

Autonomous safety system for the users of vehicle
simulators

5 The invention relates to an apparatus and to a method
for operating a safety system for the users of vehicle
simulators.

10 In order to shorten the learning process involved in
learning to use different vehicles and, in practice, to
minimize risks both in the initial phase of such a
process and in relation to training, increasing use is
being made in recent times of appropriate simulators.

15 For this purpose, DE 10 2008 023 955 B4 describes a
method for simulating events and processes associated
with aircraft, land-based vehicles or watercraft and a
corresponding simulation system, for example. It is the
underlying object of this invention to activate a
simulation device in real time even though the data
20 required for activation are supplied only by a
simulation program which is not real-time, with the
intention being that a latency caused by a data manager
should be compensated.

25 Here, the term "real time" is taken to mean the time
actually required by processes in the real world. The
term "real time" does not refer to a particular speed
or processing power of the program or of the controller
but merely defines the timeframe within which the
system must respond. The term "latency" refers to a
30 period of time between an action and the occurrence of
the reaction that is to be expected, i.e. a delay.

The essential feature protected in this patent is that,
if data do not arrive on time, the data gap which
arises is filled by data from empirical values or by
35 data from previous simulation programs, and these data
are then sent to the motion controller of the real-time
simulation device.[0046]. No indications on the
operation of a safety system for the user of a vehicle
simulator can be found here.

DE 600 20 466 T2 furthermore discloses a "parallel robot" with four degrees of freedom which achieves the object of moving a mobile plate with four degrees of freedom at high speed and with a high acceleration and of positioning the mobile plate with a high rigidity and accuracy. Here, the term "parallel robot" is used to refer to a robot in which a multiplicity of actuators is arranged in parallel, it being possible to use a robot of this kind in a driving simulator for a motor vehicle, for example.

In this publication, parallel robots with six degrees of freedom are mentioned in connection with the prior art, these being used in flight simulators of the kind disclosed in US 5 333 514 and US 5 715 729, for example.

To achieve the object stated in DE 600 20 466 T2, a parallel robot is described which consists essentially of a special arrangement of a parallel linkage (3), a moving platform (4), coupling components (42) and kinematic elements (33). This publication does not deal with safety systems for the users of vehicle simulators.

It is therefore the underlying object of the apparatus according to the invention and of the corresponding method to propose an apparatus and a method where the primary concern is not only obtaining operational knowledge of vehicles but also the safety of the user of a vehicle simulator in the event of a technical fault or an accident.

The object is achieved by an apparatus as claimed in claim 1 and by a method as claimed in claim 6.

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The apparatus according to the invention is described in greater detail below. More particularly:

Figure 1: shows a perspective view of a vehicle simulator,
Figure 2: shows a plan view of an apparatus according to the invention,
5 Figure 3: shows a front view of a safety system according to the invention,
Figure 4: shows a side view of a safety system according to the invention,
Figure 5: shows a plan view of the floor structure
10 of a safety system according to the invention
Figure 6: shows a special design for a heavy vehicle cockpit

15 Figure 1 shows a perspective view of a vehicle simulator in the idle position thereof. A vehicle cockpit 3 having a cockpit upper part 2 that can be opened for boarding is moved in the desired manner in 3 dimensions by means of a flange-mounted robot arm 1 in
20 accordance with the instructions of a vehicle trainee and the defined responses of a simulation program. In the idle position, the cockpit 3 is supported on a damping layer 4 as the top part of the boarding apparatus 5, said layer being shaped to match the
25 contour of the underside of the cockpit. Respective boarding stairs 6, made wider on the topmost step for convenient boarding, lead up to the height of the boarding zone of the cockpit 3 on both sides. All the treads shown are provided on both sides with a sensor
30 layer 7, which indicates access to the vehicle simulator to the controller of the overall system as soon as someone steps onto the boarding apparatus 5.
In one particular embodiment, special sensors (not shown specially here) are provided in one or more of
35 the treads to measure the weight or mass of the respective persons climbing onto the vehicle simulator. In this way, the controller of the overall system obtains additional information for the purpose of

estimating the force that has to be applied by the robot to accelerate and move the cockpit 3. This increases the operational safety of the vehicle simulator since it is possible to make a realistic
5 estimate of the load peaks induced by the simulation program and imposed on the person and the machine.

It is furthermore important for the control program to be informed by means of a plurality of sensors on each seat and at each seat belt in the cockpit 3 whether the
10 seat is occupied and the user concerned is also belted up. The boarding process and correct closure of the cockpit must also be monitored by sensors.

Figure 2 shows a plan view of an apparatus according to the invention.

15 The working zone of the vehicle simulator is indicated in the form of the angular range 8 depicted in dashed lines. In the plan view, it is possible to see here the robot arm 1 and the connection thereof to the vehicle cockpit 3 in the region of the boarding stair 6. In
20 figure 2, the pedestal of the robot used is denoted by 12.

The slewing ring 17 can be seen concentrically around the pedestal 12, together with the running rail 14 of the rescue unit 13 in the position forming the
25 extension of the robot arm 1. A side view relating to the use of the rescue unit 13 can be found in figure 4. The safety perimeter 9, which is interrupted only by two entry doors 10, is shown around the entire access zone and working zone in this figure. Monitoring
30 sensors 11 are installed at all the corners of the safety perimeter 9. These monitoring sensors 11 can be designed as optical sensors which, in interaction with respective light-emitting units, have the function of a light barrier for each section to be monitored. Here,
35 the range of the light wavelength used can extend from visible light to infrared light.

In the lower area of figure 2, a projection surface A denoted by 33 and a projection surface B denoted by 34

are shown in cross section from above by way of example. Here, projection surface 34 represents the simplest case of a projection wall with a single bend. Projection surface 33 is embodied as a projection wall
5 with two bends. In both cases, the top surface, which likewise serves as a projection surface, cannot be seen in such a representation. Basic remarks relating to the projection method used can be found at the end of the description.

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Figure 3 shows the front view of a safety system according to the invention.

In addition to the sketched robot arm 1, the vehicle cockpit 3, the damping layer 4, the boarding apparatus
15 5 and the boarding stair 6, shown in front view, the left-hand entry door 10 and part of the safety perimeter 9 are specially indicated in this view. Moreover one of the monitoring sensors 11 mounted at each corner is specially indicated.

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Figure 4 shows a side view of a safety system according to the invention.

In addition to the pedestal 12 of the robot and the slewing ring 18 of the robot arm 1, revolute joint 1
25 denoted by 19, revolute joint 2 denoted by 20, revolute joint 3 denoted by 21, revolute joint 4 denoted by 22 and revolute joint 5 denoted by 23 and the direct attachment of the cockpit 3 thereby can be seen here in sequence. The slewing ring 17 of the rescue unit 13,
30 which was shown from above in figure 2, is furthermore installed concentrically with the slewing ring 18 of the robot arm.

The rescue unit 13 is based on a carriage 15, which can be moved to the location of use thereof along a running
35 rail 14. The drive required for this purpose is omitted here for reasons of clarity. The same applies to the slewing ring 17 of the rescue unit 17. The rescue unit 17 furthermore consists of a lifting unit 27 for

lifting a rescue platform 25, which is secured all the way around by a railing 24. Descent from the rescue platform 25 can be accomplished by lowering the lifting unit 27 or, in urgent cases, by means of the rescue slides 26. In this figure 4, the formation of zones with a function denoted as "airbag equipment" can be seen in the floor, denoted by 16. This is illustrated in greater detail in figure 5.

In the right-hand area of figure 4, the projection surface 33 is shown from the side. Basic remarks relating to the projection method used can be found at the end of the description.

Figure 5 shows a plan view of the floor structure 16 of a safety system according to the invention. The circular areas shown there represent particular safety zones 28, for example, within which an airbag can inflate from each of said areas when there is a risk of impact by a person or a machine in order to damp a corresponding impact from above, as in the case of the airbag in a car. A sensor (not shown) which is assigned to each of the round partial areas required and which detects a rapid approach by falling masses is used in each case as a trigger for such events. The required covering depends on the area of the airbag in the inflated stage and the operating zone of the robot arm 1 that is to be expected and/or is technically possible in interaction with the cockpit 3.

Figure 6 shows a special design according to the invention for a heavy vehicle cockpit 3. In this design, the robot arm 1 is replaced by the robot arms of a total of three robots. In this way, the load of the vehicle cockpit is distributed between the three robots 29, 30 and 31, which jointly support the vehicle cockpit 3 via the platform 32. Here, the slewing ring 17 of the rescue unit 13 with a running rail 14 of appropriate length and the carriage 15 is assigned to

robot 29. Instead of interaction between three robots, interconnection of two robots may also be sufficient in some cases.

5 Acoustic detection and evaluation of characteristic machine noises can be used as a special embodiment of the means of ensuring protection from damage to machine components that could lead to the unforeseeable failure of a robot and hence to a risky situation for users of
10 the vehicle simulator according to the invention. The spectrum of normal noises that occur during the operation of industrial robots is recorded by acoustic sensors and used as a reference. Both airborne noise signals and structure-borne noise signals are suitable
15 here. If noises outside the bandwidth of the normal frequency and/or of the noise level occur during the operation of such a robot, this is detected by an electronic analysis circuit and reported to the controller for the entire system. Depending on the
20 extent of the deviation detected in this way, it may be necessary to switch off the entire system at the next acceptable time or to perform appropriate additional checks during the next service.

As another embodiment, provision can be made, in the
25 case of drives using belt-like transmission elements, where premature failure can be detected acoustically only with very great difficulty, to employ optical sensors. With such sensors, it is possible to detect and record unusual flapping or impermissible vibration
30 of components. If unusual measured values occur, the same measures must be taken as in the case of acoustically detected faults.

Damage to electrical components of a vehicle simulator can also lead to unwanted and, in particular,
35 unforeseeable failures of the entire system. Since such damage is often revealed by the formation of smoke, sensors for detecting noticeable smoke formation are provided as a special embodiment in the relevant parts

of the system. Moreover, emergency generating sets and/or buffer batteries are provided to counter failure of the electric power supply.

- 5 A typical operating sequence is shown below in 19 steps:

10 **Method steps for the operation of the
simulator according to the invention while
taking account of safety lights for users**

1. **Standby**
sensors, working zone (on)
sensors, boarding zone (on)
15 sensors, entry gates (on)
sensors, canopy (on)
sensors, seat (on)
light (red)
- 20 2. **Personal ID**
sensors, working zone (on)
sensors, boarding zone (on)
sensors, entry gates (on)
sensors, canopy (on)
25 sensors, seat (on)
light (red)
3. **Parking, ready for operation**
sensors, entry gates (off)
30 sensors, boarding zone (off)
sensors, working zone (on)
sensors, canopy (on)
sensors, seat (on)
light (green)
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4. **Boarding access, gate unlocking, gate closure**
sensors, entry gates (off)
sensors, boarding zone (off)

sensors, working zone (on)
sensors, canopy (on)
sensors, seat (on)
light (green)

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5. Open canopy, boarding

sensors, entry gates (on)
sensors, boarding zone (off)
sensors, working zone (on)
sensors, canopy (off)
sensors, seats (off)
light (green)

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6. Put on belts

sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone (on)
sensors, canopy (off)
sensors, seats (on)
light (green)

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7. Close canopy

sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone (on)
sensors, canopy (on)
sensors, seats (on)
light (red)

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8. Working position, adjustment

sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone, perimeter fence, (on)
sensors, canopy (on)
sensors, seats (on)
light (red)

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9. Start simulation

sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone, perimeter fence, (on)
sensors, canopy (on)
5 sensors, seats (on)
light (red)

10. End simulation

10 sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone, perimeter fence, (on)
sensors, canopy (on)
sensors, seats (on)
light (red)

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11. Return to parking position

20 sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone, perimeter fence, (on)
sensors, canopy (on)
sensors, seats (on)
light (red)

12. Parking position

25 sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone, perimeter fence, (on)
sensors, canopy (on)
sensors, seats (on)
30 light (red)

13. Unlock canopy, open

35 sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone, perimeter fence, (on)
sensors, canopy (off)
sensors, seats (off)
light (red)

14. **Undo belts, get out**
sensors, entry gates (on)
sensors, boarding zone (on)
5 sensors, working zone, perimeter fence, (on)
sensors, canopy (off)
sensors, seats (off)
light (red)
- 10 15. **Close canopy**
sensors, entry gates (off)
sensors, boarding zone (off)
sensors, working zone, perimeter fence, (on)
sensors, canopy (on)
15 sensors, seats (off)
light (green)
16. **Exit via boarding zone, open gate, close door,**
20 sensors, entry gates (off)
sensors, boarding zone (off)
sensors, working zone, perimeter fence, (on)
sensors, canopy (on)
sensors, seats (on)
25 light (green)
17. **Leave boarding zone, close gate**
sensors, entry gates (on)
sensors, boarding zone (on)
30 sensors, working zone, perimeter fence, (on)
sensors, canopy (on)
sensors, seats (on)
light (red)
- 35 18. **Standby**
sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone, perimeter fence, (on)

sensors, canopy (on)
sensors, seats (on)
light (red)

5 **19. Switch off, charge batteries of emergency systems**

sensors, entry gates (on)
sensors, boarding zone (on)
sensors, working zone, perimeter fence, (on)
10 sensors, canopy (on)
sensors, seats (on)
light (red)

One significant component of a vehicle simulator is the
15 projection surface which simulates for the user the
reality to which he must match his motor responses.
Conventional projection methods often use curved
projection surfaces which not only require complex
controllers for the respective partial areas and
20 expensive projectors but are also dependent on a heavy
and expensive holding apparatus for such a curved
overall surface. A large-area holding structure of this
kind itself already represents a risk since the
necessary stability is often skimped here. The
25 autonomous safety system according to the invention
therefore uses a projection surface which consists of
flat but flexurally rigid, lightweight projection
surfaces. In the simplest case, these can be two
vertical projection surfaces abutting at a suitable
30 angle which are covered by another surface, as it were
as a "lid", to simulate the sky. The abutting edges,
formed in this case, of the adjoining surface
components are precisely defined and can therefore be
managed relatively easily in terms of programming.
35 Moreover, the illumination points representing these
abutting edges are very small and the corresponding
transition zones therefore do not appear in the overall
image. The relatively light holding apparatus for a

projection surface configured in this way represents an additional safety aspect.

Control of the complex motion processes and signal
5 processing of the sensors used require a special control program.

List of reference numerals

	1	robot arm
	2	cockpit upper part
5	3	cockpit
	4	mounting layer for the cockpit
	5	boarding apparatus
	6	boarding stair
	7	sensor layer
10	8	operating zone of the vehicle simulator
	9	safety perimeter
	10	entry door
	11	monitoring sensor
	12	pedestal of the robot 1
15	13	rescue unit
	14	running rail of the rescue unit
	15	carriage of the rescue unit
	16	floor with airbag equipment
	17	slewing ring of the rescue unit
20	18	slewing ring of the robot arm
	19	revolute joint 1 of the robot arm
	20	revolute joint 2 of the robot arm
	21	revolute joint 3 of the robot arm
	22	revolute joint 4 of the robot arm
25	23	revolute joint 5 of the robot arm
	24	railing of the rescue platform
	25	rescue platform
	26	rescue slide
	27	lifting unit of the rescue platform
30	28	safety zone
	29	robot 1
	30	robot 2
	31	robot 3
	32	platform
35	33	projection surface A
	34	projection surface B

Patent claims

1. An apparatus for the safe use of a vehicle simulator in
5 the form of a simulation cockpit (3) actuated by means of a
6-axis robot around a pedestal with a slewing ring, in
particular of a flight simulator, having

a) an access zone to said simulation cockpit (3),
which is open only to those authorized and has a number of
10 safeguards, wherein said simulation cockpit (3) is
supported on a damping layer (4) when in the idle
position, said layer being shaped to match the contour of
its underside, and in its boarding zone on both sides lead
respective boarding stairs (6), whose treads are provided
15 with a sensor layer (7), which indicates access of a
person to the overall system,

b) a rescue unit (13), which can be moved by an
carriage (15) on a running rail (14) to each location of
the operating zone of the vehicle simulator being
20 supported around the pedestal (12) of the 6-axis robot by
the slewing ring (17), wherein this rescue unit has a
rescue platform (25) having a lifting unit (27), a railing
(24) and a rescue slide (26),

c) a shock-absorbing surface installed throughout the
25 entire operating zone, wherein said surface extends over
the entire operating zone of the simulation cockpit (3),
wherein the shock-absorbing surface comprises circular
safety zones (28) and wherein by means of sensors
detecting falling masses, in each safety zone (28) an air
30 bag can inflate,

d) a projection surface (33, 34) made up of a
plurality of planes.

2. The apparatus as claimed in claim 1, characterized in
35 that

the simulation cockpit (3) is secured on a platform (32) which is, in turn, actuated not by just one 6-axis robot but by at least two 6-axis robots.

5 3. The apparatus as claimed in claim 1 or 2, characterized in that
the access zone is formed by at least one access door safeguarded by at least one monitoring sensor (11), and in that each access door leads to a boarding stair (6), which is
10 monitored by means of a sensor layer in respect of the weight of the person entering.

4. The apparatus as claimed in one of claims 1 to 3,
15 characterized in that
imminent failures in the robot components are detected by means of acoustic and/or optical means, and failures in the electrical systems are detected by means of smoke detecting means, and said failures are taken into account in the
20 programming.

5. The apparatus as claimed in one of the preceding claims, characterized in that
an alarm is triggered in the event of predetermined fault
25 indications or foreign-body indications.

6. A method for the safe use of a vehicle simulator in the form of a simulation cockpit (3) actuated by means of a 6-axis robot around a pedestal with a slewing ring, in
30 particular of a flight simulator, having
a) an access procedure (method steps 1. to 5. and 11 to 19) which safeguards the access zone,
b) provision of a rescue unit which can be moved to any location of the vehicle simulator (method steps 6 to 10),
35 c) the provision of a shock-absorbing surface installed throughout the entire operating zone, wherein said

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surface extends over the entire operating zone of the cockpit
(3) (method steps 6 to 10),

d) the provision of a projection surface (33, 34) made
up of a plurality of planes, (method steps 6 to 10).

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7. The method as claimed in claim 6, characterized in that
the simulation cockpit (3) is actuated not by just one 6-axis
robot but by at least two 6-axis robots.

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8. The method as claimed in one of claims 6 or 7,
characterized in that
imminent failures in the robot components are detected by
means of acoustic and/or optical means, and failures in the
15 electrical systems are detected by means of smoke detecting
means, and said failures are taken into account in the
programming.

20

9. The method as claimed in one of claims 6 to 8,
characterized in that
an alarm is triggered in the event of predetermined fault
indications or foreign-body indications.

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10. A computer program having a program code for carrying
out the method steps as claimed in one of claims 6 to 9 when
the program is executed in a computer.

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11. A machine-readable medium having the program code of a
computer program for carrying out the method as claimed in
one of claims 6 to 9 when the program is executed in a
computer.