A Concept Study on Wearable Cockpit for Construction Work
- not only for machine operation but also for project control -

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ABSTRACT: Construction work needs in many cases human sense and decision, and consist in combination of every task and machine. In this aspect it must be effective that an operator can proceed a project while she/he is managing and operating tasks and several machines at a site with just-in-time accurate decision by means of constant monitoring. The existence of human being however causes problems as human inefficiency, inaccuracy and occupational danger and strain. And simple extension of object in operation, from a machine to all tasks in a project, is afraid to result only in increase of work load for a person.
The wearable cockpit aims total control of a construction project. This means extension of the concept "to a cockpit for project control from that for only operation of a machine". This concept includes multi-operation of several machines and total management of all tasks at a site. In the concrete the wearable cockpit includes 1) a tele-operation system for multi-operation, 2) assistance of decision making inclusive of enhancement of recognizing ability in time and space, 3) optimal task ordering and 4) optimizing of machines.
In this study we consider to apply a RFID system with AR technology to the enhancement of recognition inclusive of on demand visual communication. For task ordering and machine optimizing, analysis of time allowance in each sequence is considered. On the automation unfriendly sequence a tele-operation system is usefully applied. By means of these kinds of assistance an operator makes accurate decision timely. Besides the human decision making lightens difficulty and costs for filling construction up with automation.
As a result of these considerations an operator can control a project accurately and efficiently with technology of wearable equipment.

KEYWORDS: Wearable Cockpit, Augmented Reality (AR), Radio Frequency Identification (RFID), Embedded System, Wearable Computer, Project Control.

1. INTRODUCTION

Inclusive of not only many private cars but also industrial vehicles, which include for example construction machines, loading machines and trains, vehicles play an inestimable role in present society. Therefore improvements and developments of vehicle have been occupying a large area in history of Industry. Mainly the working efficiency and in addition the easiness and safety of operation have been greatly progressing. Furthermore consideration on the environmental aspect has been already long taken into account, inclusive of environmental load, outward danger and aesthetic appearance.
On-board operation is general as a driving mode of vehicles. Then we consider a driving space, which is usually called a cockpit even if it is not on an airplane or a racing car. A cockpit requires comfortableness and safety of an on-board operator. As a result an operator can continue driving accurately while she/he is feeling hardly any tiredness and strain. Many researches and developments have been executed and some of the results are already in practical use, for example "Ergonomic Innovation / Comfortable vehicle cabins [TNO]", "The Workplace of Tomorrow / Futura II; concept study on mobile excavators [O&K]".
Now there is an "automatic drive" as the best mode of comfortable and safe operation. People can achieve the purpose to be quite free from occupational danger and strain without operation, and there is a case that the work efficiency rises up as well. Therefore this has been also regarded as, as it were, an ideal mode. But compared with factory machines which are fixed and whose objects and movements are relatively constant, a premise of "a vehicle moves itself" requires constant monitoring to surroundings and adequate

decision. As a result it makes the automating of vehicle difficult. Also it limited an automatic drive to a few opportunities of use. In fact it constraint us to say that an automatic drive is not practical enough but still in a level of assistance. It means, in the function of surroundings sensing (monitoring) and decision making, the technology does not catch up a total ability of human being yet. In the other hand, a concurrent elimination of driving pleasure and working opportunity with the removal of strain may cause a problem from humanistic or social aspects.

By the way, operation of a construction machine consists in combination with the other tasks and machines among all works at a site. In this aspect it must be effective that an operator can proceed a project with just-in-time accurate decision while she/he is managing and operating tasks and several machines at a site by means of constant monitoring. Yet there are many tasks requiring what is called human ability in the form of multitask activity, sensible sensing or decision making in construction works. The existence of human being causes problems as human inefficiency, inaccuracy and occupational danger and strain. And simple extension of object in operation, from a machine to all tasks in a project, is afraid to result only in increase of work load for a person.

Recent progress of robotics makes us possible to consider the application of this technology to human ability required tasks. One research direction is full replacement of works with a robot, the other is only assistance to human being of a robot who helps us to keep from danger and strain. The former is an application of an autonomic robot who has human ability, what is called a Humanoid, and the latter is an assistant of manual operation occasionally with a wearable robot who enhances human ability. A tele-operation belongs to the latter because a human being makes decision and operation. Incidentally in vehicle driving at present the applied humanoid robot still premises a tele-operation. This means that full automatic driving with a robot is not realized yet [Hasunuma 2002].

2. PRESENT DEVELOPMENTS ON CONSTRUCTION VEHICLE OPERATION

2.1. Improvements of driving situation

Construction vehicles have been improving in the cockpit for all human impressions in order that an operator can continue comfortable and accurate operation while she/he is feeling hardly any tiredness and strain. The measures in concrete are for example improvement of the seat, sound and light control, air conditioning, structure design for safety, betterment of panel layout, aesthetic appearance, environmental friendliness and so on.

In addition to these spatial measures, considerations on comfortable and safe driving expand the aspects wider. For example an improvement of equipments inclusive of those for sure operating response, accurate monitoring and adjustment, better communicating situation. Additionally as well humanistic aspects which are for example those on clothes or health management, and social ones such as those on qualification system, reward, interval of rest.

2.2. Tele-operation

Besides the improvements of driving situation, technology for operation without boarding such as automatic control, tele-operation or monitoring by means of remote communication is surely improving. The object is also comfortableness and safety of an operator, which is the same as that of the present measures on cockpits. It enables an operator to perform her/his tasks from a convenient, comfortable and safe place.

Aside from automatic control, progress of technology in radio communication, use of a satellite and virtual reality improves the performance of tele-operation remarkably. That in for example a suppression of time delay, a exact transmission of sensible human sense such as a tactile sense of finger, a development of high reality tele-operation by virtual reality and so on, enables an operator accurate monitoring, decision and operation, as if she/he were really on board. At the same time it frees her/him from occupational danger and strain, and precludes her/his mistake and trouble.

For tele-operation a special machine is normally prepared. Many of the parts are off course the same as those of a normal machine, therefore it is in many case prepared as an altered machine. Mainly the alteration on operation system such as a change of hydraulic system or an addition of a radio communication apparatus is necessary. It is not a rare case that the alteration costs, which are too expensive to recover in relative a few opportunities of using tele-operation, make us adopt alternative measures. For this reason there are developments for less or no alteration, for example that of applying an attachable operation unit or a humanoid robot on a normal machine.

3. STUDY ON APPLICATION OF PRESENT TECHNOLOGY FOR WEARABLE ROBOT

3.1. Background and Today of the progress

From another aspect that is on a purpose of utilizing human ability such as a general but suitable sensing and deciding, there is ordinarily a way of manual operation besides an application of a humanoid robot. Nothing is more efficient than human operation to display human ability so far as there is no danger or it is not in a bad situation.

Then here comes a better way of wearing a robot, which keeps an operator from danger and makes the working situation better. It becomes more efficient when it covers her/him from human defect such as mistake and tiredness, when it reduces troublesomeness of mastering the operation, and in addition when it enhances human abilities for multitask, decision making, and sensing. The follows are main present research areas to answer the purpose of enhancing or recovering human ability.

- Embedded chips or systems
- Wearable computers
- Exoskeleton systems

These technologies are already being used in practice. Especially the ones for medical use are currently advancing.

Augmented reality system on wearable computer, which assists us in visual and acoustic sense and partly memory by means of virtual reality technology, is expected to bear effective industrial use.

On the other hand wearable robot, which consists mainly of exoskeleton systems, is still now not used in practice. But some of the application are under practical consideration, for example that for enhancing or recovering our physical ability on demand.

3.2 Expected utility

The most expected functions in construction site are from one aspect monitoring of the situation and decision making, and another aspect prevention of tiredness and occupational stress (strain or danger). Monitoring usually requires all of human five senses (or six senses), especially visual sense. Therefore the utility of AR technology, before mentioned, is greatly expected on enhancement of visual sense. Generally the follows are some of the industrial utility of AR (Figure 1). [ARVIKA]

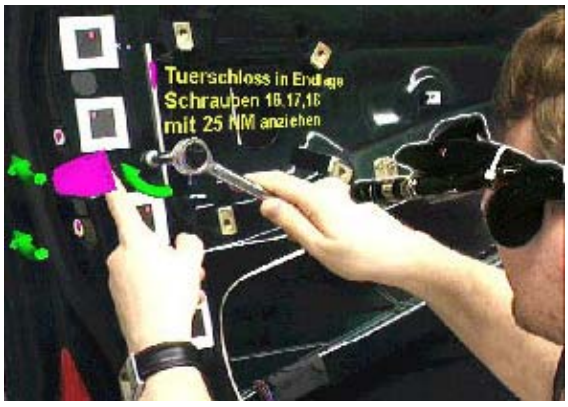

Figure 1. Work assistance by AR (ARVIKA project).

- Task indication of position and time in real sight
- Visual comparison between a plan and a present progression
- High visibility
    - No dead angle, Transparency through obstacles, Visualization of inner structure or underground
    - Clear sight in fog, darkness and dusty air
- Visual help for consideration
    - Visualization of temperature, humidity, air flow, smell, sound and others
- Visual check with the help of related data for construction materials and parts
- Pre-check of process and simulation of result
- Communication assistance
- Training

We can apply each of the utility directly to site management, machinery operation and monitoring of the situation. And in addition some computer technologies assist us in decision making and memory. These results enable a manager or an operator to preclude mistake and trouble, and to work comfortably and efficiently. Thereto the expected reduction of her/his tiredness results in prevention of accident.

From another aspect we can consider the utility of tele-operation besides that of AR, because wearable cockpit presupposes the technology for operation without boarding. In addition to the utility of tele-operation itself, possibility of multi-task should be mainly expected, which includes operation of several machines and control of additional work beyond operating. As a result an operator can monitor all objects at a site and control a project efficiently with technology of wearable equipment.

4. STUDY ON WEARABLE COCKPIT

4.1. Enhancement of sensing

Most of monitoring at construction site, which is all the time necessary, relays on human senses. Therefore a direct assistance in human sensing is effective at first. Especially many problems of unsatisfactory sight in construction works, such as danger of a crash, inefficiency and inaccuracy, make us expect greatly the technology of exclusion from obstructions in sight. Some of the technologies of visual enhancement are already being used in practice. These are for example a function of clear visibility in the dark, visualization of dead angle or backward sight. The practical technologies are however still now only through a fixed monitor. We are therefore now studying an application of AR technology to the enhancement of visual sense, in order to make an operator feel as if it were her/his real sight.

4.2. Enhancement of identification

Decision making needs an object to indicate clearly the situation in process. A visual instruction of work, such as a virtual indication of planned form of excavating in the operator's real sight, and a process management by visual comparison are the examples. Besides the before mentioned method of enhancing human sense, an easy identification method of objects by picking up preliminary inputted data must be more effective for situation recognizing and decision making.

We are trying to apply an embedded system of RFID for this purpose. [Bock, Ashida 2002] Basic data of each object are preliminary registered in the chip and it is embedded in the object. Such an ability of RFID as on demand registering of the necessary data enables us to be free from a complicated data preparation or management which causes sometimes a so-called data cemetery. Additionally we can also rewrite the difference in situation between plan and process if necessary.

By the RFID system we can identify all objects in the radio effective distance at the same time on demand and recognize the specification of them quickly and easily. AR system can in addition indicate the visual situation such as the position, appearance, movement. Therefore a manager can take also an invisible object into account. On operator's requirement, the system can relate an object to the more detail data automatically.

From these aspects we can consider the RFID embedded system to be one of effective method that enhances our ability of identification for decision making.

4.3. Project control system

When we control a construction site totally and manage all tasks in a project, the working load increases according to the number of objects. The less working load increases, the more efficiently a project would be controlled. To lighten the load on an operator, each task must have some automated process in itself. On the other hand however a full automation in construction work complicates the system and needs high technology, therefore it limits opportunity for the application at present. Because a decision making sequence is difficult to automate, where human ability is required.

In this aspect we are studying a system, that classifies tasks under the automatism and considers each allowance of time. And then we apply automatic systems on automation friendly sequences, for example a repeated task such as simple transportation by cranes or forklifts. These kinds of task need no continuous monitoring but only accidental alarms and an end signal of the sequence. We can in addition consider a partial automation in the same sequence, which includes for example both automatic transportation and manual adjusting of final positioning for the fixing.

We will make no effort to automate automation unfriendly sequences but analyze them as manual ones to result in minimum loss of time as follows;

1) Consider whole allowable time of each sequence in the rest of a project period.
2) Calculate the allowable time for decision making, which is difference between whole allowable time of the sequence and required.
3) Make an optimal combination in time with automated sequences and put the tasks in order.
4) Check the total loss in time and repeat the analysis

This system shows an operator the next necessary task in consideration of total efficiency of a project. She/He can make an accurate decision by this system without being puzzled. Priority of task is always repeatedly considered and the order is replaced if necessary.

In addition this system can analyze an allowance of automated sequence as well. It enables us to consider minimum and enough performance of the

machine. We can optimize machines for better running and less load on environment.

As a result of these considerations an operator can control a project accurately and efficiently.

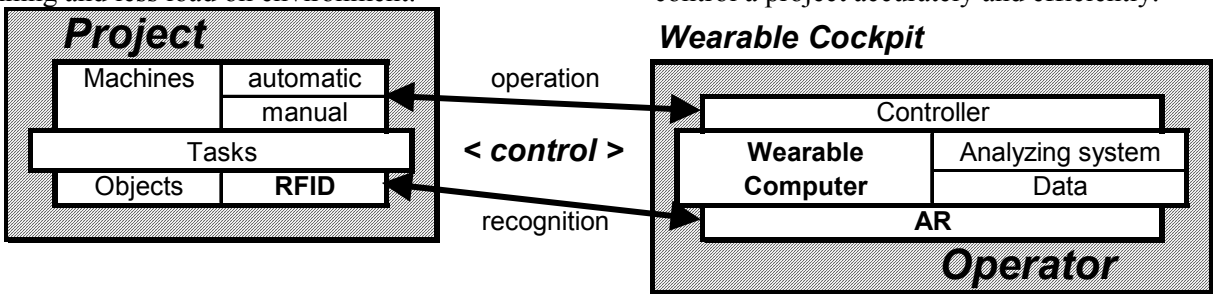

Figure 2. Concept outline of the wearable cockpit.

5. CONCLUSIONS

Construction work needs in many cases human sense and decision, and consist in combination of every task and machine. The wearable cockpit aims total control of a construction project. This means extension of the concept to a cockpit for project control from that for only operation of a machine. This concept includes multi-operation of several machines and total management of all tasks at a site. In other words, the wearable cockpit includes not only 1) a tele-operation system for multi-operation but also 2) assistance of decision making inclusive of enhancement of recognizing ability in time and space, 3) optimal task ordering and 4) optimizing of machines.
In this study we consider to apply a RFID system with AR technology to the enhancement of recognition inclusive of on demand visual communication. For task ordering and machine optimizing, the analysis of time allowance in each sequence is considered. On the automation unfriendly sequence a tele-operation system is usefully applied. By means of these kinds of assistance an operator makes accurate decision timely. Besides the human decision making lightens difficulty and costs for filling construction up with automation.

6. OUTLOOK

While the wearable cockpit enhances management ability of an operator, she/he controls all tasks in a project. She/He manages machines as if they were employees. She/He works her-/himself as well. Surely she/he can not always control all tasks in a project alone but proceed them as optimal as possible. On the other hand we can expand our consideration in future into ubiquitous control of several projects.

We intend to progress our study further to realize this efficient project control in the direction of assisting an operator, that is, enhancing a human ability as a result. Be that as it may, because this study is still in the step of concept, we need to bring the system soon into practical study.

7. REFERENCES

[TNO] TNO Work and Employment, Team Ergonomics and Innovation, *Ergonomic Innovation / Comfortable vehicle cabins,* Leaflet 2001/03/02/022e.

[O&K] O&K Orenstein & Koppel AG, *O&K-Technologie-Studie "Futura II",* Leaflet, E464.0/2-0301.

[Hasunuma 2002] H. Hasunuma, M. Kobayashi, H. Moriyama, T. Itoko, Y. Yanagihara, T. Ueno, K. Ohya and K. Yokoi, 2002, *A Tele-operated Humanoid Robot Drives a Lift Truck,* Proceedings of the 2002 IEEE International Conference on Robotics and Automation.

[ARVIKA] The coordinating project ARVIKA, *Augmented Reality for Development, Production and Servicing.* http://www.arvika.de

[Bock, Ashida 2002] T. Bock, S. Ashida, 2002, *A Concept of the Robotoid Manager with AR,* Proceedings of the 19th International Symposium on Automation and Robotics in Construction.