

PACKING SYSTEM WITH FOLDABLE FLAP ROTATION ANGLE DETECTION

Technical Field

This disclosure relates generally to a packing system and method, and more
5 particularly to a packing system and method for inspecting, using computer vision, a
packaging container having one or more flaps that are foldable to close an open side
of the packaging container.

Background

In the process of shipping one or more articles from one location to another, a
10 packer typically places some type of dunnage material in a packaging container, such
as a foldable card-board box, along with the article or articles to be shipped. The
dunnage material partially or completely fills the empty space or void volume around
the articles in the container, thereby preventing or minimizing undesirable movement
of the articles that could cause damage during the shipping process. Some
15 commonly used dunnage materials include plastic airbags and recycled paper
dunnage material.

The dunnage material can be manually or automatically deposited into the
container. A common container is a cardboard box with upright flaps that can be
folded down to partially or completely close an open side of the box after the
20 dunnage material is deposited into the box.

Automated object dimensioning systems typically employ a scanning
mechanism to scan boxes and generate digital data representative of contours of the
box based on the scan. Such data often may include digital range data
representative of the distance from the scanning element to sampled points along the
25 scanned object and may be measured with respect to a polar-type coordinate
system. Automated object dimensioning systems may include signal processing
circuitry to process electrical signal produced during each scan. An exemplary
dimensioning system is disclosed in U.S. Patent No. 7,344,082.

In addition, automated packaging systems may employ a packaging line that guides containers in a downstream direction and one or more sensors to determine one or more dimensions of a container on the packaging line. A dunnage dispenser may be positioned on the packaging line downstream of the sensors to dispense
5 dunnage into a void volume in the container as it passes the dunnage dispenser. A container closer on the packaging line, positioned downstream of the dunnage dispenser, then closes the container. An exemplary automated packaging system is disclosed in U.S. Patent No. 7,337,595.

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Summary

The present disclosure provides an improvement to automated and semi-automated packaging systems by providing a way to automatically, or as-desired upon receiving a corresponding input, detect and measure an angle of tilt of one or more flaps (also referred to as "flap angle") relative to a flat plane of digitally
15 generated points fitted to an open side of a packaging container. Deviation from vertical of each flap may be determined by performing a normal analysis, that is by determining deviation of a detected flap relative to a normal plane that is perpendicular to a base of the packaging container input for evaluation. Consequently, a given packaging container may be identified as suitable for filling
20 with dunnage material if the flap angles of all flaps each remain within a pre-set plane-angle tolerance threshold, such as fifteen degrees of outward rotation away from the described normal plane. After filling with dunnage material, such packaging containers may be subsequently sealed for shipment. Alternatively, flap angles exceeding deviation of the pre-set tolerance threshold, or inwardly rotated flap angles
25 describing flaps extending inwardly over an opening into the packaging container, may indicate that the respective packaging container is not suitable for filling with dunnage material, as the proximity of such flaps to the opening of a packing container may result in obstruction and interference with measuring the void volume or filling the void volume in the packaging container with dunnage material through

the opening or otherwise with closing the flaps effectively after insertion of the dunnage material.

More particularly, the present disclosure describes an exemplary packing system for inspecting a packaging container having one or more flaps that are foldable to close an open side of the packaging container. An exemplary packaging container may be one or a regular slotted container (RSC) or a half-slotted container (HSC). The packing system includes an imaging device that may generate a point cloud that is representative of the packaging container by digitally capturing multiple images of the packaging container. The point cloud is defined by a collection of points of data in three-dimensional (3D) space. In some embodiments, the described collection of points may include multiple top-most layer points, which are representative of the one or more flaps. For example, in such embodiments, the multiple top-most layer points may be projected onto a two-dimensional plane defining various features that are representative of a respective foldable flap. In some embodiments, points that represent contours and/or surfaces of the box are identified and filtered out using various machine vision algorithms including point cluster detection in order to isolate points representative of the box body and box flaps. Point cluster detection allows for the identification and measurement of the box flaps relative to the box walls in order to determine the relative flap angles. A computing unit is communicatively coupled to the imaging device. The computing unit may measure an angle of tilt for each flap by fitting a plane to the open side of the packaging container and performing a normal analysis on the plane.

In one or more embodiments of the disclosure, the imaging device includes a depth sensing camera that may generate the point cloud by capturing what is termed "dimensional information" of the packaging container. "Dimensional information," as generally defined and understood in the field of computer vision, may include or relate to data describing depth images, alternatively referred to as "depth maps" each depth image or depth map presented in the form of an image having pixel values correlating to depth information at a respective pixel location. In addition, the packing system may include a computing assembly housing the imaging device and the

computing unit. The computing assembly may fit a line segment to a respective flap feature of the plurality of features, wherein the line segment is representative of a corresponding dimension of the packaging container. In some embodiments, described computer vision techniques may perform two-dimensional (2D) line fitting
5 as well as three-dimensional (3D) shape fitting to the points representing, for example, the box body and box flaps. Further, in some embodiments, the packaging container has multiple walls, where the computing unit may detect points representative of one or more walls.

In one or more embodiments, the computing unit includes data describing a
10 pre-set maximum flap rotation threshold that is defined as detected outward rotation of a respective flap of fifteen degrees or more relative to the open side of the packaging container. Consequently, the computing unit is operable to identify the packaging container as unsuitable for automatic void filling based on whether detected rotation of the respective flap exceeds the pre-set maximum flap rotation
15 threshold. In addition, in some embodiments, the computing unit may determine a smallest rectangle capable of encompassing the point cloud when the point cloud is projected onto the two-dimensional plane.

In one or more embodiments, the packaging container defines a residual void volume defined as a void volume representative of empty space accounting for any
20 items retained within the packaging container, and the computing unit is operable to reduce the point cloud to a square grid-map having a constant size; and compute the residual void volume by using hole-filling algorithms to mitigate potential measurement error caused by occlusion due to placement of the imaging device relative to the residual void volume. In one or more embodiments, disclosed systems
25 and related apparatuses may be communicatively coupled with a void filling apparatus. The void fill apparatus may dispense dunnage through an opening of the packaging container and at least partially fill the packaging container based on whether the angle of tilt conforms to the pre-set conformance threshold of the packaging container. A closure apparatus may be communicatively coupled with at
30 least the void fill apparatus, where the closure apparatus may fold one or one or

more flaps of the packaging container inward over the opening and correspondingly close the opening for securing all flaps in a folded position after dispensation of dunnage.

5 In addition, in some embodiments, the computing unit may measure the angle of tilt for each flap relative to the plane fitted to the open side of the packaging container by extracting a sample subset of points representative of a corresponding flap, fitting a plane to the sample subset of points, and analyzing the plane relative to a corresponding geometric normal.

10 The present disclosure also provides an exemplary packing system that includes a conveyor belt assembly that is operable to guide a packaging container downstream from an initial loading position to a final deployment position. The conveyor belt assembly includes an input conditioning unit located at the initial loading position and on the conveyor belt assembly. The input conditioning unit may perform a pre-inspection operation of the packaging container. More particularly, in 15 one or more embodiments, the input conditioning unit is operable to perform the pre-inspection operation of the packaging container by detecting one or more of a fill level, box orientation relative to the conveyor belt assembly, flap tilt angles, or a conformance condition relative to a pre-set conformance threshold of the packaging container. A computing assembly is located downstream of the input conditioning unit 20 and on the conveyor belt assembly. More particularly, in some embodiments, the conveyor belt assembly is operable to direct the packaging container along a selected route from a group of routes including a standard route leading to a packaging container aggregation area; and a reject route leading to a specialized handling zone connected to the conveyor belt assembly of the packing system.

25 The computing assembly includes an imaging device that may generate a point cloud that is representative of the packaging container. More particularly, in one or more embodiments, the whole or a portion of the point cloud may be projected onto a two-dimensional plane that defines multiple features representative of a respective foldable flap, or at least an edge of a respective foldable flap, of the 30 packaging container. The computing unit is communicatively coupled to the imaging

device, where the computing unit may measure an angle of tilt for each flap relative to the walls of the box. A determination of whether the packaging container can be automatically processed by inserting dunnage and closing the foldable flaps may be made based on comparing the measured flap angles against a pre-set threshold. The
5 computing assembly is operable to use machine vision algorithms and generate the point cloud as a collection of points of data in a three-dimensional space. In some embodiments, the collection of points may include multiple top-most layer points representative of one or more flaps of the packaging container or one or more edge surfaces of respective flaps.

10 An output quality assurance (QA) unit is located at the final deployment position and on the conveyor belt assembly downstream of the computing assembly. The output QA unit is operable to perform a post-box closing (e.g., also referred to, in some embodiments, as a “pre-deployment operation”) by confirming that the foldable flaps are effectively closed and the packaging container is sufficiently sealed. For
15 example, in some embodiments, an extent of closure of the described foldable flaps may be evaluated by comparing an angle of tilt for one or more respective flaps against a pre-set threshold angle value, such as 15 degrees of outward rotation relative to an adjacent box wall for that flap. Further, in some embodiments, the output QA unit may detect one or more of a damage condition or a label quality
20 inspection of the packaging container by using machine vision algorithms and taking measurements of the packaging container, which may be presented in various conditions, such as fully open, partially open (e.g., with one or more flaps at least partially obscuring an entrance opening into the package), or fully closed and/or sealed (e.g., subsequent to insertion of dunnage into detected void volume of the
25 package).

In some embodiments, the computing unit is pre-loaded with multiple intralogistics operations thresholds including data describing definitions for categorizing the packaging container into one category selected from multiple categories including a first category describing conformance of the packaging
30 container to multiple intralogistics operations thresholds a second category

describing one or more of partial conformance or total non-conformance to the multiple intralogistics operations thresholds.

The present disclosure also includes an exemplary method for inspecting a container having one or more foldable flaps adjacent to and foldable over an open side of the container within a packing system. The method includes the following steps: generating, by an imaging device located on a conveyor belt of the packing system, a point cloud that is representative of the container by digitally capturing multiple images of the container; measuring, by a computing unit communicatively coupled to the imaging device, an angle of tilt for each flap based on the point cloud and relative to an opening into the container; and comparing, by the computing unit, the container against multiple pre-set container characteristic thresholds. More particularly, the pre-set container characteristic threshold may include data describing: a container fill-level; a container flap tilt angle of one or more container flaps; and a container height and width. The method also includes comparing, by the computing unit, an exit condition of the container as it exits the conveyor belt against the multiple pre-set container characteristic thresholds, the exit condition including data describing a secured position or a non-secured position of one or more container flaps relative to a main body of the container; a location of a dunnage tail relative to the main body of the container; and a location of a shipping label on the container which enables Quality Assurance (QA) functionality.

In addition, in one or more embodiments, the method may include defining, by the computing unit, the point cloud by using machine vision and detecting a collection of points of data representative of the container in three-dimensional (3D) space, where the collection of points includes multiple top-most layer points that are representative of one or more foldable flaps of the container; and projecting, by the computing unit, the multiple top-most layer points onto a two-dimensional plane; and defining multiple features representative of a respective foldable flap of the container based on projection. The method may include determining, by the computing unit and using machine vision, a minimum rectangular box bounding the plurality of top-most layer points when projected onto the two-dimensional plane.

Brief Description of the Drawings

FIG. 1 is a schematic view of a packing system provided in accordance with the present disclosure.

5 FIG. 2 is an elevation view of an exemplary packing system provided in accordance with the present disclosure.

FIG. 3 is a schematic view of an example configuration of the packing system of FIG. 2 provided in accordance with the present disclosure.

10 FIGS. 4A-4B are schematic views of an exemplary packaging container used in the packing system of FIG. 2.

FIGS. 5A-5E are schematic views of an exemplary packaging container used in the packing system of FIG. 2.

FIGS. 6A-6E are schematic views of an exemplary packaging container used in the packing system of FIG. 2.

15 FIG. 7 is a flowchart for processing the packaging container of the packing system of FIG. 2.

FIGS. 8A-8B are schematic diagrams of point cloud representations of a packaging container for use in the packing system of FIG. 2.

20 FIGS. 8C-8D are schematic diagrams of points projected onto a two-dimensional (2D) plane from the point cloud representations of FIGS. 8A-8B.

FIG. 9 is a schematic diagram of points representative of a flap of the packaging container of the packing system of FIG. 2 and a corresponding tilt angle measurement of the flap relative to a plane of the packaging container. FIG. 10A is a schematic diagram of a point cloud representation of a half-slotted container (HSC) as provided by the present disclosure.

FIG. 10B is a schematic diagram of points projected onto a two-dimensional (2D) plane from the point cloud representation of FIG. 10A.

Detailed Description

30 Cardboard boxes are industrially prefabricated boxes, commonly used as containers for storage or transportation of contents stored therein. Conventional

boxes typically have flat, parallel, and rectangular sides and may vary in size from relatively small (e.g., a matchbox) to relatively large (e.g., a shipping box for furniture). Boxes may be made of a variety of materials, both durable, such as wood and metal; and non-durable, such as corrugated fiberboard and paperboard.

- 5 Corrugated metal boxes are commonly used as shipping containers transported by trucks, rail, and ships. While most boxes have flat, parallel, rectangular sides, making them rectangular prisms, boxes also may have other shapes based on end usage preferences or application needs. Boxes may be closed and shut with flaps, doors, or a separate lid. Non-durable boxes, typically made of paper, often are secured shut
10 with adhesives, or tapes.

In the context of the present disclosure, several types of non-durable boxes may be used in packaging (also referred to as “packing”) and storage, such as corrugated boxes and folding cartons. A corrugated box is a shipping container typically made from corrugated fiberboard, generally paper-based, mostly used to
15 transport products from a warehouse during distribution. Corrugated boxes may also be known as cartons, cases, and cardboard boxes. Folding cartons (also referred to as “folding boxes”) are typically paperboard boxes manufactured with a folding lid. These are used to package a wide range of products and can be used for either one-time (non-resealable) usage, or as a storage box for more permanent use. Folding
20 cartons often are first printed (if necessary) before being die-cut and scored to form a blank; these are then transported and stored flat, before being constructed at the point of use.

Any of the described boxes, such as a corrugated box fabricated as a folding or foldable carton, can further be designated into several sub-categories based on
25 configuration, including regular-slotted-cartons (also referred to as “RSCs” or “RSC boxes”) and half-slotted-cartons (also referred to as “HSCs” or “HSC boxes”). RSC boxes are considered an industry standard and are commonly used for shipping various types of products. HSC boxes generally resemble RSC boxes, with the exception that HSC boxes lack flaps necessary to close the opening into the box.
30 HSC boxes are sometimes referred to as “shoebox”-style boxes and can only be

closed by a separate cover or lid secured over an open side of the HSC. As a result, HSC boxes tend to be more suitable for convenient product insertion and display of products within the HSC box, rather than for shipment of contents where securing and cushioning products is also necessary, unless a separate cover or lid is secured
5 over an open side of an HSC.

RSC boxes typically include a pair of major flaps and a pair of minor flaps positioned perpendicularly relative to the pair of major flaps. Both types of flaps typically must be opened and folded away from an opening or open side of the box to accommodate convenient and reliable placement of products and cushioning
10 materials into the box prior to subsequent closure for shipping. Currently, various automated end-of-line packing systems automate measuring and filling void volumes with dunnage, closing, and securing the flaps of RSC boxes. The boxes that are handled by automated end-of-line packing systems are required to meet strict specifications to maximize throughput as well as the effective and efficient processing
15 of boxes.

Flap opening angle has emerged as an important indicator on whether items can be automatically inserted into a respective box through its opening. That is, boxes, once assembled, may have items inserted into them through their respective openings, either manually or automatically in a packing system. In the latter example,
20 box flaps which protrude inwardly toward the opening may obstruct and thereby interfere with insertion and placement of products into the box. As a result, a key specification of boxes as they progress through packing systems is the orientation of the flaps relative to the opening. Depending on the automation system, different flap tilt angles may be allowable.

25 Aspects of the present disclosure recognize that packing systems may ensure that RSC flaps are within certain pre-set thresholds by using computer vision or machine vision executed by a computing unit, also referred to herein as a "Vision System." An imaging unit may be connected to the computing unit. The imaging unit and the computing unit may be collectively referred to as a "Decision Tower," which
30 typically may be mounted vertically above a conveyor belt moving boxes. The

Decision Tower may generate a point cloud that is representative of a respective box by digitally capturing multiple images of that box as it passes underneath the imaging unit on the conveyor belt. The Decision Tower then can use that point cloud to measure each flap's orientation relative to a corresponding plane of the box and
5 determine whether all flaps remain within applicable pre-set thresholds. Such measurements can in turn be used to make decisions before out-of-spec RSC boxes can potentially create problems, such as downstream blockages (referred to as "jams"), in end-of-line packing systems.

As a result, the described Vision System can measure the flap tilt angle for
10 each flap of an RSC box. Depending on the preset threshold, boxes that have flaps tilted (either inward toward the box opening or outward away from the box opening) beyond a corresponding predetermined threshold will be flagged for remediation by the packing system or by manual processing. The flap tilt angle threshold for major flaps may be different from the flap tilt angle threshold for minor flaps and also may
15 correspond to other applicable box dimensions, such as length, width, and height once the box is assembled.

Specifically, in one or more embodiments, the Decision Tower measures the orientation of the flaps by first capturing a depth image of a scene containing the box - this image is digitally converted into a three-dimensional representation based on
20 known camera characteristics. The captured scene is filtered and manipulated to isolate the three-dimensional information of the box from the environment. This information is used to localize the box and identify its dimensions, as well as the location of the flaps alongside their respective attachment and crease lines relative to the main body of the box. With the box localized and the flaps identified, the
25 orientation of the flaps can be measured accurately relative to planes fit to each of the upright orientation of the box walls. The orientation of the flaps is measured in a directional manner - the tilting direction of the flap (rotation inward or outward) can be determined. The directionality of the measurement allows for additional rules to be implemented, such as different thresholds for major and minor flaps, or different
30 thresholds for inward-tilting vs. outward-tilting flaps.

Referring now to the drawings in detail, and initially FIG. 1, an exemplary packing system 10 includes identifying means, such as a container scanner 12, for identifying a dimension of a container, a dunnage dispenser 14 for dispensing dunnage into the container, and closing means, such as a container closer 16, for closing the container, all arranged in series along a packaging line. As shown in FIG. 1, the dunnage dispenser 14 may be positioned downstream of the container scanner 12, and the container closer 16 may be positioned downstream of the dunnage dispenser 14. The dunnage dispenser 14 and the container closer 16 are communicatively coupled with the container scanner 12. In addition, the container closer 16 may include an adjustable member 20 that is adjustable based on the identified dimension from the container scanner 12 to accommodate random container sizes. Containers move through the system in an upstream-to-downstream direction, as shown by the downstream direction 22.

The illustrated system 10 further includes a controller 24 in communication with the container scanner 12, the dunnage dispenser 14, and the container closer 16. The controller 24 generally includes a computer processor or other computational device, a memory, and input and output devices. The controller can be remotely located or integrated into the container scanner 12, the dunnage dispenser 14, or the container closer 16. Alternatively, the functions of the controller 24 can be dispersed to one or more of the container scanner 12, the dunnage dispenser 14, and the container closer 16.

Operationally, the packing system 10 may function to receive a container, such as a packaging container. Any of the packaging container types, such as an RSC box or an HSC box, may be prepared as a corrugated carton and/or foldable box and may be one exemplary form of a packaging container suitable for usage with the packing system 10. In one embodiment, an RSC box (not shown in FIG. 1) may be placed on a conveyor belt (not shown in FIG. 1) generally running in the direction shown by the downstream direction 22 from the container scanner 12, past the dunnage dispenser 14, to the container closer 16. For example, in one or more embodiments, the dunnage dispenser 14 may dispense dunnage into the packaging

container as it passes underneath the dunnage dispenser 14. Such dispensation may be obstructed by the positioning of flaps of the packaging container relative to the upright orientation of its walls. The container scanner 12 may include, in one or more embodiments, an imaging unit connected to a computing unit, which may be collectively referred to as a "Vision System." This Vision System, as further described herein, may generate a point cloud that is representative of a respective packaging container by digitally capturing multiple images of the packaging container. As a result, the Vision System may measure each flap's orientation relative to a corresponding plane of the box and whether all flaps remain within applicable pre-set thresholds, such as within fifteen degrees of rotation about a horizontal fold or crease line in a direction relatively outward away from an opening of the box. The Vision System also can determine whether each flap's orientation includes no inward rotation beyond being parallel to the upright orientation of the walls of the packaging container.

Referring now to FIG. 2, an exemplary packing system 10 is shown. Packing system 10 of FIG. 2 may be one example of the packing system 10 of FIG. 1. In the packing system 10 shown in FIG. 2, the container scanner 12 is a container scanner, the dunnage dispenser 14 is a dunnage dispenser, and the container closer 16 is a container closer with an adjustable member 20 that includes an adhesive applicator, for example, a tape applicator. The controller 24 is remotely located and is linked in communication with the container scanner 12, the dunnage dispenser 14, the container closer 16, and the packaging line 30 through a wired or wireless communication network 26.

The packing system 10 also includes a packaging line 30 that guides containers 32 in a downstream direction 22. The packaging line 30 includes a conveyor 34. Sections of the packaging line 30 can be powered or unpowered to control packaging container placement, orientation, movement, and separation.

The container scanner 12 is the first station on the packaging line 30 and includes a sensor 36 that can identify a dimension of a container 32 on the packaging line 30, such as a height sensor that can identify a height of the container 32 or a bar

code sensor or radio frequency device that identify the container 32, its size, or its height. The sensor 36 can include a laser, an ultrasonic device, or any other apparatus for measuring a distance. To further improve the accuracy of the sensor 36 or to use the sensed information to identify a dimension indirectly, the sensed
5 information can be compared to a database of container heights, stored in a memory in the container scanner 12 or the controller 24. The dimension identified by the sensor 36 also can be used to determine a void volume in the container 32. An exemplary container scanner is disclosed in U.S. Pat. No. 7,337,595, which is hereby incorporated herein in its entirety. The void volume is defined as the volume of the
10 container that is not otherwise filled by an object or objects packed or placed in the container.

In addition, in one or more embodiments, the container scanner 12 may include the Decision Tower, including the Vision System as described earlier (alternatively referred to as a "Vision Measurement System" or "VMS"). The Decision
15 Tower may include an imaging unit communicatively connected to a computing unit. The imaging unit may be any digital camera, device, lens, assembly, photoreceptor and the like capable of performing digital imaging or digital image acquisition. Digital imaging is the creation of a digital representation of the visual characteristics of an object, such as a physical scene or the interior structure of an object. The term may
20 also imply or include the processing, compression, storage, printing, and display of such images.

The Decision Tower may further employ computer vision, which are tasks including methods for acquiring, processing, analyzing, and understanding digital images, and extraction of high-dimensional data from the real world in order to
25 produce numerical or symbolic information, e.g., in the forms of decisions. Understanding in this context means the transformation of visual images (the input to the retina in the human analog) into descriptions of the world that make sense to thought processes and can elicit appropriate action. This image understanding can be seen as the organization of symbolic information from image data using models
30 constructed with the aid of geometry, physics, statistics, and the like. In addition, the

Decision Tower may also, or alternatively, employ machine vision, which is the technology and methods used to provide imaging-based automatic inspection and analysis for such applications as automatic inspection, process control, and robot guidance, usually in industry. Machine vision may refer to many technologies,
5 software and hardware products, integrated systems, actions, methods, and expertise.

In one or more embodiments, the Decision Tower uses Machine Vision algorithms to take measurements of the packaging container 32 as it moves in the downstream direction 22 on the conveyor 34 toward and past the container scanner
10 12 (e.g., configured here as the Decision Tower as described earlier). In this way, the Decision Tower captures two-dimensional (2D) and three-dimensional (3D) images of the packaging container 32 as it passes the Decision Tower. Captured images may be aggregated and collectively analyzed to measure various dimensions and configurations of the packaging container, such as its length, width, height, location,
15 flap orientation, content fill height or contour, and the like. Accordingly, measurements made by the Decision Tower are later used by the packing system 10 regarding decision-making relating to whether a given packaging container 32 may be automatically processed, or if it must be separated into a separate refurbishment area and/or specialized handling zone for correction prior to re-insertion onto the
20 conveyor 34.

Further, various preset or predetermined thresholds, such as maximum permissible tilt angle of flaps, box orientation relative to the conveyor 34, box damage tolerances, and the like may be entered into the packing system 10 and Decision Tower by, for example, a user based on specifications of downstream automation
25 machines and/or the nature of the intralogistics operations thresholds and rules. This may be completed to define which boxes are “acceptable” and which boxes are “unacceptable” and in need of redirection to a specialized handling zone. The measurements taken by the Decision Tower may be compared to the preset rules to determine if a box can be automatically processed.

In one or more embodiments, the Decision Tower can read or otherwise electronically communicate with several other sensors including barcode scanners (e.g., which may read a barcode 70 of FIG. 6E imprinted on a side of the packaging container 32 exposed to the container scanner). The decision made on the automatic operability of a box may then be aggregated with other identifying information about the packaging container 32, such as a License Plate Number (LPN) or some other unique identifier imprinted on a surface of the packaging container 32 that is exposed to the container scanner. The decision (e.g., whether to progress the packaging container 32 along the downstream direction 22 for further processing or to redirect it to a refurbishment area) and ID of the box may then be communicated to a client network using any suitable and supported communication protocols.

The Decision Tower may provide just-in-time information to a client network (e.g., via a warehouse management system, "WMS"). In addition, in one or more embodiments, the Decision Tower may be equipped with several industry standard communication protocols (e.g., message-oriented middleware products, such as IBM/MQ, and/or Ethernet/IP, dry contact, etc.) available for use. Further, modularity of the packing system 10 may further enable the integration of even more communication protocols as needed, in a short amount of time.

In one or more embodiments, measurements and decisions taken by the Decision Tower may be logged for further analysis and insight creation. These logs may be collected locally on the Decision Tower with the ability to sync to a remote server. In addition, the logs collected may be then analyzed and reported to create improved insight into the operations of a customer's site. These reports may be used to identify issues in the customer's operations as well as opportunities to optimize the packing system 10.

Accordingly, the container scanner 12 may perform pre-inspection of the packaging container 32 prior to its progression further into the packing system 10 by, for example, ensuring one or more of: (1) that boxes are not over-filled; (2) that box flaps are not tilted outwardly away from an upright box wall of an opening into the box beyond a threshold of, for example, fifteen degrees relative to the opening, (3) that

boxes remain within preset or predetermined specifications input into packing system 10; and (4) that images of boxes may be obtained by the Decision Tower for accurate identification of boxes corresponding to, for example, one or more order selections.

Further, in one or more embodiments, an additional instance of the container scanner 12 may be positioned after either the dunnage dispenser 14 or the container closer 16 and function as a quality assurance (QA) unit for boxes that have already been initially input into and processed by the packing system 10 and have progressed by the dunnage dispenser 14. In addition, in some embodiments, the QA unit, as described here, may function to evaluate closed and/or sealed boxes. That is, for example, the QA unit may use any one or more of the described computer vision and/or digital imaging techniques to digitally observe and/or detect various contours and/or surfaces of a respective package to, for example, confirm positioning of the package relative to a conveyor belt, uniformity of shape of the package, and other physical condition related parameters. The container scanner 12, when functioning as a QA unit as described above, may ensure one or more of: (1) that boxes are closed correctly by ensuring that all flaps are shut and taped/glued correctly; (2) if open, that boxes do not have dunnage protruding outwardly outside the box; (3) that boxes are not damaged during processing by the packing system 10; and (4) that shipping labels are applied correctly to the shipping container.

Still referring to FIG. 2, the packaging container 32 may progress through the container scanner 12 as described above and progress toward the dunnage dispenser 14 positioned downstream of the container scanner 12 and on the conveyor 34. Void volume, which is empty space within the packaging container 32 unoccupied by its contents, may be filled with dunnage to protect objects during shipment. Dunnage is material used to load and secure cargo during transportation, such compressible wastepaper, cardboard, or other packing materials used to fill the empty volume to minimize movement, cushion, and optionally also retain the contents of the packaging container 32. In one or more embodiments, the dunnage dispenser 14 is at a dunnage dispensing station along the packaging line 30 downstream of the container scanner 12 and its sensor 36. The dunnage dispenser

14 is in communication with the container scanner 12 and the sensor 36 and is operable to dispense dunnage material to a void volume in a container 32, including dispensing a volume of dunnage material based on one or more identified dimensions of the container 32.

5 The illustrated dunnage dispenser 14 is a dunnage conversion machine 40 for converting a stock material, such as a sheet stock material, for example paper, into a relatively lower-density dunnage product. A supply 42 of stock material, such as the illustrated stack of fan-folded paper, a sheet stock material, is provided for the conversion machine 40 in the illustrated embodiment. An exemplary sheet stock
10 material is kraft paper. Exemplary void-filling dunnage conversion machines are shown and described in U.S. Patent Nos. 6,676,589 and 7,788,884, which are hereby incorporated herein in their entirety.

 The dunnage dispenser 14 generally can be controlled to dispense or output dunnage through a range of speeds without compromising the quality or desired
15 characteristics of the dunnage being supplied. In addition, if the dunnage is supplied too rapidly, an operator may not have sufficient time to direct the dunnage into the packaging container 32. In one or more embodiments, dunnage may be dispensed by the dunnage dispenser 14 at various speeds, including speeds faster than an operator can manually guide or direct it into the packaging container 32. Accordingly,
20 maximum dunnage dispensation limits may be input into the packing system 10 to limit to how fast dunnage can be dispensed to, for example, minimize or optimize the amount of time required to pack the container. Moreover, while the quality of the dunnage produced by the dunnage dispenser 14 may be sufficient to fill the packaging container 32 over a range of dispensing speeds, a slower dispensing
25 speed may provide different packaging qualities and characteristics in comparison to the dunnage produced at a higher speed. The different qualities and characteristics of dunnage produced at different speeds may be more desirable in certain situations. Accordingly, there may be situations where a lower dunnage dispensing speed is desirable both for the characteristics of the dunnage product produced and for the

convenience of the packer. Where possible, however, a higher dispensing speed can be used to reduce the overall packing time.

To improve the speed of the packaging line and reduce the time required for the packing process, the present disclosure also provides a way to control the dunnage dispenser 14 as a function of the size of a void volume of the packaging container 32 as measured by the container scanner 12. Specifically, if the void volume equals or exceeds a predetermined value, the rate at which the dunnage dispenser 14 dispenses dunnage may be increased. In other words, the rate at which the dunnage dispenser 14 dispenses dunnage may be a function of the measured void volume.

For example, if a container with a void volume of 56,633 cubic centimeters (approximately two cubic feet), a standard rate of fill of 139.7 cm per second (approximately 55 inches per second) and a fill ratio of about 16,000 centimeters per cubic meter (approximately 15 linear feet per cubic foot) are used, it will take approximately 6 seconds to fill the void volume in the container. If this void volume is above a predetermined value, such as 50,000 cubic centimeters (approximately 1.76 cubic feet), the rate of fill can be increased to about 280 centimeters per second (approximately 110 inches per second) and the fill time reduced to 3.5 seconds.

Faster dispensation speeds may be most beneficial for rapidly filling relatively large void volumes, as a relatively smaller void volume may be filled very quickly and result in dunnage positioning challenges due to the reduced total dunnage fill time. As a result, for relatively smaller variants of the packaging container 32, a slower dispensing rate may be chosen for the convenience of a packer to secure the dunnage in the container. However, such reduction in dunnage the dispensation may not materially increase overall packing times for the packaging container 32. The analysis of the void volume relative to a predetermined value or values established for changing the speed of the dunnage output can be performed by the controller 24, or any logic device in the container scanner 12 or in the dunnage dispenser 14, to thereby reduce the amount of time the container remains at the dunnage dispenser 14.

Additionally, if the Decision Tower determines that no dunnage is required, such as when the void volume is small or nonexistent, the packaging container 32 can be conveyed past the dunnage dispenser 14 without any dunnage being dispensed.

5 The container closer 16 is positioned downstream of the dunnage dispenser 14 and is operable to close packaging containers 32. In the case of an RSC with multiple flaps, each initially positioned in an upright orientation relative to the upright walls of the packaging container 32 when assembled, the container closer 16 may function to fold the flaps inwardly to a substantially horizontal orientation and then
10 seal the flaps in place, such as with an adhesive, such as an adhesive tape, for example. If different sizes of packaging containers 32 are used in the packing system 10, the container closer 16 will include an adjustable member 20, typically a height-adjustable member, which may include a taping head. The wireless communication network 26 provides a communication link between the container scanner 12 and the
15 sensor 36, and the container closer 16. This allows the container closer 16 to adjust the adjustable member 20 based on the identified dimensions, facilitating use of the container scanner 12 and container closer 16 with random sizes of containers. The container scanner 12 is adjustable, and more particularly the adjustable member 20 is movable, to accommodate containers 32 with different heights, but also can adjust
20 for containers having different widths as well. The container closer 16 includes an adhesive applicator, such as a tape applicator, to seal containers closed. The adhesive applicator may be mounted to the adjustable member 20.

 The present disclosure also provides a packaging method which can be described in conjunction with the operation of the system 10 shown in FIG. 2. The
25 method includes the steps of using the container scanner 12 to identify a dimension of a container 32, controlling the dunnage dispenser 14 to dispense a determined quantity of dunnage into the container 32 after the identifying step, adjusting the container closer 16 after the identifying step based on the identified dimension by moving the adjustable member 20, and closing the container 32 with the container
30 closer 16 after the controlling step.

In one embodiment, the identifying step may include sensing a height dimension of the packaging container 32 or using the sensed height dimension of a container to determine a packaging container height from a database of container heights, or both. Alternatively, the identifying step can include reading the barcode 70 to identify a container, and then referencing the bar code in a database to identify the height dimension for that container. The identifying step also can include identifying a void volume within the container and communicating the void volume information to the dunnage dispenser 14.

In a semi-automatic system, a packer controls the dispensing of dunnage, via a switch, for example; and in an automatic system a packer guides the dunnage material into the container but does not control the dispensing of dunnage. Alternatively, the system may automatically dispense dunnage material to a container at the dunnage dispensing station without any operator involvement. In both a semi-automatic and an automatic system, the amount of dunnage to dispense is predetermined, in contrast to a manual system where the packer controls both the dispensing of dunnage and the quantity of dunnage to dispense.

At the container closer 16, the adjusting step can include adjusting a height of the adjustable member 20 of the container closer 16. The adjusting step occurs before a container 32 leaves the dunnage dispensing station where the dispensing step occurs and can occur simultaneously with or before the dispensing step. The adjustable member 20 may begin moving to the required position after the identifying step, as soon as a preceding container is closed.

If the container is a non-conforming container, having some type of defect, such as having a flap angled outwardly at a tilt angle exceeding a preset threshold value, or is an HSC passing along the packaging line, the adjustable member 20 can be raised to its maximum height to allow the container to pass without being closed. Non-conforming containers, such as damaged containers, overfilled containers, etc., alternatively can be diverted around the container closer 16 for further inspection and automatic correction, or correction by operators, and then either manually closed or reinserted into the packaging line for transit through the container closer 16.

The system 10 also can include an input device 50 that is remotely located relative to the container closer 16. If a container needs to pass through the container closer 16 without being closed, for example, the input device 50 can be used to signal that to the container closer 16 or the controller 24. That can cause the adjustable member 20, including the taping head, to move to its maximum elevation to allow the container to pass unimpeded. This can be useful if the container is an HSC or other container that does not need to be closed (or requires a different type of closure) but needs to be passed along the packaging line 30.

The system 10 also can use one or more sensors 52, such as a grid sensor, to detect the presence of a container 32 at the dunnage dispenser 14 or dunnage dispensing station. If a container is detected, then the controller 24 can control the packaging line 30 to prevent another container from entering a pack zone at the dunnage dispenser 14. Information from the sensors 52 also can be used to control the speed of dunnage output by the dunnage dispenser 14.

Referring now to FIG. 3, an exemplary packing system 10 is shown. The packing system 10 of FIG. 3 may be one example of the packing system 10 of FIG. 1 and/or of the packing system 10 of FIG. 2, where like reference numerals refer to like features. In one or more embodiments, the packing system 10 of FIG. 3 may include multiple instances of the container scanner 12, including at positions shown in FIG. 3, such as before and after a processing unit 55 and on the conveyor 34. In one or more embodiments, the processing unit 55 may include one or more examples of the dunnage dispenser 14, dunnage conversion machine 40, container closer 16, the adjustable member 20, and the like. In addition, in one or more embodiments, the processing unit 55 may include a dunnage dispenser 14 with any type of dunnage conversion machine or dunnage dispensing system, such as described in U.S. Patent Nos. 5,871,429, 7,260,922, 7,337,595, 7,788,884, 7,814,734, 7,814,735, and 8,087,218, all of which are incorporated herein by reference in their respective entireties.

As discussed above, the container scanner 12 may be provided as a pre-inspection device (on the left) for ensuring that the packaging container 32 (not

shown in FIG. 3) traveling along the conveyor 34 meets certain preset requirements prior to entrance into the processing unit 55. In addition, the container scanner 12 may also be provided as a quality assurance (QA) device (on the right) for ensuring instances of the packaging container that progress through the processing unit 55 are suitable for subsequent operations, such as closing, sealing, or other preparation for shipment.

Still referring to FIG. 3, the container sensor 12, when configured as a Decision Tower including a Vision Sensor as described earlier, may include at least an imaging device (not shown in FIG. 3) communicatively connected with a computing unit. In addition, in one or more embodiments, the imaging device may include single or multiple depth cameras, which are devices used to produce a 2D image showing the distance to points in a scene from a specific point, normally associated with some type of sensor device. The resulting range image typically has pixel values that correspond to the distance. Accordingly, the Decision Tower may use one or more depth cameras to make accurate measurements of dimensions (such as a width “W,” a height “H”, and a length “L”) of the shipping container 32. In this way, the Decision Tower may determine the existence and positioning of contents within the packaging container 32, and additionally or alternatively may determine the positioning of flaps relative to upright walls of the packaging container 32. In addition, the Decision Tower also may use one or more depth cameras to make accurate measurements of box build quality by at least identifying a damage area 68, shown in FIG. 5E and discussed further below.

Such measurements also may be used by the controller 24 and/or suitable computing devices associated with the packing system 10 of any one or more of FIGS. 1-3 to make decisions on how to handle the packaging container 32 at an “end-of-line” location, such as prior to passing through the container closer 16, or after passing through the container closer 16. These decisions may relate to how the packaging container 32 is handled by downstream automation equipment, such as repairing or repositioning of flaps if necessary, diverting the container for a packer to inspect, or identifying areas for repair if damaged, and the like. In addition,

measurements made by the imaging device of the Decision Tower may be used to generate data that is logged for analytics both locally on a computing device associated with the Decision Tower and/or on remote data endpoints (not shown in FIG. 3).

5 As shown in FIG. 3, the Decision Tower (the container scanner 12) may be installed on the conveyor 34 before the processing unit 55 where it may perform any one or more of pre-checks (e.g., determining flap positioning, box damage, etc.) prior to processing of the packaging container 32 by the processing unit 55. In addition, in one or more embodiments, each measurement and decision-making feature of the
10 Decision Tower can be turned on or off independently. Further, the Decision Tower can include several peripherals such as a barcode scanner, weight scale, additional cameras, etc.

 The Decision Tower (the container scanner 12) also may make or assist the packing system 10 in making rejection decisions on whether to reject the packaging
15 container 32 and associate that decision to the barcode 70 (shown in FIG. 6E) and/or a license plate number (not shown in FIG. 3) where available and/or applicable.

 In one or more embodiments, the Decision Tower (the container scanner 12) may measure a height of contents within the packaging container 32 by using machine vision as described earlier. More specifically, an imaging device (not shown
20 in FIG. 3) of the Decision Tower may capture multiple digital images of the packaging container 32 as it passes through the Decision Tower. A computing unit (not shown in FIG. 3) communicatively coupled with the imaging unit of the Decision Tower may generate a pointcloud frame (such as shown in FIGS. 8A-10B) to determine at least the tallest content within the packaging container 32 as well as various contours of
25 contents within the packaging container 32.

 As a result of such measurements, the Decision Tower may determine, such as by using various specific algorithms and measurement processes further described below for FIGS. 8A-10B, if the packaging container 32 is overfilled and/or overflowing with contents for both RSC and HSC box formats. For example, for an
30 RSC box, the packing system 10 and the Decision Tower may determine that the

packaging container 32 is overfilled if the height of its contents extends beyond a flap crease line 58, as shown in FIGS. 4A-4B, and/or by a protruding dunnage segment 66, as shown in FIG. 5D. Alternatively, for HSC boxes that do not have flaps intended for closing the box, the packing system 10 and the Decision Tower may determine

5 that the packaging container 32 is overfilled if its contents extend beyond the top of the HSC box. In addition, an overfill rejection threshold can be configured and input into the Decision Tower. If the threshold is exceeded, the packaging container may be flagged as a "rejected box" and re-routed on the conveyor 34 to a suitable refurbishment area. Generation of the described pointcloud frame and related

10 decision making by systems analogous to the packing system 10 and the Decision Tower for the packaging container 32 when open are disclosed by International Patent Application Publication Nos. WO 2004/041653 A1, WO 2006/017602 A1, WO 2007/022480 A1, WO 2007/121169 A2, each of which is incorporated into the present disclosure by reference in their respective entireties.

15 In addition, in one or more embodiments, the packing system 10 and Decision Tower may measure dimensions of the packaging container 32 when closed or sealed, such as at a location after the processing unit 55 of FIG. 3 or after the container closer 16 of FIG. 2. Specifically, the Decision Tower may generate a pointcloud frame of the packaging container 32 when closed in all dimensions, such

20 as length, width, and height. Accordingly, the measured dimensions of the packaging container 32 when closed can be compared to predetermined threshold values input into the packing system 10 representative of expected closed box dimensions. That is, an expected closed box dimension can be provided by a customer's warehouse management system (WMS), or another instance of the Decision Tower positioned

25 upstream of the processing unit 55 that measures dimensions of the packaging container when open. If the margin of difference between the expected and actual dimension on any one dimension is greater than a pre-set threshold, the box can be flagged as a "rejected box". Generation of the described pointcloud frame and related decision making by systems analogous to the packing system 10 and the Decision

30 Tower for the packaging container 32 when closed are disclosed by International

Patent Application Publication Nos. WO 2004/041653 A1, WO 2007/022480 A1, WO 2014/047187 A1, each of which is incorporated into the present disclosure by reference in their respective entireties.

In addition, in one or more embodiments, the packing system 10 and Decision
5 Tower may determine color images of products contained within the packaging
container 32 when open. For example, the Decision Tower may detect an open box
when it is situated immediately under a depth camera (of an imaging unit of the
Decision Tower) using either depth information or optical break sensors (e.g., also
referred to as “photo-eyes”). At this time, a color image of the interior of the box may
10 be captured by the depth camera or a separate camera. Since the packaging
container will be moving when the picture is taken, the imaging device of the Decision
Tower may use artificial lighting to reduce any induced motion blur. Various benefits
of determining color images can include: (1) identification and corresponding tracking
of incorrectly identified (also referred to as “miss-picks”) of contents of the packaging
15 container 32 from earlier in the packaging process; (2) investigation of end-user
claims of missing content; and (3) data collection to supply analytics to the computing
unit of the Decision tower for artificial lighting (AL) system training.

Further, the packing system 10 and Decision Tower may be prepared to select
the packaging container 32 and to size objects intended for placement into the
20 packaging container 32. For example, any of the described processes relating to
usage of the imaging device may be used to generate a pointcloud cluster by the
Decision Tower to estimate all three-dimensional (3D) sizes of products or objects.
Specifically, the computing device of the Decision Tower may create a dimensional
estimate based on the generated pointcloud (also referred to as “object”) cluster to
25 determine a suitable packaging type corresponding to the measured object. As a
result, depending on the size or orientation of the measured objects, either a
correspondingly sized box or a mailer may be selected by the computing unit of the
Decision Tower.

Still further, the packing system 10 and Decision Tower may be prepared to
30 measure a volume of unoccupied space within the packaging container 32 after it is

loaded with contents. Such volume refers to the available space for the insertion of dunnage and is also referred to "void volume." Specifically, the Decision Tower may measure open box void volume by capturing multiple images of the interior of the packaging container 32 and generating a corresponding pointcloud frame of the interior. The measured pointcloud frame of the interior can then be compared by the computing unit of the Decision Tower against an expected void volume, which may be defined using information from a customer's warehouse management ("WMS") system. For example, the expected void volume can be used as a preset or a predetermined threshold to check against the measured void volume such that if the measured void volume is different from the expected void volume by a significant margin, such as being greater than 5%, greater than 10%, greater than 15%, or greater than 20% of the expected void volume, then the box will be flagged for further manual inspection. Those skilled in the art will appreciate that additional difference amounts, such as 25% or 30% or more also may be possible without departing from the scope and spirit of the disclosure. Accordingly, the measured void volume generated by the pointcloud frame can be used to determine an amount of dunnage necessary to be inserted into the packaging container 32 to achieve a preset or predetermined level of cushioning for objects placed into the packaging container 32.

Additionally, the void distribution inside the packaging container 32 can be analyzed by the Decision Tower using machine vision for dynamic placement of dunnage in areas of maximum voids for optimized bracing and/or protection of products. Generation of the described pointcloud frame and related decision making by systems analogous to the packing system 10 and the Decision Tower for the packaging container 32 regarding assessment of void volume available to receive dunnage are disclosed by International Patent Application Publication Nos. WO 2004/041653 A1, WO 2007/022480 A1, WO 2007/121169 A2, and WO 2014/047187 A1, each of which is incorporated into the present disclosure by reference in their respective entireties.

Furthermore, the packing system 10 and Decision Tower may be configured to perform a box squareness check by assessing squareness of the packaging

container 32 as it passes underneath Decision Tower (e.g., the container scanner 12). Specifically, the Decision Tower may use an imaging device to capture multiple images of external and/or internal surfaces of the packaging container 32 having its flaps either in an open or a closed position to geometrically determine squareness of the packaging container 32. In addition, in one or more embodiments, the Decision Tower may assess and determine angles between all adjacent walls (such as adjacent instances of an upright box wall 53 of FIGS. 4A-4B) to determine the squareness of the box. Specifically, an ideal corner angle of ninety degrees may be input into the computing device of the Decision Tower as a preset or predetermined threshold. Accordingly, the Decision Tower may compare measured angles against the threshold to thereby identify non-square boxes as "rejected boxes," which may be redirected on the conveyor 34 to a refurbishment area. An example of a non-square instance of the packaging container 32 is shown in FIG. 5A with a bulge region 62, which may extend outwardly from any side of the packaging container 32.

Even further, the packing system 10 and Decision Tower may be prepared to detect damaged boxes, such as instances of the packaging container 32 having one or more instances of the damage area 68 of FIG. 5E. Specifically, the imaging unit of the Decision Tower may capture multiple images and generate a pointcloud representative of one or more surfaces of the packaging container 32 and thereby analyze detected surfaces for various surface imperfections, such as tears, rips, bulges, extreme wrinkles, and other defects to evaluate its quality. For example, in one or more embodiments, the Decision Tower may be input with parameters describing predefined defects, such as tears, rips, etc. Accordingly, if any predefined defect is present, the severity of the defect may be analyzed by the computing device and based on a preset severity threshold (which may be a binary defect presence check, such as a "yes" or "no" indicative of the presence of a defect). Those instances of the packaging container 32 identified as having one or more instances of the damage area 68 may be correspondingly flagged as a "rejected box" when the described preset severity threshold is exceeded.

Additionally, the packing system 10 and Decision Tower may be prepared to inspect a label (not shown in FIG. 3), such as an identifying label, a shipping label and the like. Specifically, the imaging unit of the Decision Tower may use machine vision to capture an image or a series of images of a shipping label and/or manifest applied to any one or more of a flap 51, such as shown by FIGS. 4A-4B, or the upright box wall 53, also shown by FIGS. 4A-4B, of the packaging container 32. For example, the label can be placed on top (such as when all flaps 51 are folded inwardly to seal the flap opening 54 as shown by FIGS. 4A-4B) or on the upright box wall 53 such that any images taken will include the entirety of the applied label. The label may then be analyzed by the computing device of the Decision Tower, where any printed characters and/or the barcode 70 may be scanned and recorded by the Decision Tower. For example, the computing device may evaluate the recorded text and evaluate barcode data to ensure that the print is clear and legible and thereby correspondingly matches to the assigned information of the packaging container 32 based on the identifying label. Shipping containers which fail this evaluation may be identified as a "rejected box" and be redirected on the conveyor 34 to a refurbishment area.

Still referring to FIG. 3, in one or more embodiments, the packing system 10 and Decision Tower may be prepared to perform "print-on-demand" processes, which are processes involving printing onto an exposed surface, such as the flap 51 and/or the upright box wall 53. Specifically, in such an example, the Decision Tower may include a printing device, such as a laser printer or ink jet printer and the like, to imprint indicia, such as identification and/or other forms of labeling, onto exposed surfaces of the packaging container 32. In some embodiments, the printing device may print onto the entire exposed surface of the packaging container 32. Accordingly, the Decision Tower may employ machine vision to capture images representative of the full surface to which the print is applied, including onto the top, one or more instances of the flap 51, and one or more instances of the upright box wall 53 of the packaging container 32. Next, captured images may be analyzed by the computing device against the original image desired to be printed on the box

(e.g., as input into the Decision Tower earlier). The Decision Tower may then analyze the printing for quality and matching to the desired print. If the inspection fails, the box is flagged as a “rejected box” and be redirected on the conveyor 34 to a refurbishment area.

5 Still referring to FIG. 3, in one or more embodiments, the packing system 10 and Decision Tower may be prepared to perform dimension measurements on the packaging container 32 having one or more instances of the flap 51, as shown in FIGS. 4A-4B, at least partially open defining the flap opening 54. Specifically, the dimensions (e.g., length, width, and height) of the packaging container 32 may be
10 measured from a pointcloud frame captured by one or more depth cameras of the Decision Tower. In one or more embodiments, the dimensional measurements may have sub-centimeter accuracy, and the computing unit of the Decision Tower may check if measured dimensions of the shipping container remain within a pre-defined threshold. Accordingly, instances of the shipping container that exceed the pre-
15 defined threshold will be flagged as a “rejected box” and be redirected on the conveyor 34 to a refurbishment area.

 Still referring to FIG. 3, in one or more embodiments, the packing system 10 and Decision Tower may be prepared to perform measurement of a flap tilt angle 61, as shown in FIGS. 4A-4B, of the flap 51 relative to its corresponding instance of the
20 upright box wall 53. Specifically, the imaging device of the Decision Tower may capture multiple digital images of the packaging container 32 to generate a pointcloud and/or pointcloud frame representative of the packaging container 32 as well as all instances of the flap 51, the flap tilt angle 61, and the upright box wall 53 corresponding to the packaging container 32. Accordingly, these sampled points are
25 analyzed to measure the flap tilt angle 61 for each flap 51. In one or more embodiments, a measurement of the flap tilt angle 61 includes a direction of tilt “B,” as shown in FIG. 4A, assigned to a corresponding instance of the flap 51. As a result, instances of the flap 51 that are tilted beyond a preset or predefined threshold (e.g., fifteen degrees outwardly away from the direction of dunnage or product insertion
30 “A”) have a relatively higher risk of potentially jamming downstream automation

equipment (e.g., Autofill devices) in the packing system 10. The computing unit of the Decision Tower may compare each instance of the flap tilt angle 61 against the preset threshold, where instances of the packaging container 32 that have flaps tilting beyond the threshold will be flagged as a "rejected box." In addition, in one or more
5 embodiments, additional and/or unique condition checks of the packaging container 32 can be applied to measure instances of the flap tilt angle 61 and used to define complex decision structures, such as a flowchart 700 of FIG.7. Those skilled in the art will appreciate that other preset or predetermined values of the threshold may be input into the Decision Tower, such as 10°, 12.5°, 15° or more, such as 20°, where
10 instances of the packaging container 32 that have flaps tilting beyond these thresholds will be flagged as a "rejected box" and be redirected on the conveyor 34 to a refurbishment area.

Still referring to FIG. 3, in one or more embodiments, the packing system 10 and Decision Tower may be prepared to perform machine vision based "Ship-in-own-
15 Container" (SIOC) inspection of one or more instances of the packaging container 32 on the conveyor 34 by generating a pointcloud representation of the packaging container 32 to identify if a box has open instances of the flaps 51 or is fully closed. For example, if the box is fully closed, it is classified as SIOC. In one or more embodiments, SIOC-related measurements may be made by a separate SIOC
20 detector and be placed upstream of the processing unit 55 (e.g., such as an Autofill system), to thereby decide if the box should be packed and closed by the container closer 16 of FIG. 2 or if the box should be passed through as SIOC. The box is flagged as SIOC if it meets requisite preset conditions regarding closure of all instances of the flap 51.

25 The above-described detection procedures are equally applicable to instances of the packaging container 32 prepared as a regular slotted carton ("RSC") or as a half-slotted carton ("HSC"). In addition to that described above, the packing system 10 and the Decision Tower (e.g., the container scanner 12) may be prepared to perform machine vision based measurements specific to HSC boxes, which, for
30 example, either do not have instances the flap 51 or have such instances of the flap

51 folded parallel to the direction A either into the packaging container 32 or on the outside of the packaging container 32 such that no flap 51 obscures or obstructs entrance into the packaging container 32.

In such a configuration, the Decision Tower may use machine vision to
5 capture multiple images of the packaging container 32 to generate a representative pointcloud and/or pointcloud frame. The computing device of the Decision Tower may project the pointcloud onto a single (e.g., digital) plane such that a bounding box may be drawn around the projected points and used to determine an accurate length and width of the packaging container 32 when prepared as an HSC. In addition, in one or
10 more embodiments, the height of the box is computed by sampling and averaging the vertical location of a topmost subset of points, as shown, and further described in connection with FIGS. 10A-10B. Accordingly, the computing unit of the Decision Tower may compare measurements representative of dimensions of the packaging container when prepared as a HSC against a preset or predefined threshold
15 describing squareness and/or other physical dimensional characteristics of the packaging container 32 such that if a measured box size is outside the pre-defined threshold, it will be flagged as a “rejected box” and be redirected on the conveyor 34 to a refurbishment area.

Referring collectively to FIGS. 2-3 and FIGS 4A-4B, in one or more
20 embodiments, the present disclosure provides a packing system 10 for inspecting the packaging container 32 having one or more flaps 51 that are foldable to close an open side of the packaging container. The packaging container 32 may be one or a regular slotted container (RSC) or a half-slotted container (HSC). The packing system 10 includes an imaging device (e.g., incorporated within the container
25 scanner 12) that may generate a point cloud that is representative of the packaging container 32 by digitally capturing multiple images of the packaging container 32. The point cloud is defined by a collection of points of data in three-dimensional (3D) space. In some embodiments, the collection of points may include multiple top-most layer points (e.g., such as a top-most layer 85 of FIG. 8B) representative of the one
30 or more flaps 51. For example, in this way, such multiple top-most layer points may

project or be projected onto a two-dimensional plane (e.g., such as a bounding box 89 of FIG. 8D) defining various features that are representative of a respective foldable flap 51. In some embodiments, the described multiple top-most layer points may be used in any combination with other detected feature points to represent a
5 respective flap in three-dimensions. In some embodiments, described techniques may assess and/or describe a respective foldable flap in two-dimensions, such as by projection onto a two-dimensional plane as described here and/or elsewhere in the present disclosure, as well as in three-dimensions. In one or more embodiments, the container scanner 12, which may also be referred to as a Decision Tower as
10 described earlier and include a computing unit that is communicatively coupled to the imaging device. The computing unit may measure an angle of tilt (e.g., flap tilt angle 61) for each flap 51 by fitting a plane 57 to the open side (e.g., the upright box wall 53) of the packaging container and performing a normal analysis on the plane, such as by that shown and described by FIG. 9 herein.

15 In one or more embodiments of the disclosure, the imaging device includes a depth sensing camera (not shown in FIGS. 2-3) that may generate the point cloud by capturing dimensional information of the packaging container 32. The dimensional information may include depth images (e.g., as shown by representative images 8A-8D and 10A) and/or depth maps, each presented in the form of an image having pixel
20 values correlating to depth information at a respective pixel location. In addition, the packing system may include a computing assembly (not shown in FIGS. 2-3) housing the imaging device and the computing unit. The computing assembly may fit a line segment (e.g., collectively forming the bounding box 89) to a respective flap feature of the plurality of features, wherein the line segment is representative of a
25 corresponding dimension of the packaging container. Further, in some embodiments, the packaging container has multiple walls (e.g., multiple instances of the upright box wall 53), where the computing unit may detect points representative of one or more walls.

In one or more embodiments, the computing unit includes data describing a
30 pre-set maximum flap rotation threshold that is defined as detected outward rotation

of a respective flap of 15° or more relative to the open side of the packaging container. Consequently, the computing unit is operable to identify the packaging container as unsuitable for shipment based on whether detected rotation of the respective flap exceeds the pre-set maximum flap rotation threshold. In addition, in
5 some embodiments, the computing unit may determine a smallest rectangle (e.g., the bounding box 89) capable of encompassing the point cloud when the point cloud is projected onto the two-dimensional plane. In one or more embodiments, the packaging container defines a residual void volume defined as a void volume representative of empty space accounting for any items retained within the packaging
10 container, and the computing unit is operable to reduce the point cloud to a square grid-map having a constant size; and compute the residual void volume by using hole-filling algorithms to mitigate potential measurement error caused by occlusion due to placement of the imaging device relative to the residual void volume. In addition, in some embodiments, the computing unit may measure the angle of tilt
15 (e.g., the flap tilt angle 61) for each flap relative to the plane 57 fitted to the open side (e.g., the upright box wall 53) of the packaging container 32 by extracting a sample subset of points representative of a corresponding flap, fitting the plane 57 to the sample subset of points, and analyzing the plane 57 relative to a corresponding geometric normal.

20 The present disclosure also provides a packing system 10 including a conveyor belt assembly (e.g., the conveyor 34) that is operable to guide a packaging container 32 downstream from an initial loading position to a final deployment position. The conveyor belt assembly includes an input conditioning unit (e.g., the container scanner 12) located at the initial loading position and on the conveyor belt
25 assembly. The input conditioning unit may perform a pre-inspection operation of the packaging container. More particularly, in one or more embodiments, the input conditioning unit is operable to perform the pre-inspection operation of the packaging container by detecting one or more of a fill level, a tilt angle relative (e.g., the flap tilt angle 61) to the conveyor belt assembly, or a conformance condition relative to a pre-
30 set conformance threshold of the packaging container. A computing assembly is

located downstream of the input conditioning unit and on the conveyor belt assembly. More particularly, in some embodiments, the conveyor belt assembly is operable to direct the packaging container 32 along a selected route from a group of routes including a standard route leading to a packaging container aggregation area; and a
5 reject route leading to a specialized handling zone (e.g., a refurbishment area) connected to the conveyor belt assembly of the packing system 10.

Still referring to FIGS. 2-3 and FIGS 4A-4B, in one or more embodiments, the computing assembly includes an imaging device that may generate a point cloud that is representative of the packaging container. More particularly, in one or more
10 embodiments, the point cloud may include top-most layer points projected onto a two-dimensional plane (e.g., the bounding box 89) that defines multiple features representative of a respective foldable flap, or at least an edge of a respective foldable flap, of the packaging container. The computing unit is communicatively coupled to the imaging device, where the computing unit may measure an angle of tilt
15 (e.g., the flap tilt angle 61) for each flap relative to an opening 59 into the packaging container based on comparing the point cloud against a pre-set threshold. The computing assembly is operable to use machine vision algorithms and generate the point cloud as a collection of points of data in a three-dimensional space. The collection of points may include multiple top-most layer points representative of one
20 or more flaps 51 of the packaging container or one or more edge surfaces of respective flaps. An output quality assurance (QA) unit is located at the final deployment position and on the conveyor belt assembly downstream of the computing assembly. The output QA unit is operable to perform a pre-deployment operation by confirming that the angle of tilt conforms to the pre-set threshold.
25 Further, in some embodiments, the output QA unit may detect one or more of a damage condition or a label quality inspection of the packaging container by using machine vision algorithms and taking measurements of the packaging container.

In addition, in one or more embodiments, the output quality assurance (QA) unit includes a void fill apparatus (e.g., such as one configuration of the processing
30 unit 55 of FIG. 3) communicatively coupled with at least the computing unit. The void

fill apparatus may dispense dunnage through the opening 59 (e.g., in the direction A shown in FIG. 4A) of the packaging container 32 and at least partially fill the packaging container 32 based on whether the angle of tilt (e.g., the flap tilt angle 61) conforms to the pre-set conformance threshold of the packaging container 32. A closure apparatus (e.g., container closer 16 of FIG. 2) may be communicatively coupled with at least the void fill apparatus, where the closure apparatus may fold one or one or more flaps 51 of the packaging container inward (e.g., as shown by FIG. 4B) over the opening 59 and correspondingly close the opening 59 for securing all flaps 51 in a folded position after dispensation of dunnage.

10 In some embodiments, the computing unit is pre-loaded with multiple intralogistics operations thresholds including data describing definitions for categorizing the packaging container 32 into one category selected from multiple categories including a first category describing conformance of the packaging container 32 to multiple intralogistics operations thresholds a second category
15 describing one or more of partial conformance or total non-conformance to the multiple intralogistics operations thresholds.

The present disclosure also provides a method for inspecting a container (e.g., the packaging container 32) having one or more foldable flaps 51 adjacent to and foldable over an open side (e.g., the opening 59) of the container within a packing
20 system. The method includes the following steps: generating, by an imaging device (e.g., the container scanner 12) located on a conveyor belt (e.g. the conveyor 34) of the packing system, a point cloud that is representative of the container by digitally capturing multiple images of the container; measuring, by a computing unit communicatively coupled to the imaging device, an angle of tilt (e.g., the flap tilt angle
25 61) for each flap 51 based on the point cloud and relative to an opening into the container; and comparing, by the computing unit, the container against multiple pre-set container characteristic thresholds. More particularly, the pre-set container characteristic threshold may include data describing: a container fill-level; a container flap tilt angle of one or more container flaps; and a container height and width. The
30 method also includes comparing, by the computing unit, an exit condition of the

container as it exits the conveyor belt against the multiple pre-set container characteristic thresholds, the exit condition including data describing a secured position or a non-secured position of one or more container flaps relative to a main body of the container; a location of a dunnage tail relative to the main body of the container; and a location of a shipping label on the container.

In addition, in one or more embodiments, the method may include defining, by the computing unit, the point cloud by using machine vision and detecting a collection of points of data representative of the container in three-dimensional (3D) space, where the collection of points may include multiple top-most layer points that are representative of one or more foldable flaps of the container; and projecting, by the computing unit, the multiple top-most layer points onto a two-dimensional plane; and defining multiple features representative of a respective foldable flap of the container based on projection. The method may include determining, by the computing unit and using machine vision, a minimum rectangular box bounding the plurality of top-most layer points when projected onto the two-dimensional plane.

Referring now to FIGS. 5A-5E, the container scanner 12, when prepared as a Decision Tower for input conditioning of the packaging container 32 prior its entrance into the processing unit 55 as shown in FIG. 3 as described earlier and shown in at least FIGS. 2-3, may measure various physical dimensions and characteristics of the packaging container 32. These dimensions may include the bulge region 62 of FIG. 5A, lack of squareness shown by a skewed area 64 of FIG. 5B, a protruding dunnage segment 66 representative of overfill of the packaging container 32 of FIG. 5C, another instance of the protruding dunnage segment 66 extending outwardly from the packaging container 32 as shown in FIG. 5D, and one or more instances of the damage area 68 shown in FIG. 5E.

Referring now to FIGS. 6A-6E, the container scanner 12, when prepared as a Decision Tower for output quality assurance (QA) of the packaging container 32 after departing the processing unit 55 as shown in FIG. 3 and optionally before the container closer 16 as described as shown in FIG. 2, may measure various physical dimensions and characteristics of the packaging container 32. These dimensions and

characteristics may include one or more instances of the damage area 68 shown in FIG. 6B, the protruding dunnage segment 66 representative of overfill of the packaging container 32 of FIG. 6C, a flap opening 54 as shown in FIGS. 4A-4B and in FIG. 6D, and the barcode of FIG. 6E.

5 Referring now to FIG. 7, an exemplary flowchart 700 representative of operation of the packing system 10 shown in FIGS. 2-3 is shown. In one or more embodiments, the flowchart 700 includes multiple blocks 702-730, each block representative of a step or operation performed by one or more devices of the packing system 10, such as the container scanner 12 (e.g., the Decision Tower)
10 when controlled by the controller 24. In one embodiment, the controller 24 contains instructions for the container scanner 12 to measure flap tilt angles 61 at block 702 to determine whether measured flaps 51 are tilted outwardly away from the opening 59 beyond a preset threshold at block 704. Flap tilt angles 61 are measured again at block 706 to determine whether measured flaps 51 are tilted inward toward the
15 opening 59, which represents an unacceptable condition for the packaging container 32 to proceed along the conveyor 34, as indicated in block 710. Flap tilt angles are measured again in block 708 and progressed toward a solution aggregator, which may be integrated with or otherwise executed by the computing device of the Decision Tower at block 714, which also may receive a scan of the barcode 70
20 provided at block 712. Accordingly, the packing system 10 may perform a logging operation at block 716 to record any of the aforementioned information in a data log in block 718.

Still referring to FIG. 7, decision-related data produced by the measurement operations on whether the flap tilt angle 61 is within a preset threshold (e.g., 15° tilted
25 outwardly away from the opening 59) may be digitally sent to a client communication node at block 720 and later to a client server at block 722, which may be positioned within or remotely from the packing system 10. As a result, in some embodiments, the controller 24 may instruct the conveyor to perform a box routing execution at block 724 responsible for directing the packaging container 32 to a refurbishment
30 area should the packaging container 32 be rejected due to the flap tilt angle 61

exceeding the preset threshold or to an automated box closing at block 728 should the packaging container 32 remain within conformance as so described. In instances where the packaging container 32 has been rejected, it may progress toward manual box closing performed by a human operator at block 730.

5 Referring now to FIGS. 8A-8B, a pointcloud 80 is shown. The pointcloud 80 may be generated by the computing device operating in conjunction with the imaging device of the container scanner 12 (e.g., Decision Tower) and depict an accurate digital representation of the packaging container 32 in two or three dimensions, as shown in FIGS. 8A-8B. In one or more embodiments, the pointcloud 80 may be
10 generated by imaging performed along one or more axes 82 to generate a 3D representation of points 84 of at least a first representative cluster 86 and a second representative cluster 88, each cluster capturing an representing distinct surfaces of the packaging container, such as dunnage (shown by first representative cluster 86) or of portions of the upright box wall 53 (shown by second representative cluster 88).
15 The computing device may crop points of the pointcloud 80 to identify the packaging container 32 alone in space and may also crop points to generate the top-most layer 85 of FIG. 8B, which may represent the flaps 51 when folded over the opening 59 to close and seal the packaging container 32. In addition, in some embodiments, the top-most layer 85 may alternatively represent one instance of the flap 51 or an edge
20 of one instance of the flap 51.

 Referring now to FIGS. 8C and 8D, a two-dimensional plane 87 of points cropped by the computing device to generate the top-most layer 85 of FIG. 8B is shown. Accordingly, the computing device may fit the bounding box 89 to a contour 83 of the two-dimensional plane 87 of points. Specifically, points belonging to one or
25 more instances of the flap 51 are projected to the two-dimensional plane 87 and processed using the described computer or machine vision techniques to distinctly represent features of that flap 61. The flap features are then fitted with line segments (e.g., collectively defining the bounding box 89) used to measure the dimension of the flaps 51 which then translate to the dimensions of the packaging container 32. In
30 some embodiments, certain presets may be input into the Decision Tower, such as

that provided a flap width, a flap height can be computed, where the flap height equals half of the flap width on a standard Regular Slotted Carton (RSC) box. This procedure allows for the crop out of points that belong to the flap from the pointcloud.

In addition, in one or more embodiments, points that belong to the upright box wall 53 can be cropped out of the pointcloud using preset dimensions of the packaging container 32. At this point, the maximum content height of the packaging container 32 can be identified. Additionally, the total void volume inside the packaging container 32 can also be computed. Alternatively, the Decision Tower may have a robust algorithm that can detect and remove points that belong to the upright box wall 53. This method allows for an accurate content height measurement and void volume measurement. The selection of the wall removal method (between cropping and algorithmic wall removal) is a configurable parameter.

Referring now to FIG. 9, a measurement 90 representative of determining the flap tilt angle 61 is shown. Specifically, points 92 representing a contour of the flap 51 tilted outwardly away from the opening 59 may have a first line 94 fit to them. A second line 97 may be fit parallel to the upright box wall 53 such that an angle 96 (e.g., equivalent to the flap tilt angle 61 of FIGS 4A-4B) is determined between the first line 94 and the second line 97. In some embodiments, additional points 98 may further define the first line 94.

Referring now collectively to FIGS. 10A-10B, a pointcloud 100 representative of the packaging container 32 prepared as an HSC is shown, where machine vision is performed along multiple axes 102 to determine a contour 104 of the HSC box as well as dunnage 106 within the contour 104. Specifically, an alternative method to compute the box dimensions of an HSC box is to determine a smallest (e.g., alternatively referred to as a "minimum") rectangle 109 that would encompass the pointcloud 100 when projected onto a two-dimensional plane 108. The pointcloud 100 which represents the HSC box is used and the top few points are sampled and projected onto the two-dimensional plane. The smallest rectangle 109 that fits the points in two dimensions is computed.

Although the disclosure has been shown and described with respect to a certain preferred embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular

5 regard to the various functions performed by the above described elements (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not

10 structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the disclosure. In addition, while a particular feature of the disclosure may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may

15 be desired and advantageous for any given or application.

Claims

We claim:

1. A packing system for inspecting a packaging container having one or
5 more flaps that are foldable to close an open side of the packaging container, the
packing system comprising:
an imaging device operable to generate a point cloud that is representative of
the packaging container by digitally capturing multiple images of the packaging
container, wherein:
10 the point cloud is defined by a collection of points of data in three-
dimensional space, the collection of points including a plurality of top-most
layer points representative of the one or more flaps; and
the plurality of top-most layer points project onto a two-dimensional
plane defining a plurality of features representative of a respective foldable
15 flap; and
a computing unit communicatively coupled to the imaging device, wherein the
computing unit is operable to measure an angle of tilt for each flap by fitting a plane
to the open side of the packaging container and performing a normal analysis on the
plane.
20
2. The packing system of claim 1, wherein the imaging device includes a
depth sensing camera operable to generate the point cloud by capturing dimensional
information of the packaging container, the dimensional information comprising:
depth images and/or depth maps, each presented in a form of an image
25 having pixel values correlating to depth information at a respective pixel
location.
3. The packing system of claim 1, further comprising a computing
assembly housing the imaging device and the computing unit, wherein the computing
30 assembly is operable to:

fit a line segment to a respective flap feature of the plurality of features, wherein the line segment is representative of a corresponding dimension of the packaging container.

5 4. The packing system of claim 1, wherein the packaging container has a plurality of walls, and further wherein the computing unit is operable to detect points representative of one or more walls.

 5. The packing system of claim 4, wherein:
10 the computing unit includes data describing a pre-set maximum flap rotation threshold that is defined as detected outward rotation of a respective flap of 15 degrees or more relative to the open side of the packaging container; and
 the computing unit is operable to identify the packaging container as unsuitable for dunnage insertion and flap closure based on whether detected rotation
15 of the respective flap exceeds the pre-set maximum flap rotation threshold.

 6. The packing system of claim 1, wherein the packaging container is one or a regular slotted container (RSC) or a half-slotted container (HSC).

20 7. The packing system of claim 1, wherein the computing unit is operable to determine a smallest rectangle capable of encompassing the point cloud when the point cloud is projected onto the two-dimensional plane.

 8. The packing system of claim 1, wherein the packaging container
25 defines a residual void volume defined as a void volume representative of empty space accounting for any items retained within the packaging container, and the computing unit is operable to:
 reduce the point cloud to a square grid-map having a constant size; and
 compute the residual void volume by using hole-filling algorithms to mitigate
30 potential measurement error caused by occlusion due to placement of the imaging device relative to the residual void volume.

9. The packing system of claim 1, wherein the computing unit is operable to measure the angle of tilt for each flap relative to the plane fitted to the open side of the packaging container by extracting a sample subset of points representative of a
5 corresponding flap, fitting a plane to the sample subset of points, and analyzing the plane relative to a corresponding geometric normal.

10. A packing system comprising:
a conveyor belt assembly that is operable to guide a packaging container
10 downstream from an initial loading position to a final deployment position, the conveyor belt assembly comprising:
an input conditioning unit located at the initial loading position and on the conveyor belt assembly, the input conditioning unit operable to perform a pre-inspection operation of the packaging container;
15 a computing assembly located downstream of the input conditioning unit and on the conveyor belt assembly, the computing assembly comprising:
an imaging device operable to generate a point cloud that is representative of the packaging container; and
a computing unit communicatively coupled to the imaging device,
20 wherein the computing unit is operable to measure an angle of tilt for each flap relative to an opening into the packaging container based on comparing the point cloud against a pre-set threshold; and
an output quality assurance (QA) unit located at the final deployment position and on the conveyor belt assembly downstream of the computing
25 assembly, the output QA unit operable to perform a pre-deployment operation by confirming that the angle of tilt conforms to the pre-set threshold.

11. The packing system of claim 10, wherein the input conditioning unit is operable to perform the pre-inspection operation of the packaging container by
30 detecting one or more of:

a fill level,
a tilt angle relative to the conveyor belt assembly, or
a conformance condition relative to a pre-set conformance threshold of the
packaging container.

5

12. The packing system of claim 11, wherein the output quality assurance
(QA) unit further comprises:

a void fill apparatus communicatively coupled with at least the computing unit,
wherein the void fill apparatus is operable to dispense dunnage through an opening
10 of the packaging container and at least partially fill the packaging container based on
whether the angle of tilt conforms to the pre-set conformance threshold of the
packaging container; and

a closure apparatus communicatively coupled with at least the void fill
apparatus, wherein the closure apparatus is operable to fold one or one or more flaps
15 of the packaging container inward over the opening and correspondingly close the
opening for securing all flaps in a folded position after dispensation of dunnage.

13. The packing system of claim 10, wherein the point cloud includes top-
most layer points projected onto a two-dimensional plane that defines a plurality of
20 features representative of a respective foldable flap of the packaging container.

14. The packing system of claim 10, wherein the output QA unit is further
operable to detect one or more of a damage condition or a label quality inspection of
the packaging container by using machine vision algorithms and taking
25 measurements of the packaging container.

15. The packing system of claim 10, wherein the computing assembly is
operable to use machine vision algorithms and generate the point cloud as a
collection of points of data in a three-dimensional space, the collection of points

including a plurality of top-most layer points representative of one or more flaps of the packaging container or one or more edge surfaces of respective flaps.

16. The packing system of claim 10, wherein the computing unit is pre-
5 loaded with a plurality of intralogistics operations thresholds including data describing definitions for categorizing the packaging container into one category selected from a plurality of categories, the plurality of categories comprising:

a first category describing conformance of the packaging container to the plurality of intralogistics operations thresholds; and
10 a second category describing one or more of partial conformance or total non-conformance to the plurality of intralogistics operations thresholds.

17. The packing system of claim 10, wherein the conveyor belt assembly is operable to direct the packaging container along a selected route from a group of
15 routes comprising:

a standard route leading to a packaging container aggregation area; and
a reject route leading to a specialized handling zone connected to the conveyor belt assembly of the packing system.

20 18. A method for inspecting a container having one or more foldable flaps adjacent to and foldable over an open side of the container within a packing system, the method comprising:

generating, by an imaging device located on a conveyor belt of the packing system, a point cloud that is representative of the container by digitally capturing
25 multiple images of the container;

measuring, by a computing unit communicatively coupled to the imaging device, an angle of tilt for each flap based on the point cloud and relative to an opening into the container;

comparing, by the computing unit, the container against a plurality of pre-set
30 container characteristic thresholds comprising data describing:

a container fill-level;
a container flap tilt angle of one or more container flaps; and
a container height and width;
comparing, by the computing unit, an exit condition of the container as it exits
5 the conveyor belt against the plurality of pre-set container characteristic thresholds,
the exit condition comprising data describing:
a secured position or a non-secured position of one or more container
flaps relative to a main body of the container;
a location of a dunnage tail relative to the main body of the container;
10 and
a location of a shipping label on the container.

19. The method of claim 18, further comprising:
defining, by the computing unit, the point cloud by using machine vision and
15 detecting a collection of points of data representative of the container in three-
dimensional (3D) space, wherein:
the collection of points includes a plurality of top-most layer points that
is representative of one or more foldable flaps of the container; and
projecting, by the computing unit, the plurality of top-most layer points onto a
20 two-dimensional plane; and
defining a plurality of features representative of a respective foldable flap of
the container based on projection.

20. The method of claim 19, further comprising:
25 determining, by the computing unit and using machine vision, a minimum
rectangular box bounding the plurality of top-most layer points when projected onto
the two-dimensional plane.