

## Introduction of Products

# KomVision Human Detection and Collision Mitigation System PC200-11

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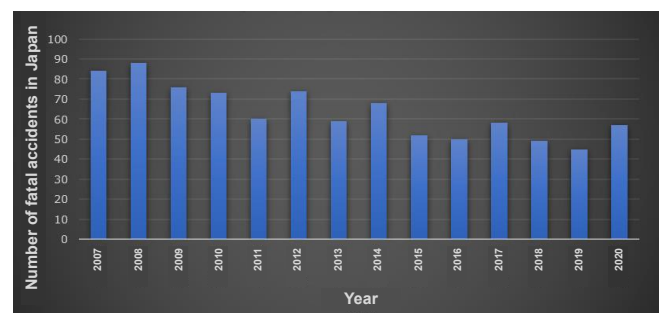
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Situations at construction sites undergo changes day by day, as the construction work progresses. People of various professions are engaged in their own work, often occupying the same space with construction machinery at such sites, which presents the ever present risk of an accident occurring. In Japan the number of fatal accidents that involve hydraulic excavators and construction machinery at construction sites is on a decreasing trend, however, the situation is such that the number of incidents continues to remain high. In order to respond to this issue by improving safety at construction sites, Komatsu proceeded with the standardized installation of KomVision (all-round machine monitoring camera system) installed on PC120 to PC1250-11 models. This feature was highly evaluated by the market, but we aimed for an early development of a system that mitigates collisions of machines and humans, by supplementing for the lack of safety awareness of operators also we developed the KomVision human detection and collision mitigation system. This paper introduces the KomVision human detection and collision mitigation system, which detects human presence in the vicinity of the vehicle and alerts the operator of detection findings by sounding a buzzer and through other means, while initiating the function for stopping the machine, which can also be retrofitted onto already shipped vehicles.

**Key Words:** Hydraulic excavator, KomVision, Human detection, Collision mitigation, Stop control, Human detection and collision mitigation system

## 1. Introduction

Situations at construction sites undergo changes day by day, as the construction work progresses. People of various professions are often found on such sites, often occupying the same space with construction machinery at such sites, which presents the ever present risk of an accident occurring. Although the number of fatal accidents that involve hydraulic excavators and construction machinery is on a decreasing trend, however, the situation is such that the number of incidents continues to remain high (Fig. 1).



<Reference> Fatal accidents database, workplace safety website, the Japanese Ministry of Health, Labour and Welfare

**Fig. 1** Number of accidents involving construction machinery in Japan

Furthermore, many of accidents that involve hydraulic excavators and construction machinery arise from collisions, with a particularly high number of these resulting from erroneous operations of operators (Fig. 2).

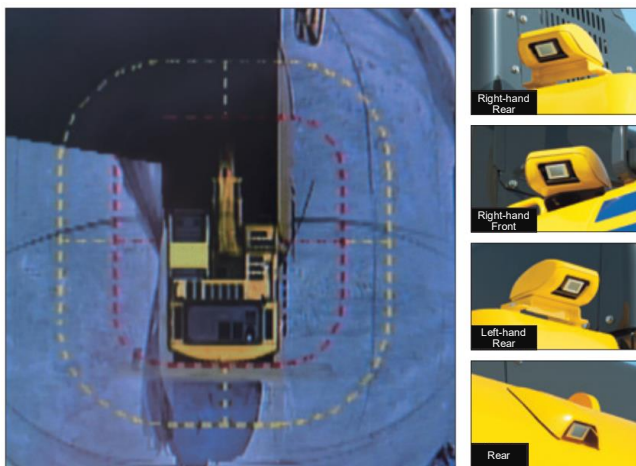


<Reference> Database of the Japanese Ministry of Health, Labour and Welfare; internal investigations at Komatsu

**Fig. 2** Details and causes of accidents involving hydraulic excavators and construction machinery

Even under such a situation, the construction industry must take on the responsibility of constructing and maintaining infrastructure. In addition, improvement of the productivity and safer work environment are required at every worksite.

In order to respond to this issue, Komatsu proceeded with standardized installation of KomVision (all-round machine monitoring camera system), hereinafter referred to as existing KomVision, on PC120 to PC1250-11 in Japan, in order to improve safety at construction sites. Three or four camera units installed on sides and at the rear of the machine capture images that comprise a bird's eye view of the surroundings that is displayed on the monitor inside the cab, which aids safety verifications for vehicle surroundings by visual recognition (Fig. 3).



<Reference> Excerpted from Komatsu customer support catalog

**Fig. 3** KomVision (all-round machine monitoring camera system)

## 2. Introduction of human detection and collision mitigation system

The KomVision (all-round machine monitoring camera system) had been highly evaluated for such aspects as providing a bird's eye view to facilitate verification of such as blind spots.

But we continued to develop the next system for reducing collision accidents involving machine and people, by offering further functional improvements that include support for lack of safety verifications. As the result we completed a human detection and collision mitigation system added to existing KomVision system for hydraulic excavator. It detects presence of humans in the vicinity of the vehicle, alerts the operator of detections on the monitor, sounds off a buzzer, and stops the machine, and can also be retrofitted onto already shipped vehicles (Fig. 4).



**Fig. 4** External appearance of PC200-11 fitted with KomVision human detection and collision mitigation system (a decal is added)

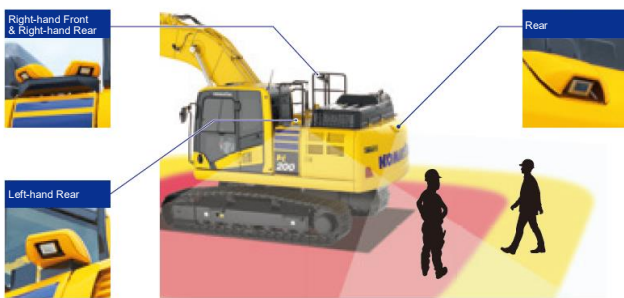
This development was conducted based on following policies, in order to keep cost increases down while achieving rapid market introduction:

- Improvements are made only by implementing changes to existing KomVision software.
- No addition range sensors which require development time

As the side effect by this policy, we would be able to add the human detection and collision mitigation system to the already shipped vehicles that installed existing KomVision by updating software.

## 2.1 Configuration of the KomVision human detection and collision mitigation system (PC200-11)

The KomVision human detection and collision mitigation system is configured with the same monocular cameras and ECU (electronic control unit) of existing KomVision systems. There is no change with the installation locations for four units of cameras that are mounted on sides and at the rear of the vehicle (Fig. 5). The KomVision human detection and collision mitigation system takes video images input by individual cameras to display the bird's eye view, which is a function of existing KomVision systems, but also executes human detection process. In the event human presence is detected in the surrounding of the vehicle, a marker is shown at the position of the person in the bird's eye view (yellow or red circle) and a warning buzzer prompts the operator to pay attention (Fig. 6).



<Reference> Excerpted from the KomVision human detection and collision mitigation system safety booklet

**Fig. 5** Configuration of human detection and collision mitigation system



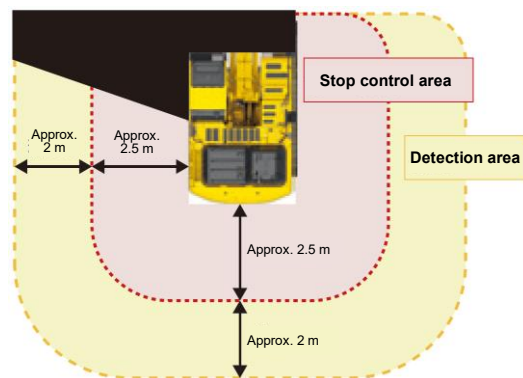
<Reference> Excerpted from the KomVision human detection and collision mitigation system safety Booklet

**Fig. 6** Monitor display of human detection and collision mitigation system

The reference line on existing KomVision served as a supplementary indication to offer the sense of distance for visual verification, but the KomVision human detection and collision mitigation system displays the human detection range in two levels (Fig. 7).

When human presence is detected inside the yellow reference line, it sounds the long repetitive beep buzzer (0.4 seconds on, 0.4 seconds interval). And when human presence is detected inside red reference line, in order to notice more dangerous situation it sounds the short repetitive beep buzzer. (0.08 seconds on, 0.16 seconds interval).

Furthermore, once human presence is detected inside the reference line (red), the short repetitive beep buzzer continues to sound for about 3 seconds even after the person is no longer present.



<Reference> Excerpted from the KomVision human detection and collision mitigation system safety booklet

**Fig. 7** Human detection area for PC200-11 (reference lines)




Furthermore a “Human Detection Status Display icon” and a “Buzzer and Machine Stop Control Status Display icon” are added to the upper left section of the bird's eye view. Conditions in which respective icons are displayed are as described below (Table 1 and Table 2).

**Table 1** Human Detection Status Display icon

Icon	Description of status
	Non-detection status
	Human presence is detected between red and yellow reference lines.
	Human presence is detected inside the red reference line
	System failure

<Reference> Excerpted from the KomVision human detection and collision mitigation system safety booklet

**Table 2** Buzzer and Machine Stop Control Status  
Display icon

Icon	Description of status
	Normal status: The buzzer for human detection and machine stop control enabled.
	Lock lever locked: Human detection buzzer is stopped.
	Swing stop control cancelling: No stop control is performed in swing operation.

<Reference> Excerpted from the KomVision human detection and collision mitigation system safety booklet

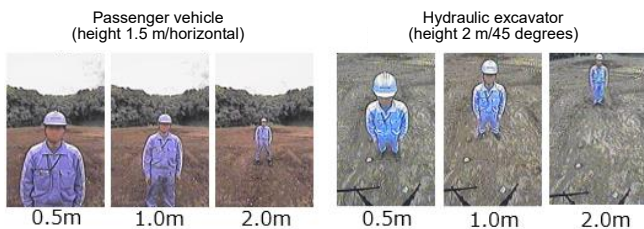
## 2.2 Principle of human detection

The KomVision human detection and collision mitigation system detects human presence based on model learning (by preparing “models for human detection”).

The KomVision human detection and collision mitigation system has “models for human detection”, consisting of feature quantities that are present as common characteristics among humans, derived by extracting features of human shapes by using human images that have been collected in advance.

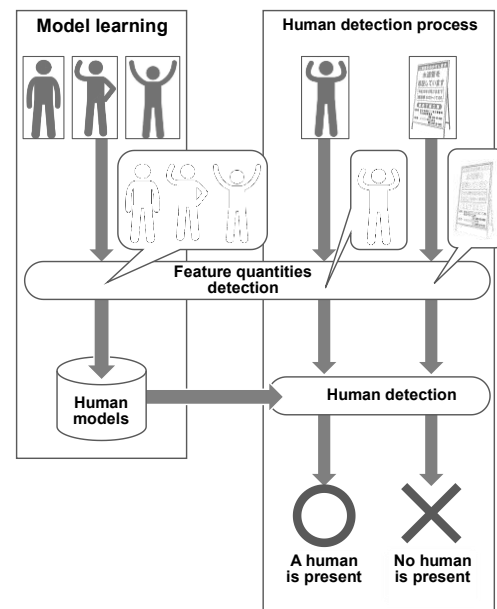
We knew there were the differences in captured images according to heights and angles of camera installation by trying to compare the human images which was taken by passenger vehicle camera (height 1.5 m / horizontal) and hydraulic excavator camera (height 2 m / 45 degrees). (Fig. 8)

We therefore collected images of humans captured by cameras from scratch, to prepare “models for human detection” for hydraulic excavators. Furthermore, considering that workers on worksites are always wearing a helmet, working clothes and a safety vest, the collected images are included various workers combinations.



**Fig. 8** Difference in captured images according to heights and angles of camera installations

By using the same logic that we created “models for human detection”, the KomVision human detection and collision mitigation system calculates the feature quantities which is the same logic that “models for human detection” is created from the every camera images. We can obtain many feature quantities common to “models for human detection” from the camera image in which human is depicted. On the other hand, we can obtain few feature quantities common to it from the camera image in which human is not depicted. Therefore we convert to numerical value as score from the commonalities of feature quantities between “models for human detection” prepared in advance and the calculation from camera image. It judges human presence or not based on the results of score. (In high score, it judge human presence.) (Fig. 9).

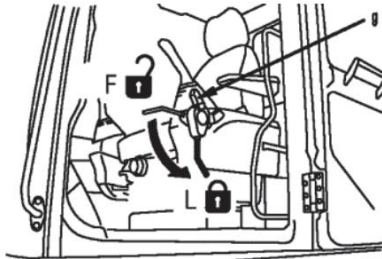


**Fig. 9** Overview of human detection

## 2.3 Buzzer sounding and resetting method

The buzzer function becomes enabled when the operation is started by setting the lock lever (g) to the free position (F). In order to stop the buzzer, on the other hand, the lock lever is set to the locked position (L) and the buzzer stops (Fig. 10). Markers indicating human detection continue to be displayed even when the buzzer stops.



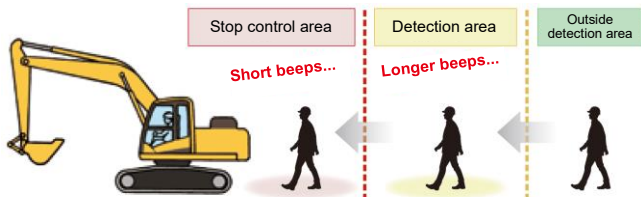


<Reference> Excerpted from the KomVision human detection and collision mitigation system quick reference sheet.

**Fig. 10** Lock lever operation

## 2.4 Machine stop control conditions and resetting method

The method for enabling the machine stop control and canceling are same as for the buzzer. The stop control is executed when the swing or travel operation is initiated while human presence is detected inside the red reference line. Furthermore, the stop control is also executed when human presence is detected inside the red reference line while the machine is traveling (Fig. 11). The stop control, however, is not executed while the machine is in the swing operation.



⚠ The buzzer is sounded to prompt caution and also stops the machine operation by manipulating the travel and swing lever. ⚠ The buzzer sounds when human presence is detected.

<Reference> Excerpted from the KomVision human detection and collision mitigation system safety Booklet

**Fig. 11** Behavior of system for each detection area

The stop control of the KomVision human detection and collision mitigation system brings the machine to an emergency stop, by setting the lock lever in the locked status in electrical on behalf of the operator. When the stop control is executed, the “Lock lever locked automatically” popup window is displayed on the monitor for this reason (Fig. 12).



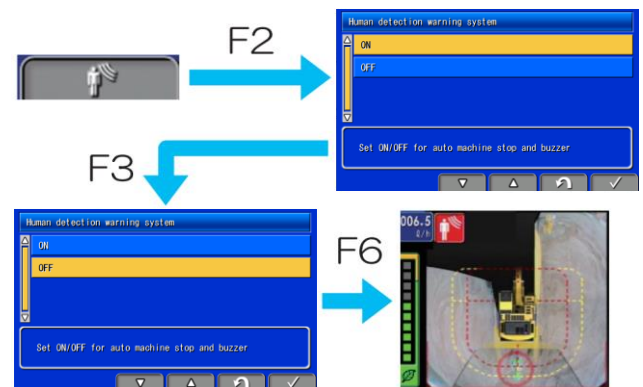
<Reference> Excerpted from the KomVision human detection and collision mitigation system quick reference sheet.

**Fig. 12** Monitor screen when stop control is activated

## 2.5 ON and OFF switching of the system

The human detection and collision mitigation system is always turned ON when the key is turned ON, however, it is also possible to turn OFF the system. The system needs to be turned OFF during loading and unloading of the machine on the trailer, for instance, when having a rapid stop executed by the machine stop control can make the machine unstable.

The ON and OFF switching of the system is performed by pressing the F2 button in the monitor console, while the lock lever is set in the locked position. The switching screen for the ON and OFF operation is displayed, and when OFF is selected, the buzzer and the machine stop control activation status display icons both turn off (Fig. 13).



<Reference> Excerpted from the KomVision human detection and collision mitigation system quick reference sheet.

**Fig. 13** ON and OFF system switching method

## 2.6 Precautions for use

Since the KomVision human detection and collision mitigation system is a system that detects presence of humans based on camera images, there may be instances where presence of humans are not detected or objects that are not humans are identified erroneously as humans, depending on the weather and surrounding conditions. Customers must be made sufficiently aware that relying on this system to operate the machine is prohibited, and that the customers need to understand characteristics of this system before using it. A safety booklet and a quick reference sheet which is equipped inside the cab are made available as aid for deeper understanding of these aspects, even after the customers have read thoroughly through the Operation and Maintenance Manual (Fig. 14).

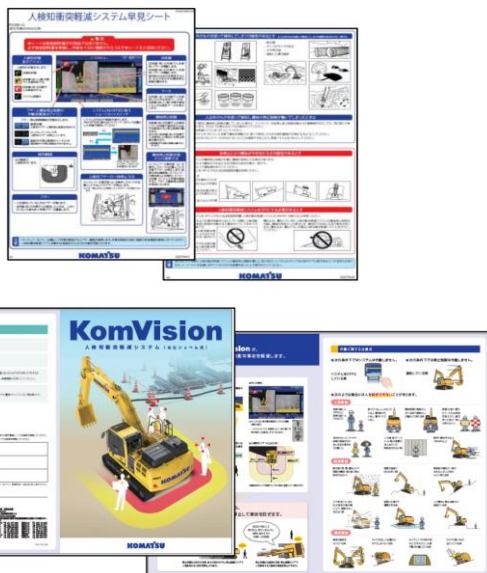
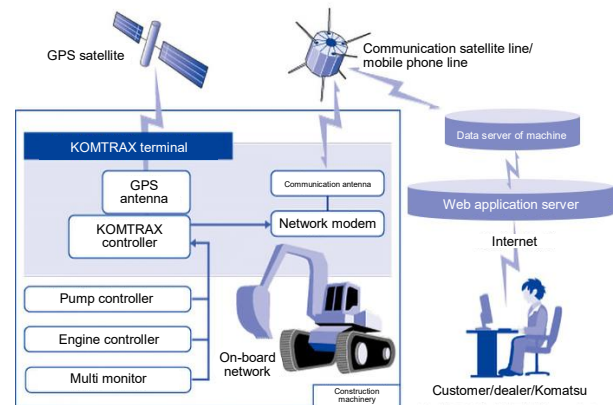


Fig. 14 Quick reference sheet (above) and Safety booklet (below)

## 3. Model implementations

### 3.1 Retrofitting the system on already shipped vehicles

The KomVision human detection and collision mitigation system consists of the same camera and ECU as the existing KomVision. The human detection function can therefore be added onto the system on already shipped vehicles, by rewriting the software on the system. The implementation of the remote rewriting product created for the purpose of rewriting software of the ECU started in November 2020.



<Reference> Excerpted from Komatsu Customer Support Home Page  
 Fig. 15 Mechanism of KOMTRAX (software updating)

A decision was made to utilize the remote software writing system, which had been used for the purpose of improving ECU quality in the past, for adding functions of the system. This function adding software rewriting work is provided for a fee, and customers are requested to purchase a card bearing a unique number (product key card). A mechanism was built to rewrite software of only those customers who have purchased such a card bearing a unique number.

This made it possible to offer customers, who have purchased existing KomVision incorporated vehicles, the same level of safety as those available on latest models (this offering is available only for PC20t and PC10t series models only as of January 2022).

### 3.2 Model implementations

The human detection and collision mitigation system has already been implemented starting with the PC200-11 series, as described above, which was followed by other models, such as the PC20t series, PC10t series and the HB20t series. Plans are in place to make the human detection and collision mitigation system available to other models in the future.



<Reference> Excerpted from Komatsu customer support catalog

**Fig. 16** Application of human detection and collision mitigation system on PC138US-11

### 3.3. Issues for various model implementations

#### 3.3.1 Issue of camera height differences

There is an issue of cameras being installed at different heights on different models when implementing the system to other models. As described in the “2.2 Principle of human detection”, the appearance of human presence differ according to heights of cameras and as such, the deterioration of the detection rate was a source of concern. The deterioration of detection performance was confirmed to be minimal, based on verifications on human detection performance conducted with respective models.

#### 3.3.2 Issue of mounted camera counts

The models of the 10t series are fitted with three cameras to generate KomVision images (overhead images), unlike models of 20t series and later (models of 20t series and later are fitted with four cameras). Since the visual field of the circumference of the machine body is secured using three cameras, there was a concern that images of humans that include their heads might not be captured in the visual field between cameras (since orientations of cameras vary greatly and gaps are formed in the visual field). Detectable ranges were determined to be within the tolerated range, based on the results derived from verification on actual machines of respective models.

## 4. Future outlook

The development of the KomVision human detection and collision mitigation system started based on the existing KomVision system, in order to keep down cost increases, while achieving a rapid market introduction. Adding range sensors and the like, as well as fusing sensor signals with image processing will become a key aspect for the future to further improve human detection performance and prevent not just accidents involving humans and construction machinery but also collisions between objects found on worksites with construction machinery. On the other hand, the situation is such that high performance range sensors are still expensive and adopting them for construction machinery with a broad range of coverage than passenger vehicles is not something that can be achieved easily. We will continue to closely observe trends of sensors in the world, in order to proceed with our consideration of the system to improve on the degree of completeness of human detection performance. Ultimately we aim to provide customers a system that is safe and secure, which identifies humans and objects in the circumference of the vehicle and stops the operation before colliding under any circumstances, with the objective of achieving 0 fatal accidents involving construction machinery.

## 5. Conclusion

We introduced the functions of the KomVision human detection and collision mitigation system, which is now a standard feature on the PC200-11 model in Japan. Also we described the installation situation about the other model. We believe we were able to develop not just the human detection function but also buzzer sounding and stop control in a short period of time, by conducting development of practically all key components in-house.

We intend to proceed with our system developments with an aim of further improving performance, targeting 0 fatal accidents involving construction machinery, which is an objective of Komatsu.

## Introduction of the authors



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## [A comment from the authors]

It was not easy to develop this system due to the target of a rapid market introduction. But bringing the all-out power of the people concerned together, we could complete it. We would like to express our sincere gratitude for people from the Evaluation Department, Sales Department and others who were involved in this development for their massive cooperation.