detection system **200** may include a horizontal display screen **201**, which may serve as display **104** to display graphical images to be seen by the user, as well as input **106** to receive input from the user (as will be described below). The screen **201** may be composed of a clear panel, such as glass or acrylic, to allow an image to be displayed via projection from below.

The system **200** may be configured to detect different types of input, such as touch-based inputs and non-touch-based inputs. Touch-based inputs may include placing an object, such as a user's finger, on the screen **201**. Non-touch-based inputs may include gestures made above the screen **201**, such as moving a user's hand over the system screen **201**. The systems for detecting these gestures may involve a series of cameras. For touch-based gestures, the system **200** may include a touch-based gesture detection system, having a series of light emitters **202** (which may be infrared) and camera **203**. Light from the emitters **202** may illuminate, and pass through, the underside of screen **201**.

When an object, such as the user's finger, is placed on top of the screen **201** from above, the object will reflect the light from emitters **202**. That reflected light may be detected by one or more cameras **203**. Images detected from camera **203** may be supplied to processor **101** for processing to determine where the screen **201** has been touched. Some touch-based gestures may incorporate movement (e.g., swiping a finger across a portion of screen **201** in a predetermined pattern), and in those cases the images from camera **203** may be sequential in time. FIG. **4**, discussed further below, provides an example process by which such gestures may be detected.

For non-touch-based gestures, the system may include a non-touch based gesture detection system, having a second camera **204**, positioned above the top of screen **201**. The second camera **204** may be a more traditional, visible light camera. Images captured from camera **204** may also be supplied to processor **101** for processing to determine where gestures were made above the screen **201**, and what types of gestures were made.

Although the two cameras **203**, **204** are described above as being useful for touch and non-touch gestures, respectively, they are each useful for both gesture types. In other words, the infrared camera **203** may also be used to detect non-touch gestures that occur near the screen **201** and are visible. Similarly, the visible light camera **204** may also detect touch gestures, for example, by determining whether the user's hand appears to be touching the screen **201**. In some embodiments herein, the combination of these two input detection approaches helps provide an effective input gesture detection mechanism.

FIG. **3** illustrates examples of touch and non-touch gestures that may be made with a user's hand. For example, non-touch gestures may involve finger configurations (such as the "Start" and "End" configurations illustrated) and/or movements (such as the "Grasping" and "Dropping" movements illustrated). Touch gestures may involve an object making contact with the screen **201**, such as one or more fingers pressing on the screen **201** at a location (or in a predetermined pattern), or a hand pressing on the screen **201**. Touch gestures may also involve movements across the screen **201**, such as a finger mopping motion of dragging the finger. In some embodiments described herein, touch and non-touch gestures can be combined, and used together to provide predetermined commands to the computing system.

FIGS. **4***a* and **4***b* illustrate an example application that can combine touch and non-touch gestures. The example application mimics the behavior of sand on the screen **201**. In FIG. **4***a*, the user may make a closed-first gesture above the screen **201** (signaling to the application that the first is holding sand), and the user may then open the hand to mimic dropping sand on the screen **201**. The computing system **100** may detect this gesture, and may display an image of a pile of sand under the user's hand. Then, the user may touch the screen **201** to clear away sand at the location of the touch; swipe/mop a finger across the surface to clear away patterns of sand; pick up sand from the screen **201** (e.g., a hand pressing touch gesture followed by a first);

and/or drop sand on the screen **201**, to create patterns and images in the sand, as illustrated in FIG. **4***b*.

FIG. **5** illustrates an example process by which a touch gesture may be detected using camera **203**. Steps in the process are shown on the left, and corresponding example images from camera **203** are shown on the right, to help illustrate the process. First, in step **501**, the camera **203** may be initialized to capture a background image in which no objects are placed on the screen **201**. Once the system has been initialized, it is ready to begin detecting touch gestures. In step **502**, the camera **203** may capture a new image or sequence of images, and in step **503**, the background image may be subtracted from the new image to yield a foreground image of the object (s) that were not present in the background during initialization. This subtraction may be performed using any desired image processing method.

In step **504**, the foreground image may be binarized to identify, on a per-pixel basis, whether an object is, or is not, present at that pixel. For example, the binarization may generate a binary (e.g., black and white) version of the foreground image, by comparing color or brightness values of a pixel with a predetermined threshold value, so that pixels having values above the threshold are indicated as white, and pixels having values below the threshold are indicated as black (or vice-versa).

In step **505**, the binarized foreground image may then be examined to isolate the region in which an object appears. In the example shown in FIG. **5**, the lower portion of the image shows the user's two hands, so this gesture region is extracted in step **505** (the gesture region is highlighted for explanation by a surrounding box in FIG. **5**). Any desired image process can be used to extract this region. For example, a connected-component method may be used, in which the brightest part of the image (e.g., the strongest point of actual contact) is first selected, and then nearby pixels having a similar brightness (or having a brightness that is within a predetermined threshold of the first point) are added, and the process continues, spreading to nearby pixels until there is a sufficient dropoff in image brightness between neighboring pixels. This method may define regions, such as the highlighted rectangular region illustrated beside step **505**.

When the gesture region has been identified, the image in that region may be compared in step **506** with predetermined templates to determine whether a gesture has been detected. This comparison may be performed using any desired image matching algorithm. For motion-based gestures, the template may comprise a series of predefined gesture images through the motion, and the steps above may be repeated to account for the various portions of the motion. Alternatively, a sequence of a plurality of images may be captured prior to comparison with a multi-image template.

If a match is found between a template and the gesture region of the image, the process may provide an output indicating that a gesture was detected, and identifying the detected gesture. The output can also include information identifying how closely the detected gesture matched the template for the gesture. For example, if the template indicates that a given gesture requires two of the user's fingers to