

CLAIMS

1. A projected augmented reality system for directing an operator to perform a manual process, comprising:
 - a video projector, configured to project a dynamically-changing image onto a surface
 - 5 within a work area of the operator;
 - a depth sensor;
 - a two-dimensional camera with a narrow field of view; and
 - a computer communicatively connected to the video projector and the depth sensor, the computer comprising a memory and a processor, the memory including instructions
 - 10 that when executed by the processor cause the computer to:
 - obtain three-dimensional pose data using the depth sensor;
 - obtain part, part placement and part quality data using the two-dimensional camera with a narrow field of view;
 - determine an output graphical image based on the part, part placement and
 - 15 part quality data, and on a current production state; and
 - sending an output image based on the output graphical image onto a surface within the work area using a video projector.
2. The projected augmented reality system of claim 1 further comprising a two-
20 dimensional camera with a wide field of view configured to capture two-dimensional images of a large area including the operator and of the work area wherein the memory includes instructions that when executed by the processor cause the computer to:
 - receive a two-dimensional image of the operator and of at least a portion of the work area from the two-dimensional camera with a wide field of view.
- 25 3. The projected augmented reality system of claim 2, wherein the memory includes instructions that when executed by the processor cause the computer to:
 - determine an output graphical image based on the sequence of three-dimensional pose data over time and on the current production state.

4. The projected augmented reality system of claim 3, wherein the memory includes instructions that when executed by the processor cause the computer to:

5 send the output graphical image to the video projector for projection onto the work area.

5. The projected augmented reality system of claim 37 wherein the part, part placement and part quality data are selected from the group consisting of correct part data, correct parts container data, correct assembly tools data, and correct assembly data.

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6. The projected augmented reality system of claim 1, wherein the memory includes instructions that when executed by the processor cause the computer to determine pose data for the operator from the two-dimensional image by:

15 determining pose data for all humans visible in the two-dimensional image; and
 filtering pose data for the operator from pose data of other humans visible in the two-dimensional image.

7. The projected augmented reality system of claim 1, wherein the memory includes instructions that when executed by the processor further cause the computer to:

20 determine estimated three-dimensional locations of the operator's hands based on the three-dimensional pose data; and

 wherein the memory includes instructions that when executed by the processor cause the computer to determine an output image based on a sequence of estimated three-dimensional locations of the operator's hands over time.

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8. The projected augmented reality system of claim 1, wherein the memory includes instructions that when executed by the processor further cause the computer to map the output graphical element into the output image for projection onto the surface using a

three-dimensional model containing a representation of at least a portion of the work area and of the video projector.

9. The projected augmented reality system of claim 1, wherein the memory includes
5 instructions that when executed by the processor further cause the computer to:
- determine pose data for the operator that includes data for the operator's fingers from either the two-dimensional image or the three-dimensional image, or both the two-dimensional image and the three-dimensional image;
 - determine a gesture based on the pose data for the operator's fingers; and
 - 10 determine a command based on the gesture.
10. The projected augmented reality system of claim 1 further comprising an eye tracking device communicatively connected to the computer.
- 15 11. The projected augmented reality system of claim 10, wherein the memory further includes instructions that when executed by the processor cause the computer to:
- receive an eye tracking signal indicative of the operator's gaze from the eye tracking device; and
 - use the eye tracking signal to determine whether the operator has properly
 - 20 inspected an assembly by scanning it with his eyes.
12. The projected augmented reality system of claim 2, wherein the computer is connected to a network.
- 25 13. The projected augmented reality system of claim 12, wherein a supervisory computer connected to the network is configured to remotely monitor the projected augmented reality system.

14. The projected augmented reality system of claim 12, wherein a factory manufacturing execution system provides production information over the network for use by the projected augmented reality system.
- 5 15. The projected augmented reality system of claim 1, wherein at least the image sensor and the depth sensor are mounted on a motorized mount that is communicatively connected to the computer, and wherein the memory further includes instructions that when executed by the processor cause the computer to move the motorized mount to track a position of the operator or of a work piece within the work area.
- 10 16. The projected augmented reality system of claim 2, wherein the memory further includes instructions that when executed by the processor cause the computer to identify the operator based on facial recognition.
- 15 17. A method for using a projected augmented reality system for directing an operator to perform a manual process, comprising:
- receiving by a computer a wide field of view two-dimensional image of the operator and of at least a portion of a work area from an image sensor;
 - determining by the computer pose data for the operator from the wide field of
 - 20 view two-dimensional image;
 - receiving by the computer a three-dimensional image of the operator and of the work area from a depth sensor;
 - updating by the computer the pose data with depth coordinates based on the three-dimensional image to provide three-dimensional pose data;
 - 25 determining by the computer an output graphical element based on a sequence of three-dimensional pose data over time, and on a current production state; and
 - projecting an output image based on the output graphical element onto a surface within the work area using a video projector;

receiving a more detailed narrow field of view two-dimensional image of a part within the wide field of view two-dimensional image;

determining a part and part placement data for the operator from the narrow field of view two-dimensional image;

5 determining an output graphical image based on the three-dimensional pose data over time, the part and part placement data, and on a current production state; and

 sending the output graphical image onto a surface within the work area using a video projector.

10 18. The method of claim 17, further comprising mapping by the computer the output graphical element into the output image for projection onto the surface using a three-dimensional model containing a representation of at least a portion of the work area and of the video projector.

15 19. The method of claim 17, further comprising: determining, by the computer, pose data for the operator that includes data for the operator's fingers from either the two-dimensional image or the three-dimensional image, or both the two-dimensional image and the three-dimensional image; determining, by the computer, a gesture based on the pose data for the operator's fingers; determining, by the computer, a command based on
20 the gesture; and executing the command.

20. A non-transitory computer-accessible medium, computer program or computer program product having computer-executable instructions for directing an operator to perform a manual process in a projected augmented reality system, wherein, when a
25 computer hardware arrangement executes the instructions, the computer arrangement is configured to perform procedures comprising:

 receiving by a computer a wide field of view two-dimensional image of the operator and of at least a portion of a work area from an image sensor;

- receiving by the computer a three-dimensional image of the operator and of the work area from a depth sensor;
- determining by the computer pose data for the operator from the depth sensor;
- updating by the computer the pose data with depth coordinates based on the three-
- 5 dimensional image to provide three-dimensional pose data determining by the computer an output graphical element based on a sequence of three-dimensional pose data over time, and on a current production state; and
- projecting an output image based on the output graphical element onto a surface within the work area using a video projector;
- 10 receiving a more detailed narrow field of view two-dimensional image of a part within the wide field of view two-dimensional image;
- determining a part and part placement data for the operator from the narrow field of view two-dimensional image;
- determining an output graphical image based on the three-dimensional pose data over
- 15 time, the part and part placement data, and on a current production state; and
- sending the output graphical image onto a surface within the work area using a video projector.