ROBOTIC SYSTEM FOR PERFORMING PATTERN RECOGNITION-BASED INSPECTION OF PHARMACEUTICAL CONTAINERS

FIELD OF THE DISCLOSURE

[0001] The present application relates generally to the inspection of pharmaceutical containers, such as syringes or vials, and/or the inspection of samples within such containers.

BACKGROUND

[0002] In certain contexts, such as quality control procedures for manufactured drug products, it is necessary to examine fluid or other (e.g., lyophilized) samples for the presence of various attributes, such as particles, bubbles or stains. Undesired particles or other attributes can originate from a number of different sources, such as the environment, incorrect handling or storage, or byproducts/residuals of forming, packaging, or filling. Depending on the context, certain types of attributes may be acceptable (e.g., bubbles), while others may be unacceptable (e.g., particles, specific types of particles, particles above a certain size and/or count, etc.). If unacceptable attributes are detected in a fluid sample, the fluid sample is rejected.

[0003] Image processing methods traditionally used to detect defects in large commercial inspection machines frequently struggle to achieve high accuracy when faced with challenging inspection tasks. This is particularly true for inspections that require evaluating samples in which defect and non-defect attributes can present themselves simultaneously, while also having a very similar appearance. For example, the inspection of liquid-filled syringes may entail discriminating particles or stains on the piston dome (defects) from innocuous bubbles on the piston dome (non-defects). For automated processes, this can make it difficult to ensure that defective samples are rejected at an acceptable rate (e.g., 100% of the time, or at least 99.99999% of the time, etc.), and difficult to ensure that conforming samples are approved (i.e., not falsely rejected) at an acceptable rate. The former circumstance may result in potentially dangerous situations, and the latter circumstance may result in higher costs due to the unnecessary discarding of acceptable product. While poor accuracy of an automated system may in some instances be compensated for by other means (e.g., repeated inspections, manual inspections, etc.), such approaches are generally expensive in terms of both time and cost. Similar drawbacks exist in connection with other quality procedures, such as when inspecting the containers themselves for defects.

SUMMARY

[0004] There is disclosed a system that improves upon traditional inspection techniques. In particular, a robotic inspection platform uses pattern recognition (e.g., deep learning) models/techniques to perform inspection of pharmaceutical containers (e.g., syringes, vials, cartridges, etc.) and/or inspection of samples within such containers (e.g., fluids, lyophilized products, etc.), and can handle even highly challenging inspection tasks. The pattern recognition model may be capable of reliably discriminating between particles and bubbles in a fluid sample, for example, or between specific

types of particles and specific types of bubbles, etc. The robotic inspection platform may also be configured to facilitate the initial (pre-production) development or training of pattern recognition models. In some examples, the platform may be used to perform the primary (e.g., sole or initial) inspection of containers and/or samples. Alternatively, the platform may be used to re-inspect containers and/or samples that have already been identified as rejects, or potential rejects, by another automated inspection system (e.g., a conventional automated inspection system that is less reliable/accurate).

[0005] In examples where the platform implements a machine learning model, the model may be trained using a large data set of training images and a supervised learning technique. The platform may be used to capture the training images under controlled conditions (e.g., precise, repeatable container orientations and lighting conditions), after which a human analyst may manually label attributes of the training images. For example, the analyst may label/classify objects within the training images as specific object types. To capture the training images, a robotic arm of the platform may sequentially pick up each of a number of containers, present the containers in front of the imager, and manipulate (e.g., rotate) the containers while images are acquired at different angles/orientations. Containers with purposely introduced defects (and/or holding samples with purposely introduced defects) may be used in the training process to ensure that the human analyst will encounter a sufficiently broad range of defects and/or defect types when performing the classification task.

[0006] Once the model is trained and integrated, the platform may switch to a "production," "run-time," "operational" or "processing" mode in which the robotic arm retrieves new containers (possibly holding samples), and manipulates the containers in front of the imager in the same manner that was done during the training process. The images for each container may be saved in memory, and processed by a computer using the trained pattern recognition model. The computer may also process the model outputs by applying one or more criteria to determine whether the container is acceptable, or a "reject." If the container is rejected (due to a sample within the container having defects, and/or the container itself having defects), the robotic arm may place the container in a bin or other area specifically reserved for that purpose. The robotic inspection platform may be configured to inspect only containers, to inspect only product samples (e.g., fluids or lyophilized products within the containers), or to inspect both containers and samples, depending on the example. In one example, a single robotic inspection platform can perform any of these functions, so long as the appropriate machine learning models are deployed.

[0006a] According to a first aspect of the present invention, there is provided a robotic inspection platform, comprising:

a robotic arm comprising an end effector and a plurality of articulable segments;

an imaging system comprising an imager; and

a controller configured to

cause the robotic arm to retrieve, using the end effector, a container,

cause the robotic arm to manipulate the container using the end effector, such that the container is sequentially placed in a plurality of orientations while the container is in view of the imager,

cause the imager to capture a plurality of images, with each of the plurality of images being captured while the container is in a respective one of the plurality of orientations,

determine one or more attributes of the container, and/or a sample within the container, by analyzing the plurality of images using a pattern recognition model,

determine, based on the one or more attributes of the container and/or the sample, whether the container and/or the sample satisfies one or more criteria, and

based on whether the container and/or the sample satisfies the one or more criteria, either (i) cause the robotic arm to place the container in an area reserved for rejected containers and/or samples, or (ii) cause the robotic arm to place the container in an area reserved for containers and/or samples that have not been rejected.

[0006b] According to a second aspect of the present invention, there is provided a method for performing inspection of containers using pattern recognition, the method comprising:

causing a robotic arm to retrieve, using an end effector of the robotic arm, a container;

causing the robotic arm to manipulate the container using the end effector, such that the container is sequentially placed in a plurality of orientations while the container is in view of an imager;

causing the imager to capture a plurality of images, with each of the plurality of images being captured while the container is in a respective one of the plurality of orientations;

determining one or more attributes of the container, and/or a sample within the container, by analyzing the plurality of images using a pattern recognition model;

determining, based on the one or more attributes of the container and/or the sample, whether the container and/or the sample satisfies one or more criteria; and

based on whether the container and/or the sample satisfies the one or more criteria, either (i) causing the robotic arm to place the container in an area reserved for rejected containers and/or samples, or (ii) causing the robotic arm to place the container in an area reserved for containers and/or samples that have not been rejected.

[0006c] According to a third aspect of the present invention, there is provided a method for performing inspection of containers using pattern recognition, the method comprising:

causing a robotic arm to retrieve, using an end effector of the robotic arm, a container;

causing an imager to be sequentially placed in a plurality of orientations while the container is in view of the imager;

causing the imager to capture a plurality of images of the container, with each of the plurality of images being captured while the imager is in a respective one of the plurality of orientations;

determining one or more attributes of the container and/or the sample by analyzing the plurality of images using a pattern recognition model;

determining, based on the one or more attributes of the container and/or the sample, whether the container and/or the sample satisfies one or more criteria; and

based on whether the container and/or the sample satisfies the one or more criteria, either (i) causing the robotic arm to place the container in an area reserved for rejected containers and/or samples, or (ii) causing the robotic arm to place the container in an area reserved for containers and/or samples that have not been rejected.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The skilled artisan will understand that the figures, described herein, are included for purposes of illustration and are not limiting on the present disclosure. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the present disclosure. It is to be understood that, in some instances, various aspects of the described implementations may be shown