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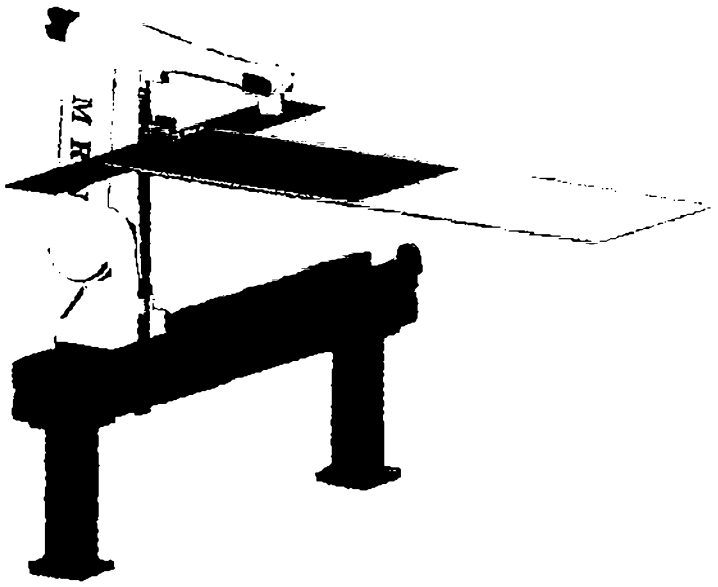
(57) Sammendrag:
The present invention relates to a safety system for a robot with one or more arms working to move loads from one position to another, in particular where the task is to stack layers of objects or goods on to pallets or vehicles, or to take objects (for example cans or boxes with different contents) from a multitude of positions to one packing position to provide the mix specified by a control program. In this situation it is convenient that persons can enter the working space to correct things or supply special goods in a safe way, which means the robot must be stopped while the persons are within the active range of the robot, but the robot can go on in its process after the persons have left the active range. According to the present invention, the safety of persons is provided by a scanner, which scans the active range of the robot below the load. In this way it is secured that persons cannot by mistake "hide" behind a load or a vehicle and go undetected into the robot's work zone. In a particularly important case the robot is working from a gantry. The robot is mounted on a movable base plate connected to a rail track on the gantry. The gantry is placed on or above a floor with one or a multitude of conveyer bands or roller tracks situated alongside or perpendicular to the gantry on one or both sides of the gantry in such a way that it can move objects (for example cans or boxes) from one conveyer band to another, for example from a multitude of feeder conveyers with different types of objects to one (or more) collector conveyer(s) with mixed object content, for example on the opposite side of the gantry. The conveyer bands may transport boxes, pallets or similar collecting containers, and the robot may be used for stacking of such containers up to a certain height.

Fortsættes...



[Fig. 4]

Title: Safety system for collaborative robot.

Description:

The present invention relates to a safety system for a robot with one or more arms working to move loads from one position to another, in particular where the task is to stack layers of objects or goods on to pallets or vehicles, or to take objects (i.e. cans or boxes with different contents) from a multitude of positions to one packing position to provide the mix specified by a control program.

In this situation it is convenient that persons can enter the working space to correct things or supply special goods in a safe way, which means the robot must be stopped while the persons are within the active range of the robot, but the robot can go on in its process after the persons have left the active range.

According to the present invention, the safety of persons is provided by a scanner, which scans the active range of the robot below the load. In this way it is secured that persons cannot by mistake “hide” behind a load or a vehicle and go undetected into the robot’s work zone.

In a particularly important case the robot is working from a gantry. The robot is mounted on a movable base plate connected to a rail track on the gantry. The gantry is placed on or above a floor with one or a multitude of conveyer bands or roller tracks situated alongside or perpendicular to the gantry on one or both sides of the gantry in such a way that it can move objects (for example cans or boxes) from one conveyer band to another, for example from a multitude of feeder conveyers with different types of objects to one (or more) collector conveyer(s) with mixed object content, for example on the opposite side of the gantry. The conveyer bands may transport boxes, pallets or similar collecting containers, and the robot may be used for stacking of such containers up to a certain height.

In a prior art system the robot must be surrounded by a fence or a light fence to prevent humans from entering the work zone. The fence is creating problems as work items are not allowed to move in or out of openings in the fence. The present invention replaces the fence by creating a safety zone around the robot by using a scanner in such a way that work items can move in and out of the zone, but the robot is stopped if a human or any other object is penetrating the zone limit.

In a prior art patent application JP2010-61772, a stationary scanner is used to detect bodies inside a defined 2-dimensional horizontal zone using a scanner beam with small vertical width. To allow vehicles to enter the scanned area without being detected, the scanner beam is deflected out of the scanner reception plane by an inclined “mirror” on the front of the vehicle. In this way, the vehicle can enter the safety zone without interfering with the working robot, but other object or persons entering the safety zone will cause the robot to stop working.

In a second prior art application DE102012108418, a device comprises two robotic controllers that are attached to a robot. One of two robotic controllers is provided with an additional safety control unit. The additional safety control unit is cross-linked with a safety sensor such as safety laser scanner. In this system, a separate safety system is stopping the work action, when objects move into the safety zone scanned by the scanner.

In the present invention, a scanner with a small vertical scanner beam width is moved up and down (and horizontally) with the load in such a way that it does not detect the load itself. This is achieved by the scanning plane being kept at a small distance below the load. At the same time, the horizontal scanner field is defining a safety area equal to the movement limits for the robot arm and its load (e.g. a grabber or other tool). When the robot arm moves, the safety area moves with it, thereby allowing people or other object to enter the work zone outside the safety area without interfering with the load. If the load is carried to a height of 2.5 meters or higher it is considered to be out of reach and therefore safe safe to move without further safety measures.

In a first embodiment, the scanner beam is following the load but scanning under the load, thereby securing that no vehicles or person can enter the scanned zone without giving a scanner signal, which is used to stop the robot. The scanner is mounted on a vertical guide rail mechanism which is programmed to follow the vertical robot head tool path using a motor and a toothed rack and pinion transmission. See fig. 1.

In a third embodiment, the scanner can also be placed on the end of the tool hanging low enough to scan a certain distance under the load. In this case a rail for the scanner can either be avoided or have a small one mounted on the tool so the scanner can pull up to the same height as the tool, allowing the tool to grab loads from conveyers or flat surfaces without the scanner being in the way.

In a second embodiment especially well suited for use with a robot moving along a gantry, the scanner is mounted on a reverse guide rail in such a way that the lower end of the rail is moved in the vertical direction at the same rate as the load (using a counterweight via a pulley system or a spring to ease the load on the motor). This enables the space under the gantry to be free for passage of conveyer belts, vehicles or goods while the robot load is away from the passageway. See fig. 2a & 2b.

Detailed description of the invention:

Components see fig. 2a

1. Base for robot.
2. Trolley
3. Wire
4. Safety scanner
5. Rail cart
6. Rail
7. SMC rail

Fig. 2a & Fig. 2b

The SMC rails cart is mounted to the base of the robot which allows the rail to travel up or down. The wire is fastened through a hole in the plinth and goes over the trolley and down to the outer rails cart where the safety scanner is mounted. By using the wire and trolley connection it allows for double the travel ratio of distance and speed. Having the SMC rail move up to the same height as the gantry allows for the possibility of having a conveyor or other objects going under the gantry without blocking the robot as it travels along the gantry.

Fig. 2c (Same principal as Fig. 1)

If there is no obstacles or conveyor under the gantry then being able to move the SMC rail up and down will be unnecessary.
So rather than having another rail on the SMC rail the SMC rail could be mounted with its back on the robot and mount the scanner to its cart. The scanner can still move up and down but the SMC rail is now stationary as it is bolted to the base of the robot.
The SMC rail will then determine the travel velocity and distance.

Robot and scanner collaboration:

The scanner emits three different warning zones with each their purpose. See fig 3 and 4.

Warning zone 1) is the yellow zone which is there to warn the robot in case someone or something is nearing its working area and therefore to drop down to half speed to avoid risk of collision.

Warning zone 2) is the red zone which is there to warn the robot that someone or something is to close to its load and causes the robot to cease all motion to avoid danger of collision.

Warning zone 3) is the orange zone which there to warn the robot of someone or something near the gantry while the robot moves along the gantry. This is to avoid collision with robot and the platform which it is mounted to.

The scanner ensures with the help of the warning zones that the robot can travel and move freely as long as nothing is near it or in its way.

Scenario examples:

When the robot is reaching down to unload or grab a load, as seen on fig. 5, the robot arm will continue its movement until it reaches the person underneath. When the warning zone reaches the person it will activate and immediately stop the robots movement.

On fig. 6 it shows when the robot moves down the red zone activates upon detection of the person. This stops the robots movement for as long as the zone is blocked.

Once the worker has removed himself from the scanners warning area and no longer stands in the path of the load then the robot can reactivate and automatically resume its operation.
On fig. 7 it is shown that the robot was able to reach down to the floor with the worker out of the way.

Should a worker happen to be in the robots working area without paying attention to the robots movement as it changes pallet position, see fig. 8, the warning zone will detect the worker as the robot moves toward him. The signal from the warning zone will then tell the robot to immediately stop.
The activation of the red warning zone ensures that the load and robot will not collide with the inattentive worker. The robot will remain still until the worker gets clear of the scanners warning zones but will resume its operation once the path again is clear.
On fig. 9 it is shown that the red zone is activated and thereby forcing the robot to stop and stay still for as long as the worker blocks the warning zone.

Given the scanner is capable of projecting a plane in at least a 180 degree angle the scanner could be mounted on the end of the tool (i.e grabbing tool or other) and still use the same warning zones to secure workers and robot. See fig. 10.

Use of scanner functions:

There are various ways to use the functions of the scanner depending on the scenario the user prefers.

If the scanner stays right under the load and the load is carried in a height of 2.5 meters along the gantry then the scanners warning zones will not be necessary as the load will be out of reach. It is important in this case that the part of the gantry where the robot travels remains free of obstacles as there will be no warnings in case of collision. The warning zones will only activate when the robot moves in its vertical direction.

In case the user wishes the robot arm to move along the gantry as soon as the scanner is clear of obstacles along the way a wider yellow warning zone could be implemented to ensure the robot will

reduce its speed in half before the obstacle reaches the more critical red warning zone. In this case the warning zones need to be active at all times.

In case of the gantry has one or both ends up against a wall the orange warning zone could be reduced to a shorter length along the gantry and be replaced with a yellow warning to reduce its speed in half before reaching the critical orange zone. This will also ensure the robot can make use of the full length of the gantry without the walls at the end blocking the orange warning zone causing the robot to cease all movement.

Depending on the programming of the scanner, various warning zones could be implemented according to the robots movement. For example it could have wider zones during horizontal movement along the gantry and slimmer zones when moving vertically.

Assuming the scanner projecting plane can be tilted up and down to have a warning zone in what is referred to as 2.5 dimensions. As the scanner moves slower than the robot this makes the scanner capable of compensating by changing the angle of its projected warning zone(s), thereby reducing its necessary travel distance and check for persons or objects below the scanner height.

Assuming the technology is available for safety purposes a scanner capable of scanning 3D volumes and creating a 3 dimensional warning zone can be mounted on the robot providing better

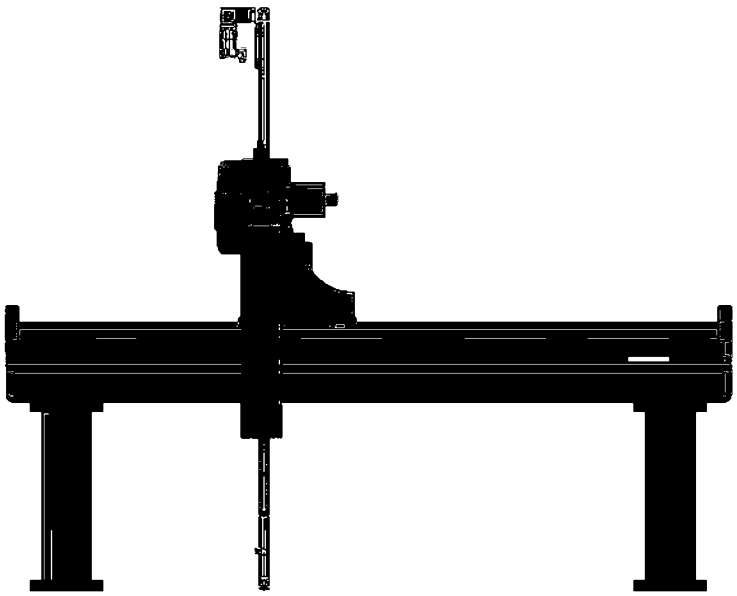
Safety controller diagram:

A diagram shows, see fig. 11, how the safety controller needs to interpret signals from the scanner and robot and how to act upon them to make the work area safe.

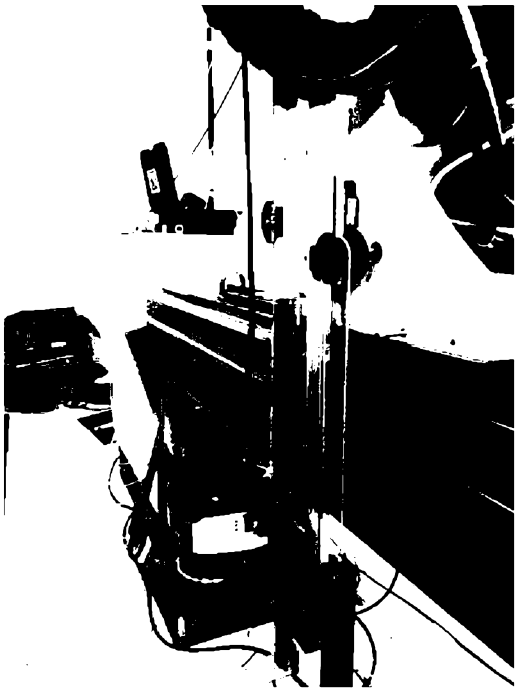
Claims:

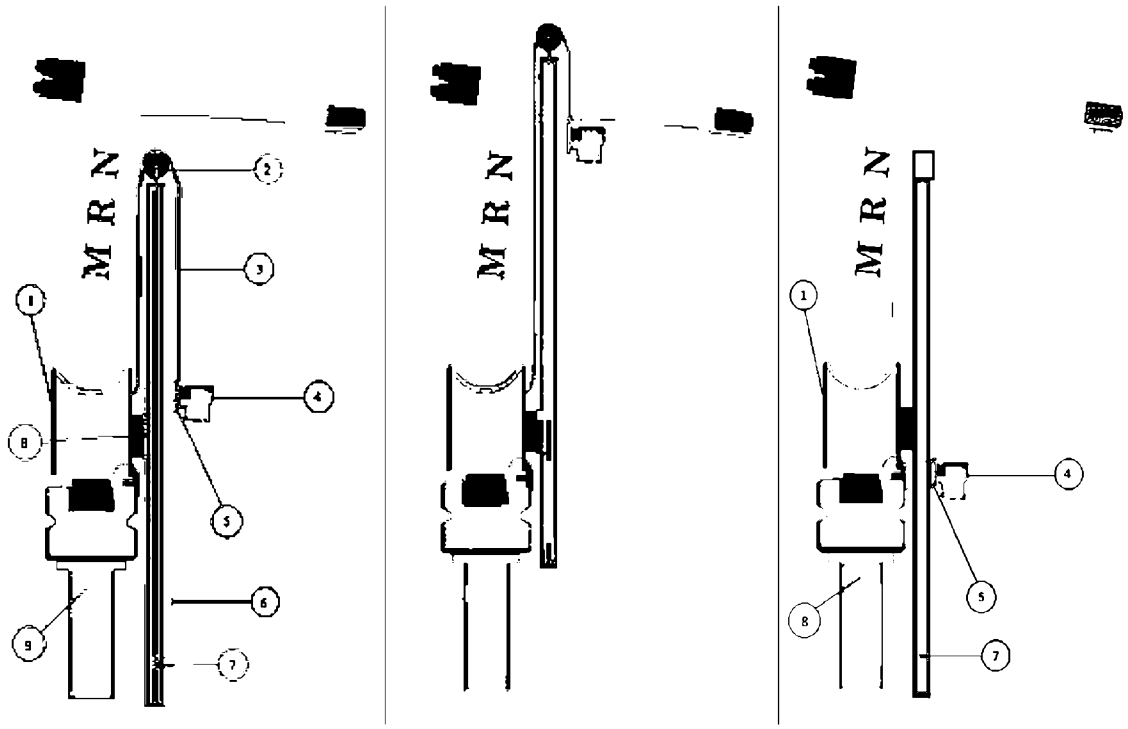
1. In a robot system provided in a work environment
   - A robot system comprising:
   - A robot working by one or more robot arms
   - A work arrangement in which objects are to be moved from one or more supply positions in a work area to target position(s) in a second work area by means of said robot arm(s)
   - A mechanism or fixture arranged to follow the robot arm(s) with load in its movements at a defined distance below the load
   - A scanner or sensor which is positioned on said mechanism or fixture in such a way as to detect persons or other objects entering the active range of the robot arm(s) with load
   - A control system which is programmed with the safe range distances of the robot arm(s) with load and which will stop the movement or reduce the velocity of the robot movement when detection of persons or other objects occur.
2. A robot system according to claim 1, wherein the robot is mounted on a movable platform moving along a gantry, comprising:
   - A mechanism arranged to follow the robot arm(s) in its Their) movements at a defined distance below the load
   - Said mechanism arranged in such a way as to allow positioning of conveyor belts, transport vehicles or other objects under the gantry without danger of collision with said mechanism
   - A scanner or sensor which is positioned on said mechanism in such a way as to detect persons or other objects entering the active range of the robot arm(s) with load
   - A control system which is programmed with the safe range distances of the robot arm(s) with load and which will stop the movement or reduce the velocity of the robot movement when detection of persons or other objects occur.
3. A robot system according to claims 1 and 2, wherein the vertical position of the scanner is variable in relation to the load position.
4. A robot system according to claims 1 to 3, wherein the scanner is able to scan a horizontal plane and has defined area limits, where a signal is generated when an object is inside said limits, the area limits being of circular, rectangular or other geometrical shapes, said signal to be transmitted to a controller which causes the robot to change speed of movement or to stop, depending on programmed conditions.
5. A robot system according to claim 4, wherein the scanning area limits are variable by pre-programmed conditions, e.g. wide when the robot is moving in horizontal directions and narrow when moving in vertical direction.

6. A robot system according to claims 4 to 5, wherein the scanner is able to scan multiple area limits, e.g. wide when only a reduction of movement speed is defined, and narrower when a stop of the robot movement is defined .
7. A robot system according to claims 4 to 6, wherein the scanner is able to scan in a horizontal plane plus to tilt said plane from horizontal to vertical and thereby scan a volume when needed (2 ½ D).
8. A robot system according to claims 4 to 6, wherein the scanner is able to scan a 3D volume when needed.
9. A robot system according to claims 1 to 7, wherein the scanner is used to detect the position of the setting-off surface for the load and secure safe and accurate set-down through feed-back to the robot control system.
10. A robot system according to claims 1 to 7, wherein the scanner is used to detect the position of the gripping surface for the load and secure safe and accurate gripping through feed-back to the robot control system.

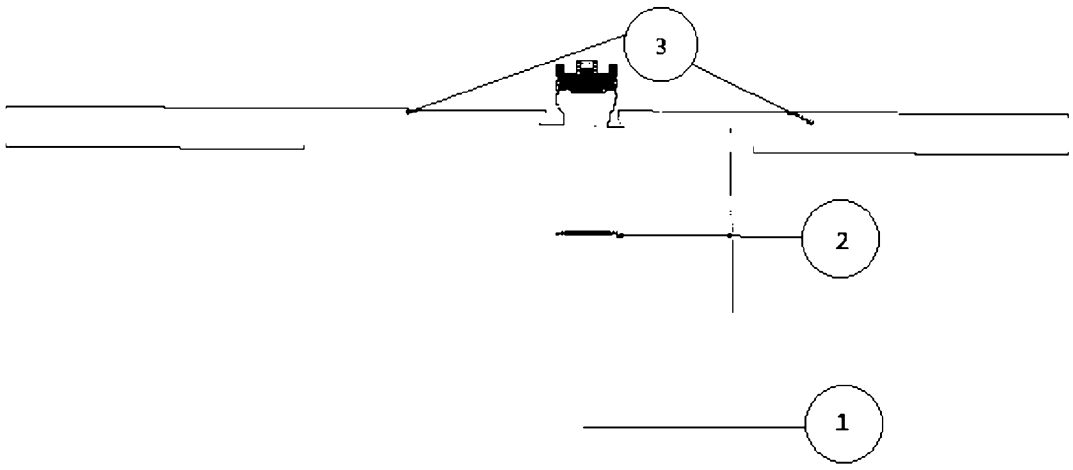


[Fig. 1]

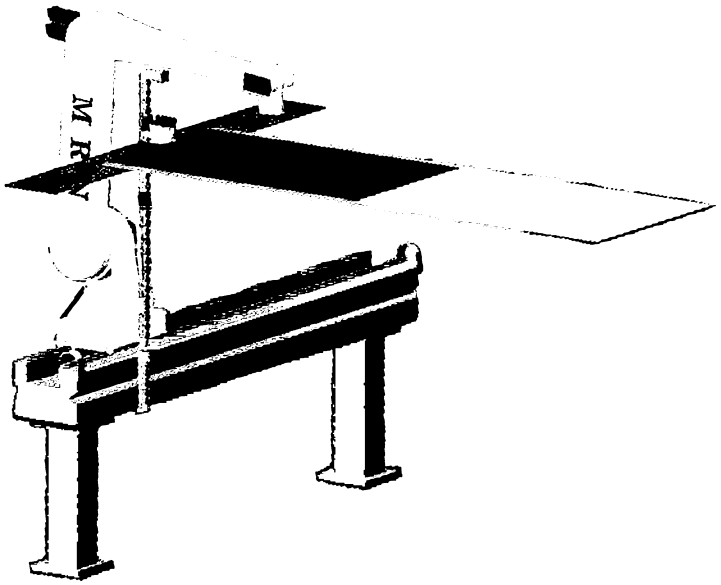




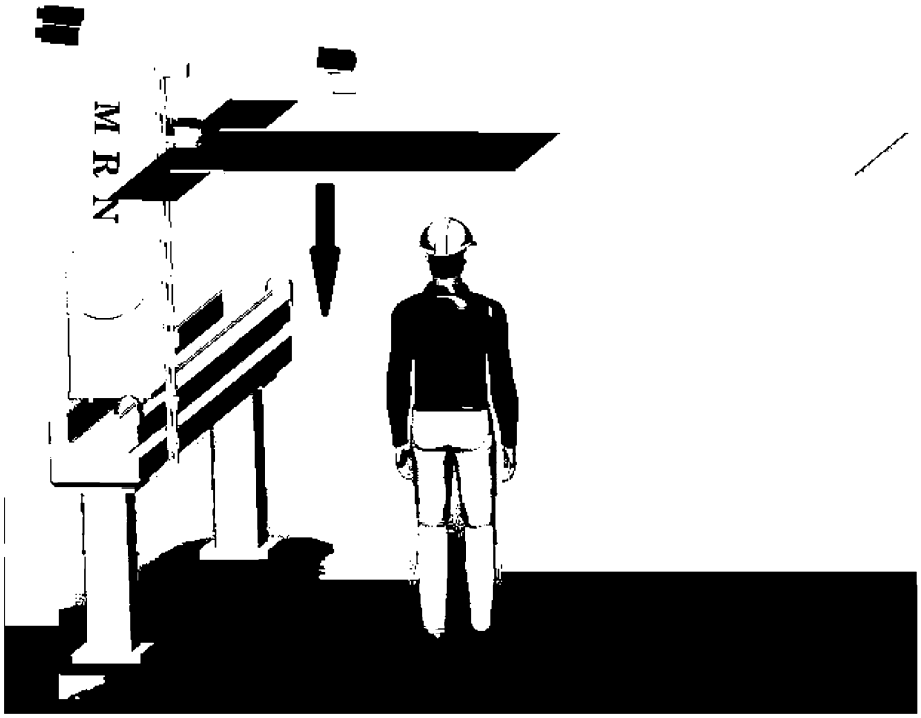
[Fig. 2a, 2b & 2c]



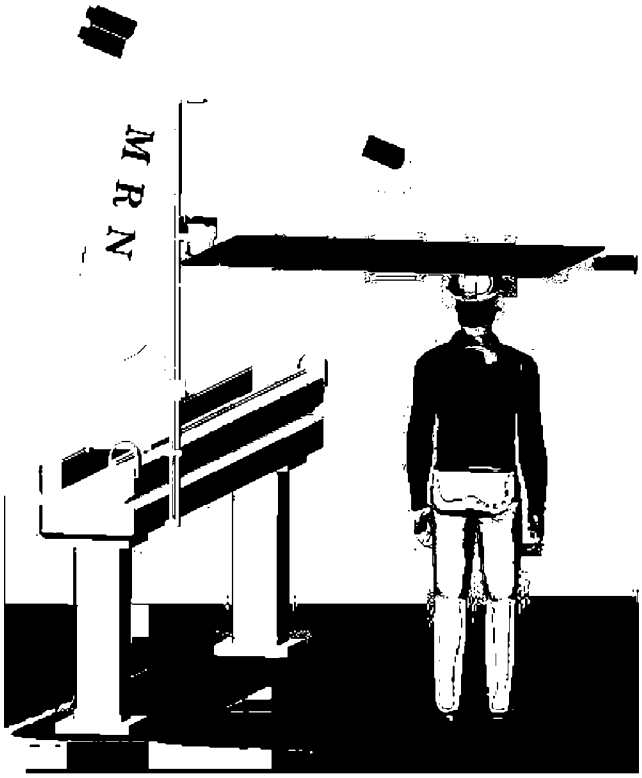
[Fig. 3]



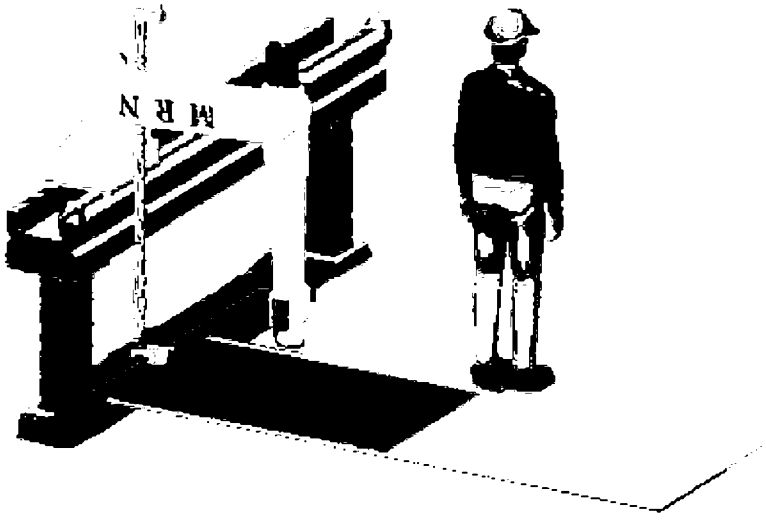
[Fig. 4]



[Fig. 5]



[Fig. 6]



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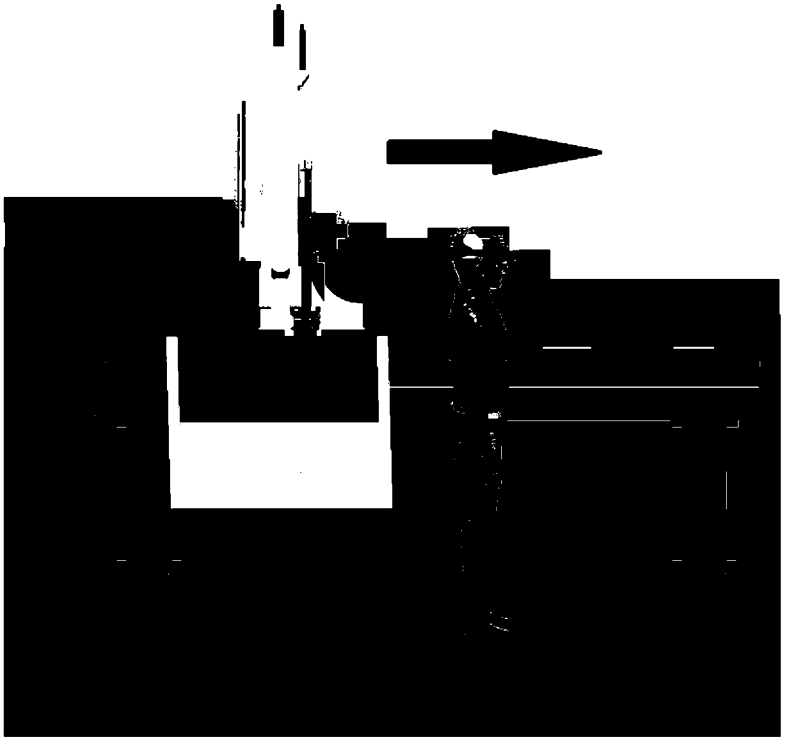
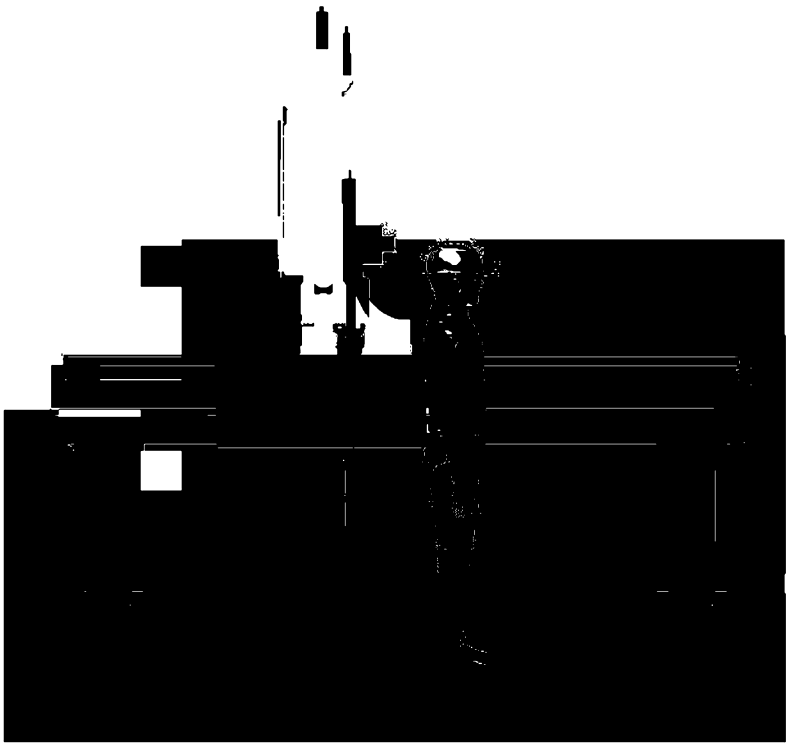
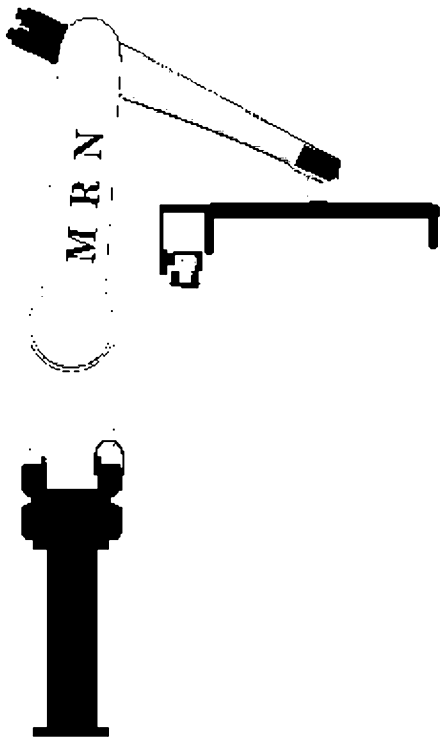
[Fig. 7]



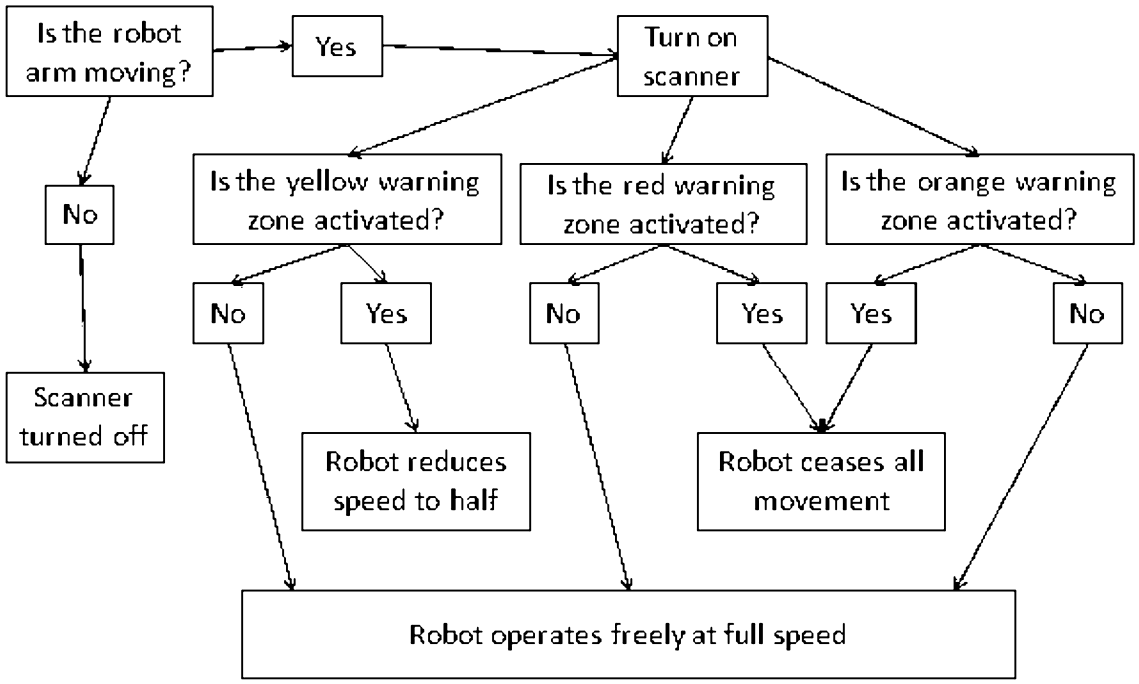
[Fig. 8]



[Fig. 9]



[Fig. 10]


Is the robot arm moving?
Yes
Turn on scanner
No
Is the yellow warning zone activated?
Is the red warning zone activated?
Is the orange warning zone activated?
No
Yes
No
Yes
Yes
No
Scanner turned off
Robot reduces speed to half
Robot ceases all movement
Robot operates freely at full speed

[Fig. 11]