CLAIMS

1. An imaging apparatus configured to be coupled to a mobile robot, the imaging apparatus comprising:

a structural support rigidly couplable to a surface of the mobile robot;

a plurality of perception modules, each of which is arranged on the structural support to have a different field of view and includes:

a two-dimensional (2D) camera configured to capture a color image of an environment;

a depth sensor configured to capture depth information of one or more objects in the environment; and

at least one light source configured to provide illumination to the environment;

control circuitry configured to control a timing of operation of the 2D camera, the depth sensor, and the at least one light source included in each of the plurality of perception modules; and

at least one computer processor configured to process the color image and the depth information to identify at least one characteristic of one or more objects in the environment.

2. The imaging apparatus of claim 1, wherein the depth sensor comprises a time-of-flight (TOF) camera.

3. The imaging apparatus of claim 1, wherein the depth sensor comprises a stereoscopic camera.

4. The imaging apparatus of claim 1, wherein the 2D camera comprises a red-green-blue (RGB) monocular camera.

5. The imaging apparatus of claim 1, wherein the structural support is configured to rotate relative to the surface of the robot, and wherein the plurality of perception modules are configured to capture corresponding color images and depth information as the structural support rotates.

6. The imaging apparatus of claim 1, wherein the plurality of perception modules include a first perception module and a second perception module, and wherein the first perception module and the second perception module are arranged vertically along a same side of the structural support.

7. The imaging apparatus of claim 1, wherein processing the color image and the depth information comprises:

registering the color image and the depth information to create a combined image; and

identifying the at least one characteristic of one or more objects in the environment based, at least in part, on the combined image.

8. The imaging apparatus of claim 7, wherein registering the color image and the depth information comprises correcting for distortion in one or both of the color image and the depth information.

9. The imaging apparatus of claim 7, wherein identifying the at least one characteristic of one or more objects in the environment based, at least in part, on the combined image comprises providing the combined image as input to a statistical model trained to identify the at least one characteristic.

10. The imaging apparatus of claim 9, wherein the at least one characteristic includes one or more surfaces of the one or more objects in the environment.

11. The imaging apparatus of claim 10, wherein

the mobile robot further comprises an arm coupled to the surface of the mobile robot, and

the at least one computer processor is further configured to control an operation of the arm based, at least in part, on the identified at least one characteristic.

12. The imaging apparatus of claim 11, wherein the at least one computer processor is further configured to select, from among the one or more objects in the environment, a next object to interact with, and

wherein controlling an operation of the arm comprises controlling an operation of the arm to cause the arm to interact with the selected next object.

13. The imaging apparatus of claim 12, wherein the at least one computer processor is further configured to determine whether to interact with a top surface or a face surface of the selected next object, and

wherein controlling the operation of the arm comprises controlling an operation of the arm to cause the arm to interact with the determined top surface or face surface of the selected next object.

14. The imaging apparatus of claim 1, wherein

the 2D camera is electrically connected to the depth sensor and the at least one light source,

the control circuitry is configured to trigger a start of operation of the 2D camera, and

the 2D camera is configured to trigger a start of operation of the at least one light source and the depth sensor.

15. The imaging apparatus of claim 1, wherein the plurality of perception modules includes a first perception module and a second perception module, and wherein the control circuitry is configured to trigger a start of operation of one or more components within the first perception module at a first timepoint and trigger a start of operation of one or more components within the second perception module at a second timepoint after the first timepoint.

16. The imaging apparatus of claim 15, wherein triggering a start of operation of one or more components within the first perception module at a first timepoint and triggering a start of operation of one or more components within the second perception module at a second timepoint after the first timepoint comprises:

triggering the at least one light source of the first perception module at the first timepoint and triggering the at least one light source of the second perception module at the second timepoint.

17. The imaging apparatus of claim 16, wherein a time between the first timepoint and the second timepoint is between 50-100 ms.

18. The imaging apparatus of claim 1, wherein the environment comprises an inside of a container, and wherein the at least one characteristic comprises one or more of a side of the container and a top of the container.

19. The imaging apparatus of claim 1, wherein
the mobile robot further comprises an arm coupled to the surface of the mobile robot, and
the environment includes the arm of the mobile robot.

20. The imaging apparatus of claim 19, wherein the at least one characteristic comprises one or more dimensions of an object coupled to an end effector of the arm of the mobile robot.

21. The imaging apparatus of claim 19, wherein the at least one computer processor is further configured to calibrate the mobile robot based, at least in part, on the identified at least one characteristic.

22. The imaging apparatus of claim 21, wherein calibrating the mobile robot comprises calibrating the arm of the mobile robot and/or calibrating one or more components of the each of the plurality of perception modules.

23. The imaging apparatus of claim 1, wherein
the mobile robot further comprises an arm coupled to the surface of the mobile robot, and
the environment does not include the arm of the mobile robot.

24. The imaging apparatus of claim 1, wherein the at least one light source comprises a plurality of light sources arranged to at least partially surround the 2D camera.

25. The imaging apparatus of claim 1, wherein the at least one light source is configured to output light in the visible spectrum, and wherein the depth sensor is configured to emit infrared light.

26. The imaging apparatus of claim 25, wherein the control circuitry is configured to control a timing of operation of the at least one light source and the depth sensor to start operating simultaneously.

27. A method of imaging one or more objects in an environment of a mobile robot, the method comprising:

capturing with a first sensor and a second sensor of a first perception module having a first field of view, a first color image of the environment and first depth information for one or more objects in the environment;

capturing with a first sensor and a second sensor of a second perception module having a second field of view, a second color image of the environment and second depth information for one or more objects in the environment, wherein the first field of view and the second field of view are different;

processing the first color image, the first depth information, the second color image, and the second depth information to identify at least one characteristic of one or more objects in the environment; and

controlling at least one operation of the mobile robot based, at least in part, on the identified at least one characteristic.

28. The method of claim 27, further comprising controlling an operation of the first perception module and the second perception module such that the first color image and the second color image are captured at different timepoints.

29. The method of claim 27, wherein processing the first color image, the first depth information, the second color image, and the second depth information comprises:

registering the first color image and the first depth information to generate a first combined image;

registering the second color image and the second depth information to generate a second combined image;

providing as input to a statistical model trained to identify the at least one characteristic, the first combined image and the second combined image; and

identifying the at least one characteristic based, at least in part, on an output of the statistical model.