A Field-Oriented Test-Simulation of Embedded Lift Information System for High Rise Building

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ABSTRACT

For the past few years, numerous high-rise buildings have been built all around the world. Among them, vertical movement management of materials and labors is closely related to productivity of super-high rise construction. The objective of this study is to develop an embedded lift information system(ELIS) which can increase productivity of multi-cage temporary lift for construction site. And verify usefulness of ELIS through field-oriented test-simulation. The algorithm used in this system is expected to enable efficient respond to complex movement in high-rise construction lifts by applying principles of the vertical lifting operation. The developed algorithm can optimize lift operation time by using lifting cycle estimating method which is generated based on installed lift's specification and real-time sensor data. Current status of lift uploaded transmitted sensor data every two seconds on average has become a vital part of arithmetic computation based on current optimum lift selection algorithm. This algorithm process is main decision-maker of ELIS based lift control module. This and follow-up study aim to develop unmanned smart construction lift with a goal of improve productivity and safety of vertical lifting in high-rise construction site.

Keywords -
Construction Lift; ELIS(Embedded Lift Information System); High-Rise Building

1 Introduction

Numerous super high-rise buildings have been built around the world, and many more are planned to be built that are often over 100 stories high[1]. Larger, higher buildings are subject to more restrictions in terms of construction planning and operation[2]. Among them, movement management of materials and labors is closely related to productivity of super-high rise construction, and its importance grows as the buildings become higher.

Currently, at super high-rise construction sites, an experienced site supervisor and operator manage the lift operation for movement of materials and labors[3]. This lowers efficiency of vertical movement in operating construction lift. The lift user's queue time increases in higher buildings.

Several construction lifts are planned and built in constructing super high-rise buildings over 100 stories. Unlike elevators installed at the core of the structure, construction lifts are built outside the building, upon the mast, and they are hard to control in an integrated manner. Often construction lifts are operated redundantly, delaying construction schedule in a large project. Given these circumstances, this study conducts a simulation on construction lift operation, explores how to improve movement of materials and labors in super high-rise construction by developing optimized operation algorithm. The simulation results are assessed based on the cycle time of daily unit work processes according to lifting cycle time calculation (Cho, 2010).

2 Research Trend

Sacks et al. developed an automated lifting equipment monitoring system (Sacks et al, 2005). Cho et al. conducted a study on construction lift operation planning in terms of lifting height and loading (Cho, 2011). Further, Shin proposed optimal operation of temporary construction lifts in a super high-rise building based on simulation and genetic algorithm. Before them, most studies focused on the use of tower crane or mobile crane, and other studies on construction lift tended to emphasize lifting planning rather than lifting operation.

As super high-rise construction becomes more popular in Korea, there is a growing need for a systematic construction planning and site management. The government and private corporations are actively undertaking studies on operation planning of construction lifts and tower crane lifting. Kim et al. studied how to calculate a number of necessary construction lifts at super high-rise construction site (2008), and Shin et al. (2010) proposed a construction lift movement planning model for super high-rise construction. Cho et al. (2011) proposed an algorithm that calculates lifting time in consideration of acceleration and deceleration capability of construction lifts (2011). While there are many studies on construction lift planning, few have been conducted on the system, management and algorithm of construction lift operation, with no empirical analysis.

3 Smart Lift

This study aims to advance construction technology of super high-rise buildings, with a goal to optimize vertical lifting of materials and labors in erecting a super high-rise building.

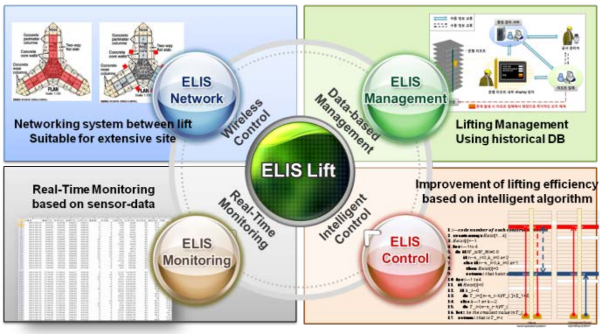

Figure 1. Component of ELIS-Lift

In this study, the designed smart lift is operated by main head-server named ELIS(Embedded Lift Information System). Collecting data and data analysis are performed in ELIS simultaneously. This ELIS based operation order will be expected to optimize vertical lifting of materials and labors in high-rise building construction site. Therefore, the focus is on measuring effectiveness of ELIS based construction lift operation through field-oriented test.

3.1 Embedded Lift Information System

The highest building in the world, Burj Khalifa, used 17 vertical construction lifts during the construction. Each mast is put in different places, depending on the site conditions, and currently, work schedule is made to prioritize the order of materials and labors for integrated management. However, only with predetermined scheduling before beginning construction step, it is hard to flexibly respond to the unexpected situations at the site. Thus, an integrated control system is needed to manage construction lift operation.

The control server examines algorithm to select the optimum construction lift, requesting the following data:

1. Velocity of Lift car
2. Position of Lift car
3. Direction of Lift car
4. Real-time available transportation capacity

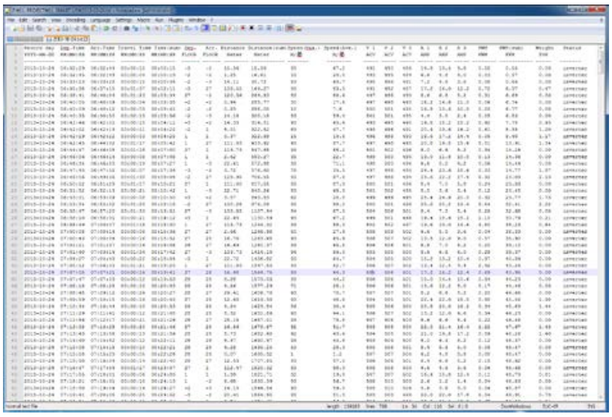

Figure 2. Text type daily lift database output

The smart lift algorithm flow basically depends on elevator distribution algorithm for labor movement Figure. 2. The difference between elevator is that the control server analyses condition of the construction lifts by receiving operation data from the wireless network. Data related lift operation includes Velocity, Current Position, Moving Direction, Weight, Electricity Power, Cable tension and Guide roller status. We set up data intervals 200ms for this server system.

The system named ELIS(Embedded Lift Information System) stands on basis sensor device data. The sensor module consist of Double Senor type Encoder, Limit Switch, Separating type Current Transformer, Proximity Sensor, Load Cell. Figure 2 shows text type lift operation database.

Figure 3. ELIS display for equipment manager

Original purpose of ELIS database system designed for lift safety monitoring and sending the out-of-order signal. But this information data has more important value by using computational algorithm.

Figure 4. ELIS display for construction manager

3.2 Lift control based on ELIS

In this study, a test simulation was conducted for the operation information system that manages four construction lifts. Figure 4 illustrates a display device that shows detailed information and operation status of construction lifts on the control server

Each construction lift requires information collecting device to send four sets of real-time data to the wireless network as shown above. The double sensor type position detector provides information on the direction and position of a construction liftt. In the detector, two proximity sensors read grooves of the internal gear to detect upward or downward movement of a construction lift, and examine rotation of the rack gear to calculate the velocity.

Figure 5 Lift control management U/I

The construction lift moving information collected by the sensors is transmitted to the control. The information provides a basis for the algorithm to select optimum construction lift when the next call comes in. The information provides a basis for the algorithm to select optimum construction lift when the next call comes in. Figure 6 describes the selection flow, how it eliminates unsuitable construction lifts by lift direction, present location and load capacity. As described Figure 6, ELIS basically use sensor data for two kinds of purpose as moving DB and Error detect DB. Even though the preliminary purpose of each data type, both data are finally matched in display process to calculate digits for what manager wants.

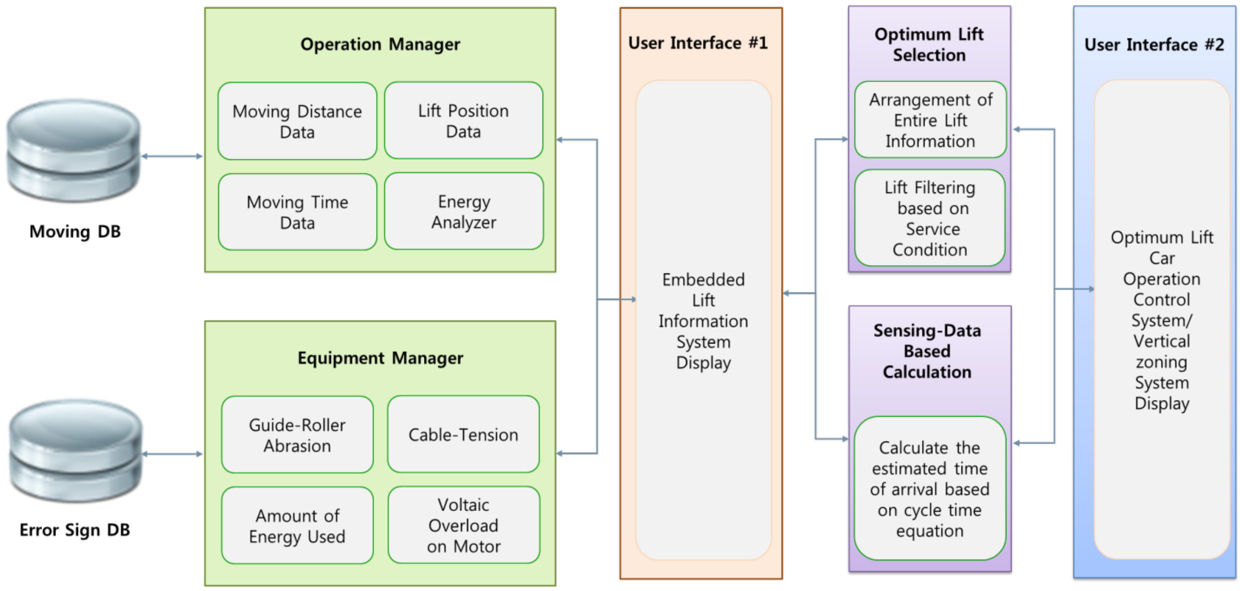

Figure 6. Data Flow in ELIS smart lift control system

4 Field test simulation

The algorithm flow Figure 7 shows a moving order system that yields the order of lift car selection based on cycle time calculation. First round of selecting is done by moving control U/I considering the present load capacity and accordance of the direction. Second round of selecting is done by rule of lift cycle time equation calculating the lift with minimum travel time.

After the first round of filtering, travel time is calculated for the remaining lifts; the calculation formula are different for lifts that are presently operating and lifts that are idle at the moment. It is because time for power supply, acceleration and reduction should be considered. For example, acceleration time needs not be considered for currently operating lift; only deceleration time matters at time of arrival.

The following hypotheses were adopted to verify workability of the proposed twin or multi-cage operation algorithm.

First, except for the ground floor, all floors have a same floor height.

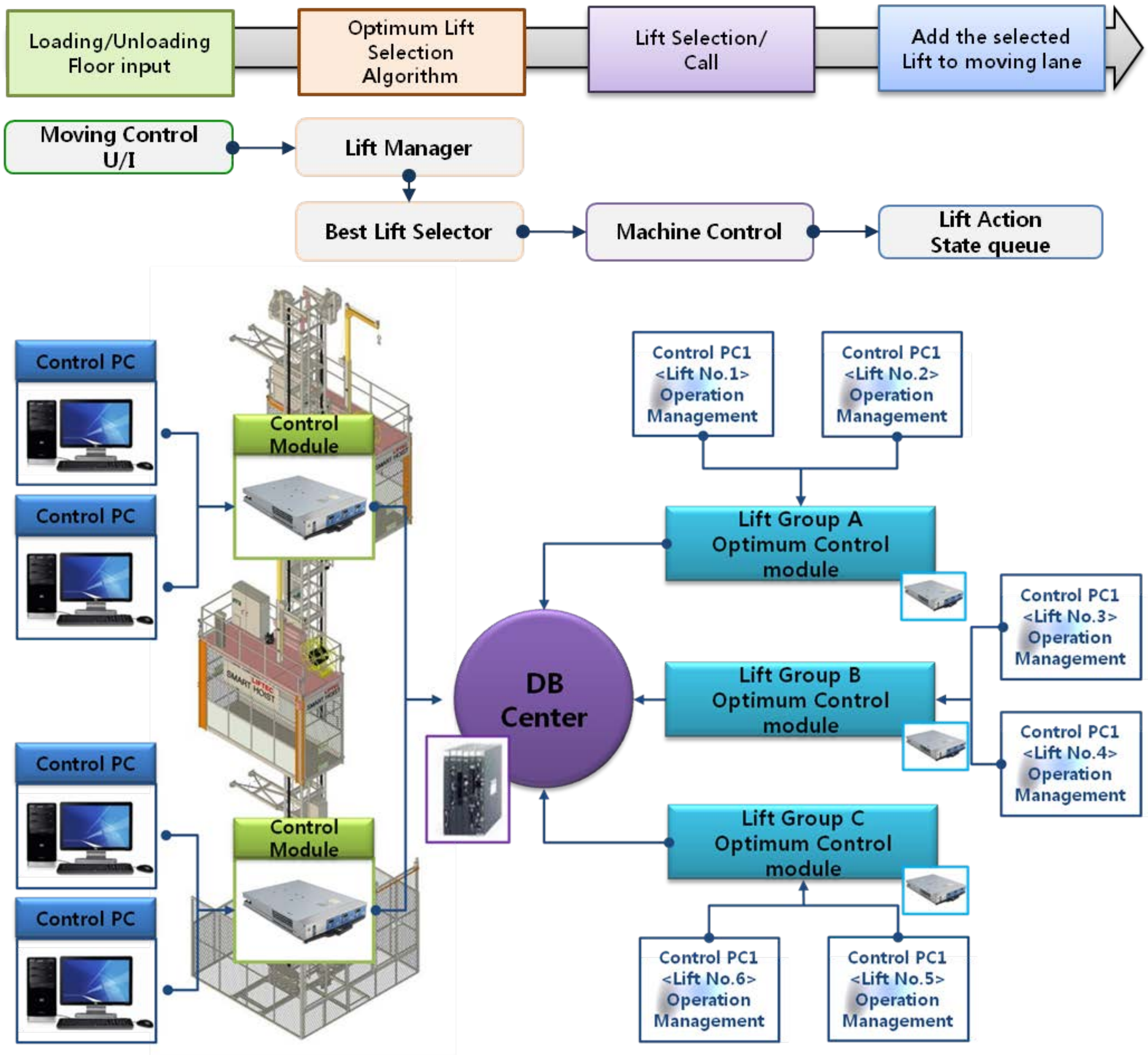

Figure 7. Lift hardware information & control algorithm flow

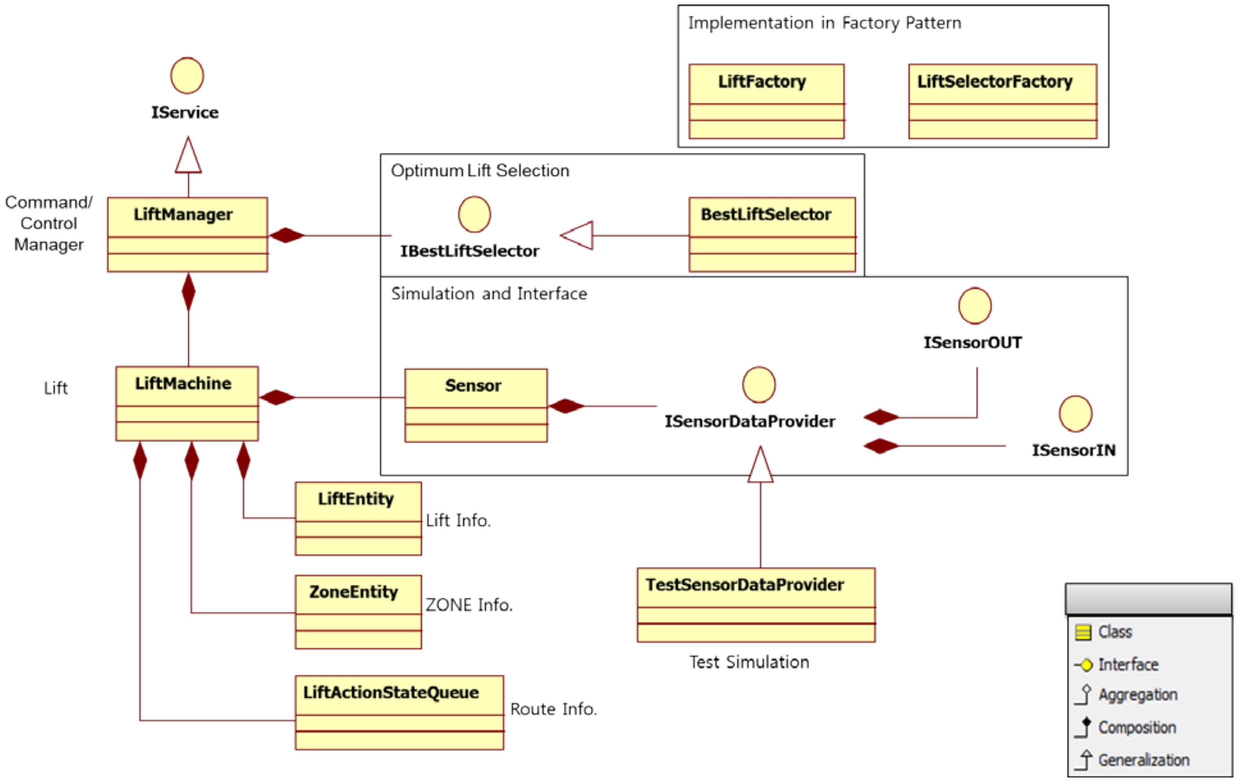

Figure 8. Simulation test flow

Second, the building has two masts and four construction lifts.

Third, when a floor call comes in and a selected construction lift begins to move, other lifts do not respond.

Fourth, rated velocity, acceleration and reduction time are pre-set for each type of construction lift. More specifically, velocity of construction lift A and D is 100m/min; their acceleration and reduction capacity are 0.60m/sec ^{2} and 0.57m/sec ^{2} respectively. For construction lift B and C, the velocity is 70m/min, and their acceleration and reduction capacity are 0.55m/sec^2 and 0.53m/sec^2 respectively. In other words, operation speed and acceleration speed are given as constant, not variables, in an algorithm for optimum construction lift selection. Fifth, considering that a construction lift moves materials and labors at the same time, algorithm process identifies construction lifts that are operating over 80% of the load capacity.

Sixth, since this study deals with lifting operation rather than lifting planning, the optimum travel route will be to assign a construction lift for materials and labors in the shortest time.

An analysis was made on the lifting operating simulation to examine reliability of the optimum construction lift selection algorithm according to the six aforementioned conditions.

Figure 9. Data box in field test

The study conducted simulation to measure lifting cycle time of the materials, and the result was compared to the manual construction lift operation. Currently, an operator judges the floor calls, and sometimes multiple lifts are operated redundantly, lacking information on their status. This happens because an operator merely responds to floor calls without considering the overall management of the lifting operation.

The proposed algorithm for selection of optimum unmanned smart lift uses a formula to decide travel route that reduces total cycle time, and it can solve the problem of redundant operation. The lifting model was based on the lifting cycle time of four construction lifts; assuming that the lifts are in operation, current position, direction, velocity, weight and call order were randomly assigned to each lift.

Figure 10. Installation sensor module and gear

Then, floor calls were generated at random floors at a regular interval to calculate lifting cycle time for both the current system and the proposed algorithm for optimum construction Lift selection.

Table 1 Simulation Conditions

Loading/ Unloading Time	0.1 min	Door Open/Close Time	0.05 min
Total floor	30	Number of Lift	4

	Lift A	Lift B	Lift C	Lift D
Lift Model	High Speed	Medium Speed	Medium Speed	High Speed
Maximum Capacity	3000kg	2000kg	2000kg	3000kg
Weight	600kg	1000kg	800kg	0kg
Velocity	100 m/min	70 m/min	70 m/min	0 m/min
Direction	↑	↓	↓	-
Floor	9	27	23	5
Call Floor	15	21	9	-
Target Floor	1	1	25	-

Lifting Priority	Call Floor	Floor call Time	Target Floor
1	13	0:00	1
2	7	0:30	1
3	17	1:00	18
4	29	1:30	13

Cycle time was calculated based on the cycle time calculation formula (Cho et al, 2010)[7].

As a result in simulation via simulation model table 1, cycle time data of two masts is table 2 and table 3. When 4 hoists in 2 masts are operated under twin or multi-cage algorithm, in following table2 and 3, every possible duplicated operation can be eliminated. Black marked part means selection of hoist at floor call is occurred.

When 4th floor calls are occurred through simulation condition of table 1. The time spending for total lifting is 154.25sec considering material loading time and door-open time.

Table 2 Operation Cycle Time <Mast 1>

	Lift A		Lift B		
Event	(↑/↓)	Floor	(↑/↓)	Floor	Time (sec)
FLOOR CALL A	↑	9	↓	27	0.00
ARRIVE FLOOR CALL A	-	15	-	21	19.62
FLOOR CALL B	↓	12	↓	20	30.00
ARRIVE FLOOR CALL B	↓	3	↓	14	49.70
FLOOR CALL C	-	1	↓	11	60.00
FLOOR CALL D	↑	11	↓	2	90.00
ARRIVE FLOOR CALL C	-	17	-	1	104.81
FINISH EVENTS	-	18	-	1	154.25

Table 3 Operation Cycle Time <Mast 2>

	Lift C		Lift D		
Event	(↑/↓)	Floor	(↑/↓)	Floor	Time (sec)
FLOOR CALL A	↓	23	-	5	0.00
ARRIVE FLOOR CALL A	↓	16	-	13	19.62
FLOOR CALL B	↓	12	↓	12	30.00
ARRIVE FLOOR CALL B	-	7	↓	4	49.70
FLOOR CALL C	↓	6	-	1	60.00
FLOOR CALL D	-	1	-	1	90.00
ARRIVE FLOOR CALL C	-	1	↑	7	104.81
FINISH EVENTS	-	1	-	25	154.25

5 Conclusion and Further Study

In this study, we proposed a ELIS(Embedded Lift Information System) based smart lifting system and devised an optimum construction Lift control algorithm on twin or multi-cage. And verify the productivity of proposed system through field-oriented simulation test. Proposed control system is considering lift velocity, direction, position and weight capacity. Using optimum construction lift selection algorithm process, eliminate all the duplicated call operation and minimize the queue time of materials and labors.

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