.21%
	A-H1	3.30%	4.92%	5.95%	4.72%
Site-D	D-B1	11.95%	11.72%	9.42%	11.03%
	D-B2	10.18%	7.65%	4.68%	7.50%
	D-H1	10.32%	9.80%	5.00%	8.37%
Site-E	E-B1	8.67%	5.80%	12.65%	9.04%
	E-B2	7.25%	14.18%	19.57%	13.67%
	E-H1	8.87%	12.47%	9.84%	10.40%
	E-H2	6.03%	13.28%	4.76%	8.02%
Average by Time Interval		8.85%	10.63%	10.51%	10.00%

5.4.5 Summary

The average observation error rates for full-observation were higher than those for partial-observation. The average error-rate-graphs of full and partial-observation indicate fairly similar trends. As noted above, there was approximately a 10% difference for each interval. Additionally, an average error rate graph of all sites by partial-observation was compared and it was almost identical to an average error rate graph of sites A, D, and E by partial-observation. Figure 33 shows the average observation error rate graphs of sites from full and partial-observation.

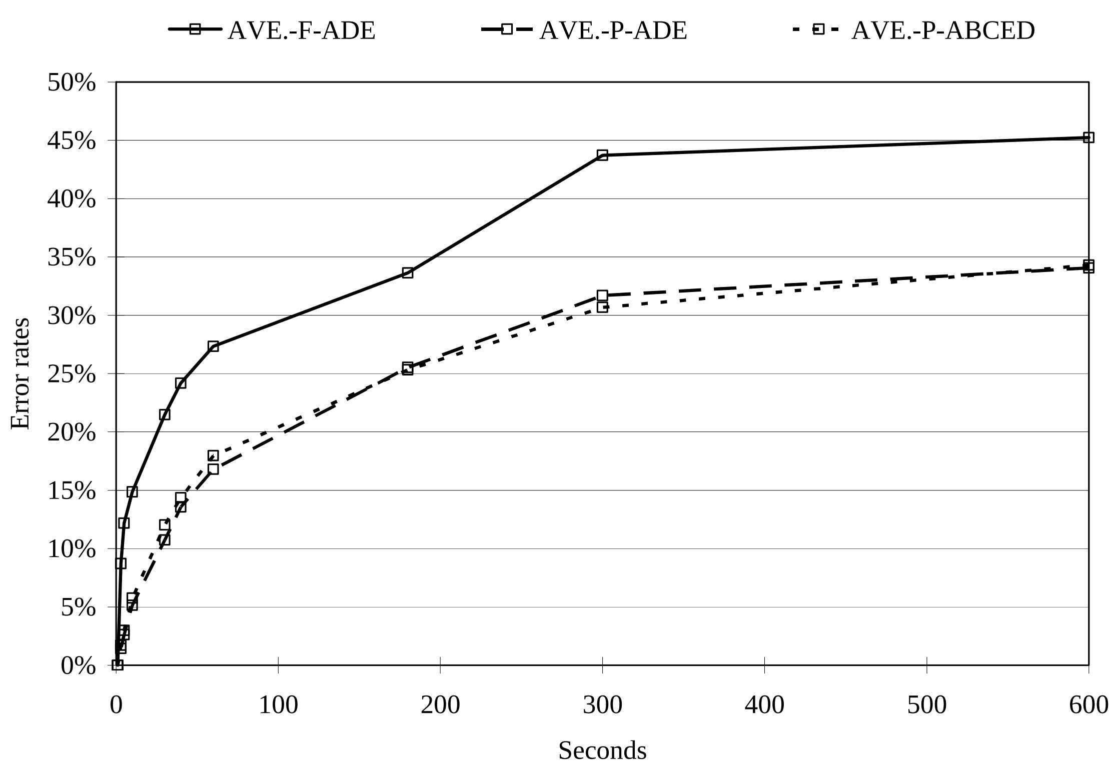

Fig. 33. Graphs of average observation error rate of sites from full and partial-observation

5.5 Discussion for Better Analysis

During the analysis of time-lapse photos, I discovered how difficult it is to categorize human behavior. Although there were three categories: effective, contributory, and ineffective work, many times the behavior of a worker was vague, making it challenging to judge what type of work the worker was performing. This problem happened more frequently as the time interval lengthened, but it also happened when examining one-second interval photographs.

The reasons for this problem at a long interval and a short interval were different. At a long interval, the main reason was that there was no clue what the worker was doing just before the observation. On the other hand, at a short interval, there were a number of reasons. First, relatively low-resolution photographs make it difficult to judge; second, a worker in the distance was hard to see; and third, although there were guidelines for defining worker activity, human behavior is so diverse that more detailed classification was needed in order to classify without ambiguity. Additionally, the analysis of all workers by examining all photographs was a repetitive and tedious task. Thus the examiner was easily distracted and could conceivably have lost his/her judgment.

In order to prevent this problem, increasing resolution of photographs, creating more detailed guidelines to classify worker activities, and taking a good rest during the examination of photographs are important for effective research. Additionally, observing and grading by multiple people instead of one person can be good to prevent errors from the bias that one observer can have.

CHAPTER VI

CONCLUSIONS & FUTURE RESEARCH

6.1 Introduction

This research started with a single question: how much could the frame rate of a webcam be lowered and still be able to monitor construction operations at a jobsite? Before initiating the research, a goal was set: to determine the maximum time interval for time-lapse photos that enable professionals to interpret construction operations and productivity. To achieve this goal, time-lapse photographs, using various time intervals, of brickwork were produced. Interpreting these photographs, observation error rates were collected and analyzed. Finally, the error rate graphs were generated and analyzed. The trend of error rate graphs were examined and interpreted to determine the maximum time interval for brickwork.

6.2 Conclusions

Overall trends of observation error rates by full and partial-observation were identified. The observation error rates of most workers by full and partial-observation increased rapidly until the 60-second interval; after that, they increased slowly. This was also confirmed from the shape of the average trendline of full and partial-observation. Because the steep slope implies that loss of much information happens between 1-second interval and 60-second, it is no wonder that 1-second interval is the best interval to monitor construction operations. However, in order to reduce review time and to use cellular webcams, longer than 1-second interval should be considered. Thus, it may be possible to use a 60-second or less interval photo set for interpreting construction operations and productivity, because the observation error rate slopes from 1-second interval to 60-second interval remain constant. This constant error rate slope will provide predictable error when professionals interpret construction operations or perform worker productivity studies. Thus we might consider a 60-second interval as the maximum time interval for time-lapse photos, to enable professionals to interpret construction operations and productivity.

However, there is another consideration. Because the observation error rate on intervals greater than 30-second varies too much according to workers, it is hard to generalize the error rate at the 60-second interval. For instance, the observation error rate of worker B2 of site-C at the 60-second interval is 27% while, at the same interval, the observation error rate of worker B2 of site D is 9%. Therefore, finding an observation error rate of each worker at the 60-second interval is necessary. In order to find the error rate at the 60-second interval, performing a pilot test could be one possible method to address this problem.

Additionally, the observation error rates of full-observation were higher than those for partial-observation, but the full and partial-observation error-rate-graphs of most workers showed similar trends. That means if a situation does not allow full-observation, partial-observation may substitute for full-observation by adding a certain amount of error rate.

After considering the above findings, with a 60-second interval error rate, the error rate at less than the 60-second interval might be predicted. These predicted observation error rates at less than 60-second interval would help professionals interpret worker activities and perform productivity studies.

6.3 Future Research

After the research, some questions have arisen. First of all, in this research, only brickworks at residential homebuilding sites were selected and analyzed and the 60-second interval was identified as a possible maximum interval for monitoring construction operations. If other work settings (for example, commercial building sites) are selected and analyzed, will the maximum interval remain the same as that for residential brickwork?

Second, as noted above, the error rate on intervals more than 30-second varies too much according to workers. According to the short analysis from worker B2 of site-D (the worker who worked the majority of the time) there was less room to detect errors. One must ask: is this discrepancy related to personal work behavior or to specific types of work behavior? If it is related to specific types of work behavior, can it be generalized? Research regarding those matters is worth conducting in the future and will complement this research.

Third, because the analysis of all photographs was conducted by one person, the results could be different due to the examiner’s different experience or interpretation of operations. Thus, despite the use of predefined classifying guidelines to judge worker activities, the result could differ from that of other people. Therefore, analysis of the same or similar photographs by other people and comparing the results would be worth conducting.

Finally, the purpose of monitoring construction operations in this research was mainly for productivity study. As noted in the introduction, recently, the purpose of using webcams on a jobsite is diversified and the safety management on sites is one of the main purposes. The use of webcams on a jobsite for safety, however, has been considered as an investigation tools for an accident that already happened rather than preventive tools for potential accidents. Thus the study about the potential use of a webcam as a preventive tool for accidents would be worth conducting and if it is, investigating the appropriate time interval for monitoring construction operations to prevent accidents would also deserve to study.

REFERENCES

Abeid, J., and Arditi, D. (2002). “Time-lapse digital photography applied to project management.” *J. Constr. Eng. Manage.*, 128(6), 530-535.

CDPD (Cellular Digital Packet Data) Technology Overview. (2001) (novatelwireless.com), Available: http://www.novatelwireless.com/support/CDPD%20Tech.html (Accessed: 2 May 2003).

Davies, S. G. (1998). “CCTV: a new battleground for privacy.” *Surveillance, closed circuit television and social control,* edited by C. Norris, J. Moran, & G. Armstrong, Ashgate, Aldershot, Hants, England, 243-254

Deng, Z. M., Li, H., Tam, C. M., Shen, Q. P., and Love, P. E. D. (2001). “An application of the Internet-based project management system [Electronic version].” *Automation in Construction*, 10, 239-246.

Everett, J. G., Halkali, H., and Schlaff, T. G. (1998). “Time-lapse video applications for construction project management.” *J. Constr. Eng. Manage.*, 124(3), 204-209.

Geier, J. (2002) “The BIG Question: 802.11a or 802.11b?”, (wi-fiplanet.com), Available: http://www.wi-fiplanet.com/columns/article.php/961181 (Accessed: 22 May 2004).

Gilbreth, F. B. (1909). *Bricklaying system*. The Myron C. Clack Publishing Co., London

Gilbreth, F. B., and Gilbreth, L. M. (1973). *Applied motion study*. Hive Publishing Company, Easton, PA.

Kumar, R. (2002). “Aerial video surveillance and exploitation.” *Video-based surveillance systems computer vision and distributed processing*, edited by P. Remagnino, G. A. Jones, N. Paragios, & C. S. Regazzoni, Kluwer Academic., Norwell, MA, 29-38

Lyon, D. (2001). *Surveillance society monitoring everyday life*. Open University Press., Buckingham, England.

Marks, L. V. (2003) “The 802.11g standard -- IEEE .”, (ibm.com), Available: http://www-106.ibm.com/developerworks/wireless/library/wi-ieee.html#author1 (Accessed: 22 May 2004).

McCormack, C. (2002) “Simplify your life. Visit your construction sites online.”, (oxblue.com), Available: http://www.oxblue.com/resources/Article_SimplifyYourLife_2002a.pdf (Accessed: 5 June 2003).

Moran, J. (1998). “A brief chronology of photographic and video surveillance.” *Surveillance, closed circuit television and social control*, edited by C. Norris, J. Moran, & G. Armstrong, Ashgate, Aldershot, Hants, England, 277-287

Norris, C., and Armstrong, G. (1998). “Introduction: power and vision.” *Surveillance, closed circuit television and social control*, edited by C. Norris, J. Moran, & G. Armstrong, Ashgate, Aldershot, Hants, England, 3-18

Norris, C., Moran, J., and Armstrong, G. (1998). "Algorithmic surveillance: the future of automated visual surveillance." *Surveillance, closed circuit television and social control*, edited by C. Norris, J. Moran, & G. Armstrong, Ashgate, Aldershot, Hants, England, 255-275

Oglesby, C. H., Parker, H. W., and Howell, G. A. (1989). *Productivity improvement in construction.* McGraw-Hill Inc., New York, N.Y.

Stafford-Fraser, Q. (1995) "The Trojan Room Coffee Pot.", (cam.ac.uk), Available: http://www.cl.cam.ac.uk/coffee/qsf/coffee.html (Accessed: 7 March 2003).

Staples, W. G. (2000). *Everyday surveillance vigilance and visibility in postmodern life*. Lanham, MD: Rowman & Littlefield.

Soldatini, F., Mähönen, P., Saaranen, M., and Regazzoni, C. S. (2000). "Network management within an architecture for distributed hierarchial digital surveillance systems." *Multimedia video-based surveillance systems requirements, issues and solutions,* edited by G. L. Foresti, P. Mähönen, & C. S. Regazzoni, Kluwer Academic, Norwell, MA, 143-157

Timothy, D. J., and Groves, D. L. (2001). "Research note: webcam images as potential data sources for tourism research" *Tourism Geographies*, 3(4), 394-404.

What s a Network Camera. (2002) (axis.com), Available: http://www.axis.com/documentation/whitepaper/video/what_is_network_camera.pdf (Accessed: 17 May 2003).

Wireless 2.4GHz Internet Camera. (2002) (d-link.com), Available: http://www.d-link.com/products/?model=DCS-1000W (Accessed: 2 May 2003).

APPENDIX

APPROVED IRB PROTOCOL

VPR Office of the Vice President for Research

Office of Research Compliance

Administration and Special Programs

Academy for Advanced Telecommunication and Learning Technologies

Institute for Scientific Computation

Laboratory Animal Resources and Research

Microscopy and Imaging Center

Office of Business Administration

Office of Graduate Studies

Office of Sponsored Projects

Texas A&M University Research Park

Date February 25, 2004

MEMORANDUM

TO: Jiwon Choi
COSC
MS 3137

FROM: Dr. E. Murl Bailey, CIP, Advisor
Institutional Review Board
MS 1112

SUBJECT: IRB Protocol Review

Title: "Investigating Maximum Time Interval for Monitoring Construction Operations"

Protocol Number: 2004-0079
Review Category: Exempt from Full Review
Approval Date: February 25, 2004 **to** February 24, 2005

The approval determination was based on the following Code of Federal Regulations
http://ohrp.osophs.dhhs.gov/humansubjects/guidance/45cfr46.htm

________ **46.101(b)(1)**	________ **46.101(b)(4)**
✓ **46.101(b)(2)**	________ **46.101(b)(5)**
________ **46.101(b)(3)**	________ **46.101(b)(6)**

Remarks: Request of waived signed consent has been approved.

The Institutional Review Board – Human Subjects in Research, Texas A&M University has reviewed and approved the above referenced protocol. Your study has been approved for one year. As the principal investigator of this study, you assume the following responsibilities:

***Renewal*:** Your protocol must be re-approved each year in order to continue the research. You must also complete the proper renewal forms in order to continue the study after the initial approval period.

***Adverse events*:** Any adverse events or reactions must be reported to the IRB immediately.

***Amendments*:** Any changes to the protocol, such as procedures, consent/assent forms, addition of subjects, or study design must be reported to and approved by the IRB.

***Informed Consent/Assent*:** All subjects should be given a copy of the consent document approved by the IRB for use in your study.

***Completion*:** When the study is complete, you must notify the IRB office and complete the required forms.

Texas A&M University

1112 TAMU
318 Administration Building
College Station, Texas
77843-1112

979.845.8585
FAX 979.862.3176

PART 46.101 PROTECTION OF HUMAN SUBJECTS

46.101

(a) Except as provided in paragraph (b) of this section, this policy applies to all research involving human subjects conducted, supported or otherwise subject to regulation by any Federal Department or Agency which takes appropriate administrative action to make the policy applicable to such research. This includes research conducted by Federal civilian employees or military personnel, except that each Department or Agency head may adopt such procedural modifications as may be appropriate from an administrative standpoint. It also includes research conducted, supported, or otherwise subject to regulation by the Federal Government outside the United States.

(1) Research that is conducted or supported by a Federal Department or Agency, whether or not it is regulated as defined in 46.102(e), must comply with all sections of this policy.

(2) Research that is neither conducted nor supported by a Federal Department or Agency but is subject to regulation as defined in 46.102(e) must be reviewed and approved, in compliance with 46.101, 46.102, and 46.107 through 46.117 of this policy, by an Institutional Review Board (IRB) thatoperates in accordance with the pertinent requirements of this policy.

(b) Unless otherwise required by Department or Agency heads, research activities in which the only involvement of human subjects will be in one or more of the following categories are exempt from this policy:[1]

(1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless:
(i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

(3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if:
(i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) Federal statute(s) require(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

(4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

(5) Research and demonstration projects which are conducted by or subject to the approval of Department or Agency heads, and which are designed to study, evaluate, or otherwise examine:
(i) Public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

(6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed or (ii) if a food isconsumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

Revised December 15, 2003

Texas A&M University
IRB Application
Protocol for Human Subjects in Research
Part I: Summary Cover Sheet

IRB # 2004-0079
(Internal use only)
COPY

If Requesting Exempt Status, Check Here ✔ (Exemp from Full Board Review)
Please check or provide details on the following information (enter N/A if not applicable)
New submission ✔ Re-submission ____ (IF protocol was disapproved)
Principal Investigator Name Jiwon Choi Faculty ____ Staff ____ Graduate Student ✔ Undergraduate Student ____
Department COSC Mail Stop 3137 Phone 979-458-3414
Email z1choi@tamu.edu Fax 979-862-1517
Is this study part of a Thesis or Dissertation? Yes ✔ No ____ If Yes, do you have Committee Approval? Yes ✔ No ____

Co-Principal Investigator Name ____ Faculty ____ Staff ____ Graduate Student ____ Undergraduate Student ____
Department ____ Mail Stop ____ Phone ____
Email ____ Fax ____

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Research Compliance
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Graduate Committee Chair/Faculty Advisor Name (if student) Dr. Julian H. Kang
Department COSC Mail Stop 3137 Phone 979-845-7055
Email juliankang@tamu.edu Fax 979-862-1517

Project Title Investigating Maximum Time Interval for Monitoring Construction Operations

Funding Agency N/A
Funding Administrator: RF ____ TAES ____ TEES ____ TAMU ____ TTI ____
Funding Status: Funded ____ Not Funded ____ Pending ____ **(Please attach a copy of Grant Proposal)**
Funding Amount ____
Risk Management Matrix

		Probability That Something Will Go Wrong			
		A Likely to occur immediat ely or in a short period of time, expected to occur frequently	**B** Probably will occur in time	**C** May occur in time	**D** Unlikely to occur
Seriousness of Risk	**I** May result in death	5	5	4	3
	II May couse severe injury, major damage or loss, and/or result in negative publicity for the participant involved	5	4	3	2
	III Participation presents a minimal threat to safety, health and well-being of participants	4	3	2	1
	IV No more than minimal risk	3	2	1	1

Red Zone - 4 thru 5 Yellow Zone - 2 thru 3 Green Zone - 1

If your protocol falls in the **Yellow** or **Red Zone** please call (979) 458-3624 for further instructions.

Seriousnes of Risk IV **Probability That Something Will Go Wrong** D
These three fields must be answer

Activity	Associated Risks	Method to Manage
None	None	None

Page ____ of ____

Revised December 15, 2003

Objective Estimate of Risk to Subject: None ✓ Low ___ Moderate ___ High ___

Will Existing Documents Be Used? Yes ___ No ✓ Will Existing Specimens Be Used? Yes ___ No ✓

Research Methodology: Qualitative___ Quantitative ✓ Both___

Gender of Subjects: Male ___ Female ___ Both ___ Estimated Age of Subjects N/A Total Participants (est.) N/A

Location of Research: N/A

Subjects Recruited From:
___Psychology Subject Pool
___Other Subject Pool ______
___Other TAMU Students
___Community
___Women/Fetuses
___Children
___Treatment Centers
___Hospitals
___Prisoners
___Schools
___Others ______

Recruitment Method:
___Direct person-to-person contact
___Telephone solicitation (attach script)
___Newspaper Advertising (attach ad copy)
___Posted Notices (attach copy)
___Letter (attach copy)
___Other (describe)______

Compensation for Subjects Yes___ No___ (If Yes, attach regular payment schedule)
Deception Used Yes___ No___ (If Yes, attach debriefing form)
Research/Course Credit for Subjects Yes___ No___

Invasive or Sensitive Procedures: Yes___ No___
___Blood Samples
___Urine Samples
___Physical Measurements (electrodes, etc.)
___Stress Exercise
___Review of Medical/Psychological Records
___rDNA
___Other (specify)______

Sensitive Subject Matter: Yes___ No___
___Abortion
___AIDS/HIV
___Alcohol
___Body composition
___Criminal activity
___Depression
___Drugs
___Other (specify)______
___Learning Disability
___Psychological inventory
___Sex
___Suicide

Use of Video or Audio Taping None
If yes, answer the following:
Retained Yes___ No___
Length of time retained: ______
Destroy/Erase Yes___ No___
Other ______
Use specified in consent form Yes___ No___

Provisions for Confidentiality/Anonymity
___Replies Coded
___Secure Storage
___Anonymous Response OR
___Confidential
(Cannot be both anonymous and confidential)

Requesting waiver of signature on consent form. Yes ✓ No ___ If Yes, Attach justification for waiver request. Criteria for waiver request can be found in the Federal Regulation section 45 CFR 46.116 and 46.117 at the following web address: http://ohrp.osophs.dhhs.gov/humansubjects/guidance/45cfr46.htm#46.116
Location where consent forms will be filed: N/A
(Consent forms must be kept on file for 3 years after the completion of the project. It is best to keep the forms in a campus office in a locked filing cabinet. If you are requesting a waiver of signature on the consent form, this question does not apply to you.)

Do you have any relationship with any or all of the subjects, other than your investigator role? Yes___ No___
If yes, you must explain the relationship in the "**Selection of Subjects**" section and how you will avoid any type of coercion (doctor-patient, teacher-student, counselor-student, etc.)

Abstract: Please provide a brief statement, in lay terminology, outlining the purpose of this study. *(Why you are doing this research project, and what you propose to learn.)*

A webcam is one of the tools to be used to monitor construction operations at a jobsite. Considering that more than 50% of construction operations are implemented inside a building, wired webcams can hardly be utilized for monitoring interior construction operations. Instead, a cellular-webcam (cellular phone + webcam) is expected to help professionals enhance their ability to monitor interior construction operations. However, the bandwidth for cellular-webcams is much narrower than that of wired webcams. Transmitting a picture via a cellular-webcam may take much more time. Long-interval time-lapse photos transmitted from a cellular-webcam may hinder construction professionals from fully interpreting construction operations. Therefore, investigation of an appropriate time interval of a cellular-webcam for monitoring construction operations is necessary. The primary goal of this research is to determine the maximum time interval for time-lapse photos that enable professionals to interpret construction operations.

Page ___ of ___

Email irb@tamu.edu or call (979) 458-4067 with any questions regarding this form.

Revised December 15, 2003

REQUEST FOR EXEMPTION from full IRB review

Some research projects involving human subjects are exempt from full review by the IRB. See the attached sheet on research categories exempt from full IRB review. *(Sensitive topics and subjects such as children or minors, pregnant women and prisoners are not considered for exempt research).*

Basis for Exemption [Please refer to attached "Categories Exempt From Full IRB Review."]
(Do not check unless requesting an exemption from full IRB review.)

_____Established Educational Settings/Normal Educational Practices(a letter of approval from a school official must be obtained and submitted to the IRB before the study can be conducted)**(studies with children or minors are not exempt)**

_____ Use of educational anonymous tests (cognitive, diagnostic, aptitude, advancement; **attach copy).**

_____ Survey or interview procedures, **[unless** identifying subjects places them at legal or personal risk, and unless survey or procedures deal with sensitive matters of personal behavior]

_✔_ Observations of public behavior **[unless** identifying subjects places them at legal or personal risk, and unless observations deal with sensitive matters of personal behavior]

_____ Anonymous collection or study of existing documents, records, pathological or diagnostic specimens which are without any identifiers or codes.

_____ Evaluation of agencies and programs for administrative purposes where there was no deviation from standard practice.

_____ Taste and food quality evaluation and consumer acceptance studies.

The U.S. population is becoming increasingly culturally, linguistically, economically, and ethnically diverse. The research needs to make a concerted effort to ensure that research subjects reflect the population demographically, including these groups who have been traditionally under represented. However, it is recognized that the available pool of subjects may preclude having a balanced population. If you cannot use a diverse population in your research, you must justify this action in Part II, A, 1.

NOTE: The IRB makes the final decision whether or not a proposal is exempt from full IRB review.

Please check with the IRB Program Coordinator (979-458-4067). Exempt proposals require an original and two (1) copies of each instrument, i.e., Part A, Part B (with signatures), consent forms, research instrument, recruitment materials, etc. Full IRB review proposals require an original, with signatures, and 3 full copies, including research instrument, consent forms, recruitment materials, etc.

Revised December 15, 2003

Part II:

Part A

I have read the Belmont Report, "Ethical Principles and Guidelines for the Protection of Human Subjects of Research" and subscribe to the principles it contains. In light of this Declaration, I present for the Board's consideration the following information, which will be explained to the subject about the proposed research.

Signature ____________________________________

Principal Investigator Jiwon Choi

1. Selection of Subjects

a. Source and number
N/A

b. Method of recruitment and selection
N/A

c. Ages and gender
N/A

d. Compensation
N/A

e. Location and duration of experiment
N/A

f. Specific steps to ensure confidentiality or anonymity of responses of results
N/A

g. The investigator's relationship to subjects
N/A

2. Purpose of study

The purpose of this research is to determine the maximum time interval for time-lapse photos that enable professionals to interpret construction operations.

3. Research procedures

1. Five residential construction sites in the Bryan/College Station area will be selected for this research.
2. The bricklaying work of each site will be videotaped for one hour.
3. A total of 3600 photos will be produced from one-hour recording using video editing program.
4. A total of 10 different interval photo sets will be made from the 3600 photos.
5. Each worker activity in each photo will be examined, and each worker will receive a point value per one-second time-frame according to predefined guidelines.
6. Observation error will be obtained by comparing each frame value of a worker in one-second interval photo set with the same frame value of the worker in different interval photo set.
7. With the obtained observation error data, a graph of broken lines that show the errors along the time-frames will be drawn.
8. The trend of the lines will be examined and interpreted to determine the maximum time interval for time-lapse photos.

a. Physical/Behavioral Aspects

N/A

b. Deception of Coersion

N/A

4. Risks and Benefits to Subjects

a. A description of any potential risks of discomforts to the subject.

N/A

b. A definition of benefits to the research subject or alternatives for participation in the study.

N/A

c. Do not include broad benefits to society of potential research benefits to a group as a benefit to the subjects.

Revised December 15, 2003

original signature pg in file

Part B.

SIGNATURE ASSURANCE: ***(this should be the last page of the protocol application before attachments)***

Principal Investigator/Graduate Student Assurance Statement:

I understand Texas A & M University's policy concerning research involving human subjects and I agree:

1. To accept responsibility for the scientific and ethical conduct of this research study;
2. To obtain prior approval from the Institutional Review Board before amending or altering the research protocol or implementing changes in the approved consent form:
3. To immediately report to the IRB any serious adverse reactions and/or unanticipated effects on subjects which may occur as a result of this study;
4. To complete, on request by the IRB, the Continuation/Final Review Forms.

SIGNATURE: ______________________ DATE: __________

TYPED NAME: Jiwon Choi E-MAIL: z1choi@tamu.edu

***Faculty/Research Advisor's Assurance Statement:**

I certify that I have read and agree with this proposal, that the PI has received adequate training to perform this research, and will receive adequate supervision while performing this research.

SIGNATURE: ______________________ DATE: __________

TYPED NAME: Dr. Julian H. Kang E-MAIL: juliankang@tamu.edu

*** If the principal investigator is completing this project to meet the requirements of a Texas A & M University academic program, or is a student, both the student's faculty/research advisor and the departmental head should sign the Signature Assurance Sheet.**

****Department Head**

This is to certify that I have reviewed this research protocol and agree that the research activity is within the mission of the Department and appropriate for the responsibilities and assigned duties of the principal investigator.

SIGNATURE: ______________________ DATE: __________

TYPED NAME: Dr. James C. Smith E-MAIL: jsmith@archone.tamu.edu

****If the principal investigator is also the Department Head , the College Dean or equivalent should sign the Signature Assurance Sheet.**

Email irb@tamu.edu or call (979) 458-4067 with any questions regarding this form.

VITA

Ji Won Choi

25-25 Guui-2 Kwangjin

Seoul, Korea 143-816

EDUCATION

M.S.	Construction Management	Texas A&M University	August 2004
B.S.	Architecture	Hanyang University	February 1992

WORK EXPERIENCE

Intern	FaulknerUSA, Inc. (Landmark Organization LP), Austin, Texas May 2002 - August 2002 Assisted project manager on a jobsite
Manager	Myoung-In Architects & Engineers Co., Ltd., Seoul, Korea September 1996 - July 2001 Designed commercial buildings in Korea
Self-employed	Chang-In Interior Design & Construction Co., Seoul, Korea May 1995 - September 1996 Designed and built homes and shops
Site-engineer	Sung-Il Construction Co., Ltd., Seoul, Korea February 1992 - May 1995 Built commercial buildings and high-rise apartment buildings

HONORS AND PRIZES

CH 2M Hill Scholarship	The Department of Construction Science (March 2002)
O. N. Mitchell Fellowship	The Department of Construction Science (August 2001)
Employee of the Year	Sung-Il Construction Co., Ltd. (December 1993, 1994)