(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 July 2013 (18.07.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/105900 A1

(51) International Patent Classification:
B65B 5/10 (2006.01) *B65G 47/22* (2006.01)

(21) International Application Number:
PCT/SG2013/000011

(22) International Filing Date:
9 January 2013 (09.01.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
201200203-6 10 January 2012 (10.01.2012) SG

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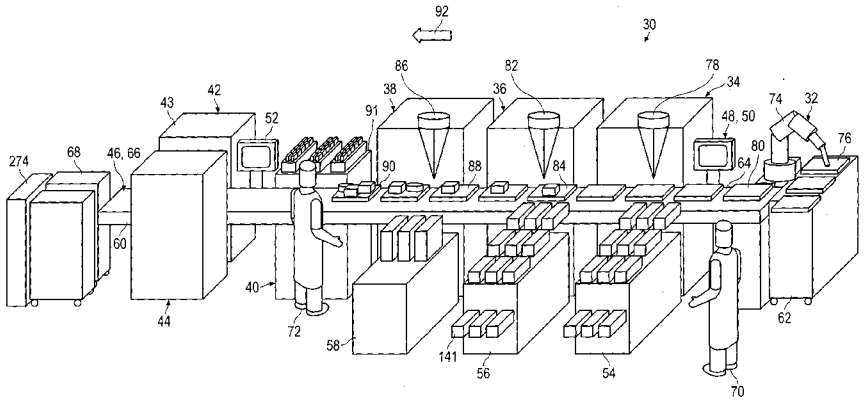
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: FLEXIBLE ASSEMBLY LINE FOR TRAY PACKAGING



(57) Abstract: A flexible assembly line (30, 210, 212, 276) for tray packaging comprises a tray dispenser (32, 62) for providing a tray (76, 80, 84, 88, 90), and a loading station (34, 36, 38, 214, 216, 218, 234, 236, 238, 250) adjacent to the tray dispenser (32, 62) for placing food or non-food items onto the tray (76, 80, 84, 88, 90) automatically.

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FLEXIBLE ASSEMBLY LINE FOR TRAY PACKAGING

[0001] The present application relates to a flexible assembly line for tray assembly, quality vision inspection and packaging. It also relates to a method of using the flexible assembly line for tray packaging.

[0002] In food catering business, food and cutleries are often served on trays. Moreover, each type of food is typically provided in separate containers, which are orderly placed in the trays. When food is supplied in large volume with great diversity, such as in airline, army or hospital food catering industries, packaging the trays with the food and cutleries becomes complex and labor-intensive. If the food has to be supplied continuously around the clock, consistency, flexibility and efficiency become critical factors of high quality catering industry.

[0003] The present invention aims to provide a new and useful flexible assembly line for tray assembly, quality inspection and/or packaging. The present invention also aims to provide a new and useful method for using the flexible assembly line. Essential features of the invention are provided by the independent claims, whilst other advantageous features of the invention are given by the dependent claims. The present application claims the priority of the Singapore Patent Application SG201200203-6 that was filed on 10 January 2012. The entire content of the earlier application is hereby incorporated by reference.

[0004] According to a first aspect of the invention, the flexible assembly line comprises a tray dispenser for providing a tray, and a loading station adjacent to the tray dispenser. The loading station has a fixing tool for placing food or non-food items onto the tray automatically. The tray dispenser is a device or machine for giving trays. For example, the tray dispenser includes a cart, a trolley a shelf or a room that can hold trays or stacks of trays for distribution. The tray is normally known as a flat, shallow container or receptacle, usually with slightly raised edges, used for carrying, holding, or displaying articles/containers of food, glass, china, etc. The tray is different from a food container that the tray typically does not touch food substances directly, unlike the food container. The fixing tool can take many forms. For example, the fixing tool is a jig that has orifices of predetermined shapes such that only food or non-food

items with corresponding shapes can pass through the orifices for dropping onto the tray. The loading station can have different types of fixing tools or jigs such that the flexible assembly line can handle items of large variety. Since the loading station can operated automatically, either by a computer installed with appropriate software packages or by one or more PLCs (Programmable Logic Controller), the flexible assembly line can operate continuously. When providing catering service of large volume around the clock, which is known to be labor intensive, the flexible assembly provides an efficient and reliable catering solution, reducing human mistakes of manual tray packaging. Consequently, the flexible assembly can provide food in trays with improved freshness.

[0005] The flexible assembly line can further comprise a tray-to-cart loading station connected to the loading station for removing a completed tray package away from the loading station. The flexible assembly line is a production line for putting various food or non-food items onto a tray according to predetermined patterns/formation, which are collectively known as a tray assembly or subassembly. Completed tray assemblies can be removed from the flexible assembly line and stacked neatly into a cart so that the flexible assembly line will not be jammed by completed tray assemblies at its end. The tray-to-cart loading station can efficiently clear the end of flexible assembly line and provide carts full of completed tray assemblies. The carts can be wheeled or carried to a warehouse for temporary storage or to an airplane for food catering.

[0006] The flexible assembly line may further comprise a conveyor that connects the tray dispenser, the loading station, the tray-to-cart loading station, or combination of any of these. The conveyor is mechanical handling equipment that moves materials from one location to another. The conveyor provides quick and efficient transportation of the food (e.g. cup of yogurt) or non-food items (e.g. cutlery package) with a wide variety. The conveyor can be a belt conveyor, a chain conveyor or a combination of both. The conveyor may be floor mounted or ceiling mounted depending on building conditions of a catering center, which accommodates the flexible assembly line.

[0007] The flexible assembly line can further comprise an inspection and reject station for checking quality of food and non-food items. The tray, food or non-food items are

examined against predetermined quality criteria. For example, a tray has to be free from dirt, water stain and deformation in order to be suitable for carrying the food or non-food items. A sealed cup of water has to be free from dirt or leakage before being loaded onto the tray. The predetermined quality criteria are preloaded into the inspection and reject station for quality compliance of the tray packaging. In one embodiment, the inspection and reject station measures weight of a tray assembly or subassembly against predetermined ranges of acceptable weight for acceptance or rejection.

[0008] The flexible assembly line may further comprise one or more sorters for organizing the food or non-food items. Sometimes, food items or non-food items are randomly congregated in a container/basket. The sorter arranges these items in an orderly manner so that the loading station or an operator can pick an item efficiently. The sorter can be a tilt tray sorter, a cross belt sorter, a carrier sorter or a combination of any of these.

[0009] The tray dispenser, the loading station, the tray-to-cart loading station, the conveyor, the inspection and reject station or a combination of any of these can comprise an industrial robot for picking the food or non-food items. The industrial robot is an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. The industrial robot may be an articulated robot, a SCARA robot, a Delta robot or a Cartesian coordinate robot (aka gantry robots or x-y-z robots). The industrial robot can be reprogrammed for assembling different types of tray assemblies, and reach out to stations or conveyor belts at various distances. Hence, the flexible assembly line becomes adaptable to meet diverse catering needs. For example, in an inflight catering center, the industrial robot can load a software program for providing tray assemblies of western food with fifty sets, and load another software program subsequently for providing tray assemblies of vegetarian food.

[0010] The tray dispenser, the loading station, the tray-to-cart loading station, the conveyor, the inspection and reject station, the industrial robot, a robotic arm or a combination of any of these may have a camera and a computer connected for having machine vision capability in order to recognize shapes of various objects. The machine vision not only enables the these machines to find an object, it also guides

movements of these machines such that these machine can pick a food or non-food item from a pile/pool of randomly scattered items, and move the selected item onto tray in forming a tray assembly or subassembly. In particular, the machine vision or computer vision, in the areas of feature detection and feature extraction, aims at identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. Detected edges form boundaries of an object such that the machine can recognize the camera-captured image to be a desired food or non-food item for tray packaging. Since the image capturing, image processing and program executing can be efficiently by one or more computers, the shape recognition can be speedily performed and improve the packaging speed markedly.

[0011] The tray dispenser, the loading station, the tray-to-cart loading station, the conveyor, the inspection and reject station, the industrial robot or a combination of any of these can have a camera and a computer connected for obtaining machine vision capability in order to scan surface texture of various objects. One or more these machines thus will be able to notice surface cracks in wrapping films of food or non-food items, to observe dirt or stain on any of the tray, food or non-food items. Checking against preloaded quality criteria, these machines can prevent faulty trays, food or non-food items from being assembled, which is costly and time wasteful in providing tray assemblies.

[0012] Method of machine vision image processing include pixel counting (counts the number of light or dark pixels), thresholding (converts an image with gray tones to simply black and white or using separation based on a grayscale value), segmentation (partitioning a digital image into multiple segments to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze), blob discovery & manipulation: inspecting an image for discrete blobs of connected pixels as image landmarks) and pattern recognition (including template matching, finding, matching, and/or counting specific patterns. The pattern recognition may include location of an object that may be rotated, partially hidden by another object, or varying in size. The method further includes color identification, barcode, data matrix and "2D barcode" reading, optical character recognition (automated reading of text such as serial numbers), gauging: measurement of object

dimensions (e.g. in pixels, inches or millimeters) and filtering (e.g. morphological-filtering).

[0013] Two or more of the tray dispenser, the loading station, the tray-to-cart loading station, the conveyor, the inspection and reject station, the industrial robot or a combination of any of these may be connected for neural net processing. The neural net processing is weighted and self-training multi-variable decision making that enables the flexible assembly line to adjust packaging speed at various machines, to send an alarm to an operator when facing fault, or sending requests for demanding various food or non-food items. Consequently, the flexible assembly line becomes intelligent and requires less human intervention. Labor cost of using the flexible assembly line will be reduced.

[0014] The tray dispenser, the loading station, the tray-to-cart loading station, the conveyor, the inspection and reject station, the industrial robot or a combination of any of these can be modularly connected to the flexible assembly line such that it can be disconnected to other parts of the flexible assembly line without affecting others. The modular design, or "modularity in design", is an approach that subdivides the flexible assembly line into smaller parts (modules) that can be independently created and then used in different flexible assemble lines to drive multiple functionalities. The flexible assembly line with the modular design has following characteristics:

I. Functional partitioning into discrete scalable, reusable modules consisting of isolated, self-contained functional elements;
II. Rigorous use of well-defined modular interfaces, including object-oriented descriptions of module functionality; and
III. Ease of change to achieve technology transparency and, to the extent possible, make use of industry standards for key interfaces.

[0015] The loading station may comprise a conveyor for feeding bins with food or non-food items, and another conveyor for removing empty bins. The conveyor is optionally linked to the main conveyor, which connects machine stations and robots of the flexible assembly line. The conveyor of the loading station facilitates the supply of input materials (e.g. food items) and removal of finished materials (empty trays) such

that the loading station is able to fully utilize its operation capacity, without being delayed by shortage of supply.

[0016] The flexible assembly line can further comprise a manual loading station for manually loading, unloading or checking food or non-food items. The optional manual loading station allows the flexible assembly line to be further adaptable to pack some food items that is too fragile to be handled by an end effector of a robot. The manual loading station further allows human intervention, which may be required at times.

[0017] The flexible assembly line may further comprise a shelving carousel that has movable loading trays for transferring food or non-food items. The shelving carousel is alternatively known as an auto bin stacker and carousel, which may be manually powered or electrically powered. The shelving carousel enables operators at opposite sides of the shelving carousel to load or retrieve food or non-food items at their convenience, without interfering each other. For example, an operator is able load an empty shelf with cutlery packages at one side, whilst another operator is able to take butter packs from an opposite side of the shelving carousel. Loading and unloading efficiency of using the shelving carousel is much higher than that of fixed shelving.

[0018] The flexible assembly line can further comprise a touch screen display connected to a main computer of the flexible assembly line for controlling the flexible assembly line. The touchscreen provides an intuitive user interface that an operator may find it easy operate. The touchscreen further avoids an extra keyboard and mouse which are often misplaced, contaminated by food or easily damaged by accidental hits.

[0019] The flexible assembly line may further comprise an automatically guided vehicle (AGV) for fetching packaged tray assemblies or empty trays. The automatically guided vehicle may be programmed to go to various designated places for taking specific food or non-food items such that the flexible assembly can change to pack different types of tray packages following different manuals. Human error is reduced by programing and connecting the automatically guided vehicle with the flexible assembly line.

[0020] The flexible assembly line can further comprise an auto food items dispenser that comprises a rotatable food hopper, a diverter and a conveyor. The rotatable food hopper has one or more compartments for storing food items. In use, the rotatable food hopper spins and vibrates such that different items in their respective compartments can be orderly dropped down into the diverter. The conveyor below has several lanes for receiving diverse items. The diverter will orientate its openings below for aiming the lanes so that appropriate items are dispatched into designated lanes respectively for packaging tray assemblies.

[0021] The industrial robot may have an end effector for rotating. The end effector is a device at the end of a robotic arm, designed to interact with the environment. The end effector may include a gripper or a tool (e.g. vacuum suction cup). The gripper can be of two fingers, three fingers or even five fingers. When picking stacked cups, partial vacuum may exist between the stacked cups. When the industrial robot lifts a cup on top, one or more cups below may be carried up too due to the partial vacuum. With the rotation, the below cups will be easily dropped off, which avoids double-picking mistakes of tray packaging.

[0022] The industrial robot can have an end effector for shaking. As the end effector vibrates, the cups below can straightforwardly detach from the top cup, which again avoids the issue of double-picking by the industrial robot.

[0023] The industrial robot may have an end effector for heating. For example, the end effector can circulate hot air at its end effector such that a picked cup is quickly heated up. A "slicked cup" below the top cup will likely separate itself from the top cup due to differential thermal expansion between the two cups.

[0024] The flexible assembly line can further comprise a cleaning and sterilization station for cleaning an end effector of the industrial robot. The cleaning and sterilization station includes a bucket that contains one or cleaning fluids, such as water, pressurized air, sanitizing gel, foam, and liquid solutions. The bucket may have an inlet and an outlet such that the cleaning fluids can circulate and being replaced for cleaning an end effector dipped inside.

[0025] The flexible assembly line may further comprise a cleaning and drying station for cleaning a belt of the conveyors. Since the conveyors or belts of conveyor contacts the trays or the food containers, the conveyors or belts may be contaminated with food particles. The cleaning and drying station provides cleaning/cleansing, drying or a combination of these to the conveyors or belts such that various food and non-food items are prevented from cross contaminating each other. For example, the conveyors or belts are spayed with water and blown with pressurized air streams. The conveyors or belts can further be illuminated with infrared or ultraviolet light for exterminate germs. The conveyors or belts may be further wiped with brushes, whilst dust pans/ trough are placed below for collecting food debris.

[0026] The flexible assembly line can include one or more pest control drawers. The drawers are containers that are attached to or installed next to one of the machines/stations, such as the conveyor. The drawers are provided below passages of the food or non-food items such that pest control drugs in the drawers are avoided from being accidentally dropped onto the passages, causing food contamination. The pest control drawers are useful for preventing infestation to the flexible assembly line.

[0027] The application further provides an inflight catering center having one or more of the flexible assembly line. The inflight catering center provides meals in packaged tray assemblies for catering numerous airlines/flights of an airport. Since the flexible assembly line can operate continuously with great flexibility and efficiency, operation efficiency of the inflight catering center and the airport will be markedly enhanced.

[0028] According to a second aspect of the invention, the present invention provides a method of using a flexible assembly line for tray packaging. The method comprises a first step of receiving an empty or partially assembled/filled tray, a second step of providing a food or non-food item, and a third step of loading the food or non-food item onto the tray automatically. Since the loading is carried out by one or more machines, operation efficiency, accuracy and reliability of the flexible assembly line become much higher than a manual assembly for tray packaging.

[0029] The method can further comprise a step of inspecting the tray, the food or non-food item, a loaded tray by machine vision (MV) automatically. The machine vision

sequence of operation includes acquisition of an image by using one or more cameras, lenses, and lighting, which provide differentiation required by subsequent processing. Machine vision software packages then employ various digital image processing techniques to extract the required information, and make decisions (e.g. pass/fail) based on the extracted information. The machine vision applications may be solved using 2 dimensional imaging, 3 dimensional imaging or both. The machine vision provides a feedback to the flexible assembly for achieving high accuracy, efficiency and quality of tray packaging. Alternative or complimentary feedback of the flexible assembly line may be provided by jigs, fixtures, orifice of predetermined shapes, position switches and weight measuring of tray assemblies.

[0030] The method may further comprise a step of transferring a loaded or completed tray into a cart for transporting. Tray assemblies, either completed or rejected, are quickly stacked into the cart for shipping to a temporary storage or to an airplane. The action of transporting keeps the flexible assembly line from jamming in operation, which is highly desired in catering centers for providing food with large volumes.

[0031] According to a third aspect of the invention, the application provides a method of installing a flexible assembly line for tray packaging. The method comprises a step of providing a tray dispenser for presenting a tray, and a further step of presenting a loading station adjacent to the tray dispenser with a fixing tool (e.g. robotic arm or industrial robot) for placing food or non-food items onto the tray automatically. Multiple flexible assembly lines may be installed and connected to each other in a catering center for supplying food with large volumes and diverse varieties.

[0032] According to a fourth aspect of the invention, the application provides a method of configuring a flexible assembly line for tray packaging. The method comprises a step of loading a software package for image processing of machine vision. The software package can be utilized to control operations of different stations, machine vision of the flexible assembly line or packaging menu of the tray assemblies.

[0033] The accompanying figures (Figs.) illustrate embodiments and serve to explain principles of the disclosed embodiments. It is to be understood, however, that these

figures are presented for purposes of illustration only, and not for defining limits of relevant inventions.

[0034] Fig. 1 illustrates a first flexibly assembly line for tray packaging;
Fig. 2 illustrates a process flow diagram for using the first flexible assembly line;
Fig. 3 illustrates a second flexible assembly line for tray packaging;
Fig. 4 illustrates a perspective view of the second flexible assembly line;
Fig. 5 illustrates a third flexible assembly line for tray packaging;
Fig. 6 illustrates another view of the third flexible assembly line;
Fig. 7 illustrates a non-food vision robotic module;
Fig. 8 illustrates another non-food vision robotic module;
Fig. 9 illustrates a food vision robotic module;
Fig. 10 illustrates another food vision robotic module;
Fig. 11 illustrates an automated carousel for one of the flexible assembly lines; and
Fig. 12 illustrates a part of the first flexible assembly line.
Fig. 13 illustrates an auto bin stacker and a carrousel;
Fig. 14 illustrates a process flow diagram for using the auto bin stacker and carrousel;
Fig. 15 illustrates a robotic arm that picks two stacked cups;
Fig. 16 illustrates the robotic arm that twists for shaking off an attached cup;
Fig. 17 illustrates the robotic arm that vibrates for shaking off an attached cup; and
Fig. 18 illustrates the robotic arm that heats up for removing an attached cup.

[0035] Exemplary, non-limiting embodiments of the present application will now be described with references to the above-mentioned figures.

[0036] Both Figs. 1 and 2 relate to an embodiment of the present invention. In particular, Fig. 1 illustrates a flexible assembly line 30 for tray packaging, which is alternatively known as a first flexible assembly line for tray packaging 30. The flexible assembly line 30 comprises several stations 32-44, which are sequentially connected by a conveyor 46. These stations include a tray dispenser 32, a first loading station 34, a second loading station 36, a third loading station 38, a manual loading station 40, an inspection and rejection station 42 and a tray-to-cart loading station 44. However, the inspection and rejection station 42 and the tray-to-cart loading station 44 are placed together, on opposite sides of the conveyor 46. A main computer 48 is

connected to all these stations 32-44 for controlling the entire flexible assembly line 30. The main computer 48 has two touch screen displays 50, 52, namely a first display 50 and a second display 52 at opposite ends of the conveyor 46. The loading stations 34, 36, 38 are also known as robotic modules such that they can be added or removed depending on working load. In other words, the loading stations 34, 36, 38 are similar to units of a plug and play system, which can selectively installed/connected or removed/disconnected for packaging different tray assemblies at various packaging speeds.

[0037] A first bin stacker 54 is positioned adjacent to the first loading station 34, and next to the conveyor 46. More particularly, the first bin stacker 54 is placed on another side of the conveyor 46, opposite to the first loading station 34. A second bin stacker 56 is located close to the second loading station 36, and near the conveyor 46 too. The vibratory bowl sorter 58 is placed in close proximity with the third loading station 38, neighboring to the conveyor 46. In other words, the first bin stacker 54, the second bin stacker 56 and the third bin stacker 58 are consecutively arranged along the conveyor 46, which has a belt 60 with an elongated form.

[0038] Fig. 1 also shows objects that interact with the flexible assembly line 30. For example, a trolley 62 filled with trays is parked next to the tray dispenser 32 at a front end 64 of the belt 60. The trolley 62 is designed with internal slots for receiving the trays horizontally. Once the trolley 62 is parked at the tray dispenser 32 near the front end 64, a fork mechanism (not shown) can incrementally lift/index the trolley 62 up vertically following gradual removal of trays. The trolley 62 is full of clean trays that are ready for receiving food and cutleries. At a back end 66 of the belt 60, the two carts 68 stand near the tray-to-cart loading station 44 for receiving installed tray assemblies. A first operator 70 and a second operator 72 are also depicted in Fig. 1. The first operator 70 stands near both the main computer 48 and the front end 64, whilst the second operator 72 stands adjacent the manual loading station 40.

[0039] The flexible assembly line 30 is designed to assemble numerous types of food and utensils onto trays. An installed/completed tray assembly includes following food and non-food items with containers:

A. Trays

i. Half tray
ii. Small tray
iii. Plastic long side plate

B. Cups
i. Plastic tea cup
ii. Drinking glass
iii. Desert bowl with fruits
iv. Pre-cupped water
v. Pre-cupped yogurt

C. Cutlery pack
i. Pepper sachet
ii. Salt sachet
iii. Sugar sachet

D. Condiments
i. Butter pack
ii. Jam pack
iii. Milk screamer
iv. Chili pack

E. Bakery items
i. Bread in wrapper
ii. Biscuit
iii. Cracker
iv. Muffin

[0040] According to Fig. 1, the tray dispenser 32 is a robot that has an arm 74 with a suction cup (end effector) at its end. The tray dispenser 32 is fixed to the front end 64 such that the arm 74 can pick an empty tray 76 from the trolley 62 onto the belt 60. The arm 74 has six axes of freedom of operation such that the arm 74 can reach an empty tray 76 of different height or distance. The arm 74 further has an intelligent vision guided system (not shown) near the suction cup for checking the empty tray 76 before transferring it 76 onto the belt 60. The tray dispenser 32 will bring the empty tray 76 to a reject bin (not shown) if the intelligent vision guided system detects dirt, stain or defects on the tray 76. The arm 74 may also have gripper or a combination of gripper with suction cup(s) as its end effector.

[0041] The first loading station 34 has a first four-axis robot 78 for taking non-food items onto a clean empty tray 80. The clean empty tray 80 is transported from the trolley 62 to the first loading station 34 by the tray dispenser 32 and the conveyor 46. After machine vision inspection, quality-compliant non-food items are picked up from the first bin stacker 54 where these non-food items are orderly stacked up. The first loading station 34 also has intelligent vision guided system (not shown) for inspecting incoming trays and the loaded non-food items. If a quality non-compliant item is found, such as a soiled teacup, the first four-axis robot 78 will seize the quality non-compliant item and transfer the quality con-compliant item into a reject bin (not shown). The first four-axis robot 78 may alternatively be replaced by a five-axis or a six-axis industrial robot.

[0042] The second loading station 36 has a second four to six-axis robot 82 that is designed to take other non-food items onto a tray 84 from the first loading station 34. The other non-food items are stored at the second bin stacker 56. The second loading station 36 is equipped with intelligent vision guided system (not shown), which are used for checking the other non-food items. The second loading station 36 will bring quality non-conforming items to a reject bin (not shown). Similarly, the second four-axis robot 82 may alternatively be replaced by a five-axis or a six-axis robot.

[0043] In contrast, the third loading station 38 has a third four-axis robot 86 installed for picking food items from the vibratory bowl sorter 58 and placing them onto a tray 88 from the second loading station 36. An intelligent vision guided system (not shown) of the third loading station 38 examines a completed tray 90 of the third loading station 38 and the third four-axis robot 86 will replace non-conforming items with standard-conforming items. The second robot 80 may alternatively be replaced by a five-axis or a six-axis robot.

[0044] The manual loading station 40 provides seats (not shown) to operators for loading fragile items, which the robots 78, 82, 86 find it difficult to handle. Especially, the manual loading station 40 offer the seats next to the belt 60 for ease of loading. In use, the operators place the fragile items onto the tray 90 from carousel shelves 91 of the third loading station 38. For example, the operators can pick soft rice packs and

place them into the half trays. The carousel shelves 91 are located next to the seats of the operators for easy access.

[0045] The inspection and rejection station 42 has several cameras, which are directed towards incoming trays from the manual loading station 40. The inspection and rejection station 42 presents final vision inspection to completed tray assemblies. Next to the inspection and rejection station 42, an auto rejection station 43 will take inspection-failed tray assemblies away from the belt 60.

[0046] In contrast, the tray-to-cart station 44 has an industrial robot (not shown) having an arm (not shown) for fetching the completed tray assemblies. The industrial robot can grab a completed tray assembly and insert it into a suitable slot of a cart 68, which is parked next to the back end 66. An empty cart will be supplied after the cart 68 is completely filled with the completed tray assemblies and moved away.

[0047] Functionally, the tray dispenser 32 can automatically transfer empty trays from the trolley 62 to the conveyor 46. Clean and empty trays 76 are loaded into the trolley 62. Once the trays 76 on the trolley 62 are used up, another trolley 62 full of empty clean trays is supplied for replacing the empty trolley. The flexible assembly line 30 can operate without interruption when replacing the trolley 62.

[0048] The vibratory bowl/conveyor sorter 58 can sort food items laterally, which is perpendicular to a longitudinal direction 92 of the belt 60, which is also the process flow direction 92 of the first flexible assembly line 30. The vibratory bowl sorter 58 shakes selected food items (e.g. butter packs) such that the selected food items are unscrambled and automatically organized with uniform orientations for picking and placing.

[0049] Each of the three loading stations 34, 36, 38 can inspect objects for acceptance or rejection. Vision components (e.g. camera and its connected computer) of the three loading stations 34, 36, 38 inspect objects on possible stain, cracks, chips, foreign particles and other non-acceptable defects. Quality criteria of for the rejection and acceptance are stored in the three loading stations 34, 36, 38 for ensuring high accuracy and consistency of tray packaging. Items that fail to comply with the criteria

are transferred to the reject bins (not shown) by the corresponding robots 78, 82, 86. The three loading stations 34, 36, 38 have fly-by inspection functions such that bottom surfaces of their picked item are also checked before placing them onto the trays 84, 88, 90. The fly-by inspection functions are provided by the vision components, which is described later.

[0050] The inspection and rejection station 42 not only screens completed tray assemblies in accordance with predetermined standard (quality criteria), the inspection and rejection station 42 also discharge compressed and filtered clean air onto the completed tray assemblies when required for cleaning.

[0051] The main computer 48 is connected to the vision stations and robots 32, 34, 36, 38, 42, 43, 44 for regulating workload and coordinating these machine/work stations 32, 34, 36, 38, 42, 43, 44. The main computer 48 can also adjust speed of the conveyor 46 via PLCs (Programmable Logic Controllers) or Personal Computers (PCs). Together with the loading stations 34, 36, 38, the inspection and rejection station takes images of defect objections for future analysis. The images and statistic data of the packaging production are kept for at least 30 days for reviewing. The statistic data is further made available online (e.g. via secured intranet or internet) by the main computer 48 for Production Performance KPI (Key Performance Indicators), Management, text/table reporting and graphical representation and maintenance planning. The main computer 48 can further send Production statistic information and the KPIs to a mainframe/central computer (not shown) at a remote place for recording, analyzing, monitoring and reporting. The main computer 48 is equipped with a modem for remote communication, such as for troubleshooting. An alarm signal will be sent if an abnormal situation occurs in the flexibly assembly line 30. The two displays 50, 52, which are both connected to the main computer 48, have user-friendly interfaces for updating production menu and tray floor plan (tray layout).

[0052] The flexible assembly line 30 has functions for maintaining high quality food hygiene of the tray packaging. For example, each of the loading stations 34, 36, 38 is enclosed with a HEPA (High-Efficiency Particulate Air) air purifier with static detection and an anti-static ionic air blower for minimizing intrusion of foreign particles, such as dust and hair. The belt 60 is enclosed by a transparent cover (not shown) for avoiding

falling foreign particles. The belt 60 is further wiped down continually by a brush as the belt 60 moves. Each part of the flexibly assembly line 30 has a schedule of cleaning procedure for regular maintenance and cleaning. Warm and dark compartments of the flexible assembly line 30 have clear labels/signs for indicating potential pest pockets, regular cleaning and routine inspection. The flexible assembly line 30 adopts lubrication-free design features for most machine components above the belt 60. Food-grade lubricant is used where lubrication is essential and the lubrication is above the height of the belt 60. Wetted areas of the flexible tray assembly line 30 are made to be of S/S316 material, whilst other areas are S/S304 compliant or has food grade. The flexible assembly line 30 has online bacteria count function for monitoring its hygiene quality.

[0053] The flexible assembly line 30 has many functions that ensure safety in using the flexible assembly line 30. For example, robotic arms and moving parts are enclosed by shields or covers. Areas of machine movements that require operator's access are installed with latched doors, safety interlocks and safety light curtain. Sensors are fitted near moving parts and critical places that detects prohibited movements or contacts such that corresponding machine parts will be stopped if the sensors detect hazardous approaches. Safety and warning labels are affixed to the flexible assembly line 30 for alerting machine users. For electrical safety, the flexible assembly line 30 is securely earthed and its electrical wirings are connected to circuit breakers.

[0054] When in use, in a preparation stage according to a method of tray packaging 100, an operator 70, 72 enters 102 a flight number into the main computer 48 via the first display 50, which causes the main computer 48 to retrieve 104 corresponding meal menus, types and quantity of food utensils, cutleries requirements, and other relevant information. The main computer 48 further uploads 106 tray floor plans, specific shapes, sizes, hygiene criteria and weights of the food and non-food items to the robots 78, 82, 86. In an airline in-flight catering center, an authorized operator 70, 72 enters the flight number, desired production quantity, tray-packaging time, and other relevant data. The authorized operator 70, 72 has a user identification code and a password that allows him/her to set these production parameters. Different levels of user authorization are made available by the main computer 48 for maintenance,

production control and other purposes. For example, the authorized user 70, 72 can upload, change and delete menus of tray packages according to flight numbers. In the meantime, the trolley filled empty trays 62, the bin stackers 54, 56 filled with non-food items, the vibratory bowl sorter 58 occupied with selected food items and the empty carts 68 are moved 108 to the flexible assembly line 30 when entering the production instruction.

[0055] Before picking up the empty tray 76 from the trolley 62, the trolley dispenser 32 inspects 110 the empty tray 76 and compare 112 images of the empty tray 76 with stored data (quality criteria). The stored data includes hygiene standard of the tray 76 and 3-D template images of a standard empty tray (e.g. color, size, etc.). If scanned/inspected empty tray 76 meet the quality criteria, the trolley dispenser 32 uses its suction cup to catch 114 the empty tray 76 and move the empty tray 76 above a camera for inspecting its bottom surface. Accordingly, the trolley dispenser 32 will command and guide a robotic arm of the trolley dispenser to place 116 the empty tray 76 onto the front end 64 of the belt 60 with a predetermined orientation if the tray 76 meets all acceptance/quality criteria. If the empty tray 76 does not meet one or more of acceptance criteria, the empty tray 76 will be dropped into a rejection bin for manual counter-checking. The reason of the rejection and images of the rejected empty tray 76 will be recorded for further study.

[0056] The clean empty tray 80 progresses 120 along the belt 60 from the front end 64 towards the first loading station 34. The first loading station 34 identifies 122 location, speed (via encoder installed on the conveyor 46) and orientation of the clean empty tray 80 once detecting 124 the incoming clean empty tray 80. The vision system of the first robot 78 captures 126 a rectangular plate that was previously stored and stacked inside the first bin stacker 54. If the rectangular plate passes the vision inspection (360 degrees around a vertical axis of the tableware) acceptance criteria, the first robot 78 will pick up and move the bottom surface of this rectangular plate above a vision camera for bottom inspection. If the rectangular plate passes the acceptance criteria too, the first robot 78 will put 128 the rectangular plate onto the clean empty tray 80 according to a tray floor plan. If failed, the first robot 78 will reject the item to the reject station (not shown). The first loading station 34 comprises of a pre-inspected buffer station (not shown). This buffer station provides a backup during

refilling for reducing downtime of the flexible assembly line 30. The buffer station stores plates for replacing rejected plates. Repeated rejection can possibly delay tray assembly packaging. The buffer station is refilled when the first robot 78 has idle/spare time.

[0057] The quality compliant tray 84 further progresses 120 to the second loading station 36. The second loading station 36 ascertains 136 travelling position, velocity and orientation of the tray 84 near its entrance. The second four-axis robot 82 stretches 138 its arms and seizes 140 a cutlery pack 141 from the second bin stack 56. The cutlery pack 141 is subsequently lifted 142 onto the tray 84 by the second four-axis robot 82. The second loading station 36 (i.e. robotic assembly module) takes 144 images around the loaded tray 88 and compares 132 them against the preloaded criteria for quality check. The images are taken at 360 degrees around a vertical axis of the loaded tray 88. The loaded tray 88 will be permitted to proceed 120 on the belt 60 if all relevant quality criteria are met. If the loaded tray 88 does not fulfill the preloaded criteria, the cutlery pack 141 will be replaced 148 by another cutlery pack 141 from the second bin stacker 56. The second robot 82 can alternatively be a five-axis robot or a six-axis robot.

[0058] The third loading station 38 senses 150 the tray 88 at its entrance. The third loading station 38 further examines 152 location, speed and orientation of the tray 88. The third four-axis robot 86 extends 154 its arms to the vibratory bowl sorter 58 and grabs 156 a fruit bowl (not shown). The fruit bowl is afterward deposited 160 onto the tray 88. Similar to the first and the second loading station 34, 36, the third loading station 38 shots 162 images of top views of the tray 90, which has the fruit bowl. Cameras of the third loading station 38 shots 162 the images on an upper hemisphere of the tray 90, around a vertical axis of the tray 90. The images are processed 164 by comparing to the preloaded criteria. The tray 90 is permitted to depart 166 from the third loading station 38 if all the criteria are met. However, the fruit bowl will be taken off 168 the tray 88 if the fruit bowl fails to fulfill one or more of the preloaded criteria. For example, the fruit bowl will be replaced 170 by another one if the fruit bowl is cracked with sharp edges. Types and sequences of tableware loaded at the loading stations 34, 36, 38 change according to catering requirements.

[0059] Several operators 70, 72 are seated at the manual loading station 40, which is immediately adjacent to the third loading station 38. The operators 70, 72 pick up 172 the soft and fragile items from the manual loading station 40 and place 174 them to designated locations on the incoming tray 90. The soft and fragile items include chili packs, bread in wrapper, yogurt pack, and others. When placing 174 these items, the operators also scrutinize 176 if there is any broken, spilled or contaminated food or non-food items. Non-compliant items are taken off 178 the belt 60 for rework. The operators 70, 72 regularly look 180 at the second display 52 for regulating the speed and status of the tray packaging. If necessary, the operators 70, 72 may intervene 182 production of the flexible assembly line 30 for immediate repair or scheduled maintenance. The second display 52 provides an alternative to the first display 50 such that the operators 70, 72 can interact with the main computer 48 at two locations.

[0060] The (final) inspection and rejection station 42 and the auto reject station 43 have machine vision capability for analyzing a completed tray assembly. The completed tray assembly includes food and non-food items for catering a meal. For example, the completed tray assembly has the food tray 76 as its base, the rectangular filled with a rice pack, the fruit bowl, a teacup holding a sealed yogurt cup, the cutlery pack, a bowl of salad, a wrapped muffin, a cracker pack and others. When in operation, the inspection and rejection station 42 takes 184 continuous photos of the completed tray assembly and compares 186 the continuous photos with the preloaded images of completed tray assemblies, which are quality criteria for acceptance.

[0061] The reject station 43 will withhold 188 a completed tray assembly that does not fulfill the preloaded criteria and stack 190 the rejected tray assembly in a reject bin (not shown). In contrast, the auto reject station 43 will take no action to a completed tray assembly if the inspection and rejection station 42 is satisfied with the completed tray assembly because all preloaded criteria are complied with.

[0062] The tray-to-cart loading station 44 receives 192 completed tray assemblies at the back end 66 of the belt 60. The tray-to-cart loading station 44 is an industrial robot or mechanical tray pusher, similar to the tray dispenser 32. In operation, the auto tray-to-cart loading station 44 reaches 194 out to the belt 60 and holds 196 a completed

tray assembly tightly. The tray-to-cart loading station 44 identify 198 a suitable slot in the cart 68 neighboring to the back end 66, and insert 200 the completed tray into the slot fully. The tray-to-cart loading station 44 will insert a subsequent completed tray assembly into a next available slot in the cart 68. The tray-to-cart loading station 44 transmits an alert signal to the main computer 48 if a cart 68 is almost full with the completed tray assemblies. The main computer 48 will show 204 messages on the displays 50, 52 for requesting empty carts 68. The empty carts 68 are supplied to the tray-to-cart loading station 44 following the request. The cart-to-tray loading station 44 will affix a label 206 to a cart filled with the completed tray assembly for future identification. The label includes one or more of bar codes, Quick Response (QR) code, Radio-Frequency identification (RFID) code and texts for both human and machine interpretation. The tray-to-cart loading station 44 can alternatively be a mechanical tray pusher.

[0063] Fig. 3 illustrates a second flexible assembly line for tray packaging 210. The second flexible assembly line 210 has parts or operation steps that are similar to those of the first flexible assembly line 30. The similar parts or method steps are labeled with identical or similar reference numerals. Descriptions of the similar parts or steps are hereby incorporated by reference where appropriate.

[0064] The second flexible assembly line 210 provides more explicit description on the modular design concept. In particular, the second flexible assembly line 210 comprises a tray dispenser 32, a first loading station 34, a second loading station 36, a third loading station 38, a manual loading station 40, carousel shelves 91, an inspection and rejection station 42, an auto rejection station 43, and a tray-to-cart loading station 44, which are mostly located along the conveyor 46 linearly. These stations are modularly designed such that they can be independently operated and are further connected together for operation. For example, the first loading station 34, the second loading station 36 and the third loading station 38 are industrial robots that have machine vision capability, which can be installed or removed without affecting each other.

[0065] Fig. 4 illustrates a perspective view of the second flexible assembly line 210. The second flexible assembly line 210 may be modified by including four lanes for

non-food items automatic picking by the industrial robots with machine vision. The second flexible assembly line 210 may also be modified by including three lanes for food items automatic picking by the industrial robots with machine vision, which operates as two modules. The second flexible assembly line 210 may be further modified by including three lanes and ten racks with the carousel shelves 91 for manual picking by the operators 70, 72, which operate as one module.

[0066] Fig. 5 illustrates a third flexible assembly line 212 for tray packaging. The third flexible assembly line 212 has parts or operation steps that are similar to other flexible assembly lines 30, 210. The similar parts or method steps are labeled with identical or similar reference numerals. Descriptions of the similar parts or steps are hereby incorporated by reference where appropriate.

[0067] Each of a first loading station 34, a second loading station 36 and a third loading station 38 has integrated a four-axis robot 78, 82, 84 respectively. Both the first loading station 34 and the second loading station 36 have integrated their bin stackers 54, 56 respectively, whilst the third loading station 38 has integrated a vibratory bowl sorter 58. All of the first loading station 34, the second loading station 36 and the third loading station 38 are sequentially located on one side of a conveyor 46, whilst a fourth loading station 214, a fifth loading station 216 and a sixth loading station 218 of the third flexible assembly line 212 are located on another side of the conveyor 46, opposite to the first loading station 34, the second loading station 36 and the third loading station 38 respectively. Both the fourth loading station 214 and the fifth loading station 216 have similar parts and functions to the first loading station 34 and the second loading station 36. The sixth loading station 218 has parts and functions similar to the third loading station 38.

[0068] Fig. 6 illustrates a perspective view of the third flexible assembly line 212. The third flexible assembly line 212 may be modified by including eight lanes for non-food items automatic picking by the industrial robots with machine vision, which operates as four modules. The third flexible assembly line 212 may also be modified by including six lanes for food items automatic picking by the industrial robots with machine vision, which operates as two modules. The third flexible assembly line 212

may be further modified by including three lanes and ten racks with the carousel shelves 91 for manual picking by the operators 70, 72, which operates as one module.

[0069] Fig. 7 illustrates a non-food vision robotic module 234, which is also known as the first loading station 34 or the second loading station 36. A plane/top view and a side view of the non-food vision robotic module 34, 36 are provided. The non-food vision robotic module 34, 36 includes a reject conveyor 220 for taking away vision-inspection failed tableware. Fig. 7 further shows a first bin 222 and a second bin 224, which are loaded with non-food items (e.g. cups) and placed on one side of a four-axis robot 78, 82. The four-axis robot 78, 82 is floor mounted. A third bin 226 and a fourth bin 228 empty carts 222, 226 are empty and they are located on another side of the four-axis robot 78, 82. The four-axis robot 78, 82 takes the non-food items away from the first bin 222 and the second bin 224, whilst depleted bins 226, 228 are taken away by a conveyor 230. In contrast, the first bin 222 and the second bin 224 are carried to the four-axis robot 78, 82 by another conveyor 232.

[0070] Fig. 8 illustrates another non-food vision robotic module 236, which is also known as the first loading station 34 or the first loading station 34. Comparing to earlier four-axis robot 78, 82, the present four-axis robot 78, 82 is ceiling mounted.

[0071] Fig. 9 illustrates a food vision robotic module 238, which is similar to the third loading station 38. The food vision robotic module 238 comprises a conveyor 240 for feeding food items 242 (e.g. cheese), and another conveyor 244 for removing quality con-complaint food items 246. A third four-axis robot 86 is ceiling mounted. Rejected food items 246, which have failed vision inspection, are transported to a reject bin 248 for manual checking.

[0072] Fig. 10 illustrates another food vision robotic module 250, which includes an auto food items dispenser 252. The auto food items dispenser 252 comprises a rotatable food hopper 254, a diverter 256 and a conveyor 258 vertically and sequentially aligned. The rotatable food hopper 254 is divided into compartments for containing respective food items (e.g. cheese, yogurt). In use, the rotatable food hopper 254 shakes for dispensing food items into the diverter 256 below. The diverter

256 has openings of predetermined shapes that allows corresponding food items to be dropped onto the conveyor 258 below for handling by the third four-axis robot 86.

[0073] Fig. 11 illustrates an automated carousel 91 for one of the flexible assembly lines 30, 210, 212, 214, 216, 218. The automated carousel 91 comprises a top sprocket gear 260, a bottom sprocket gear 262 that are connected via a chain 264, which form a roller chain, a drive chain or a transmission chain 266. The automated carousel 91 has loading trays 268 horizontally positioned and are carried by the chain 264. An operator 70 on one side 270 of the automated carousel 91 uploads food items onto suitable loadings trays 268, whilst another operator 72 on another side 272 unloads the food items away from the loading trays 268.

[0074] Fig. 12 illustrates a part of the first flexible assembly line 30. The first flexible assembly line 30 includes an Automatically Guided Vehicle (AGV) 274 for transporting objects from or to the flexible assembly line 30. For example, The AGV 274 transports carts fully loaded with tray assemblies to a warehouse of in-flight center, and moves an empty cart to the flexible assembly line 30. The AGV can further carry food or non-food items to the flexible assembly line 30 according to predetermined routes, which avoids using operators 70, 72 to move these items. The AVG 274 is more reliable and cost effective for transporting regular items continuously.

[0075] Fig. 13 illustrates an auto bin stacker and a carrousel 278, which are parts of a simplified flexible assembly line for tray packaging 276. The flexible assembly line 276 comprises an auto bin stacker and carousel 278. The auto bin stacker and carousel 278 is connected to a first loading station 34 such that bins 280 on the auto bin stacker and carousel 278 are automatically rotated in coordination with a first four-axis robot 78 for picking desired non-food items.

[0076] Fig. 14 illustrates a process flow diagram 282 for using the auto bin stacker and carrousel 278, which includes several method steps. In a first step 284, an operator inspects incoming empty trays for quality compliance (e.g. hygiene). A robotic assembly module (first loading station) 34 checks top surfaces of the incoming trays for further examination, which is a second step 286. The surface vision

inspection may be replaced or followed by a 360 degree all round vision inspection, which leads to a more complete inspection, as a third step 288. After loading non-food items by the robotic assembly module 34, a partially completed tray assembly is transported to a manual loading station 40. An operator 70 will further load food items to the partially completed tray assembly for providing a complete tray assembly. In a fourth step 290, the completed tray assembly is further manually checked for quality compliance.

[0077] Fig. 15 illustrates a robotic arm 292 that picks two stacked cups 294, 296. The robotic arm 292 is a four-axis robot similar to the first four-axis robot 78 and the second four-axis robot 82. Fig. 15 depicts a typical failure of picking where a suction cup 298 as its end effector that lifts two stacked cups 294, 296 off a third cup 300. A second/bottom cup 296 is adhered to a first/top cup 294 because of partial vacuum between the two cups 294, 296.

[0078] The robotic arm 292 is a machine vision enabled robot, which is similar to the tray dispenser 32, inspection and reject station 42, the auto rejection station 43, the tray-to-cart loading station 44, the first four-axis robot 78, the second four-axis robot 82, the third four-axis robot 86, the fourth loading station 214, the fifth loading station 216, and the sixth loading station 218. The robotic arm 292 is 2D and 3D machine vision enabled such that its machine vision (MV) provides imaging-based automatic inspection and analysis for checking washing quality (no water stain or dirt) and surface integrity of food items, non-food items and trays. and profile integrity (e.g. no chipping off) of these items. The robotic arm 292 can acquire images of the objects (e.g. cups 294, 298, 300) via cameras (not shown) under suitable illumination. The robotic arm 292 is installed with software packages then employ various digital image processing techniques to extract the required information, and make decisions (e.g. pass/fail) based on the extracted information. For example, the robotic arm 292 employs a pattern recognition technique that causes finding, matching, and/or counting specific patterns based on preloaded templates of cups 294, 296, 300. Locations, angles and orientations of an image-captured object (e.g. tray) may be rotated, partially hidden by another object, or varying in size. Additionally, the robotic arm 292 has an edge detection ability which checks dimensions and profile integrity of scanned/captured objects (e.g. cup). Broken, chipped, deformed or squashed food or

non-food items can thus be detected before packaging for avoiding wastage in operation.

[0079] Techniques for processing camera-captured images include pixel counting, segmentation, pattern recognition (e.g. template matching, finding, matching, and/or counting specific patterns), gauging (i.e. measurement of object dimensions), edge detection, neural net processing (i.e. weighted and self-training multi-variable decision making).

[0080] More particularly, the robotic arm 292 provides automated optical inspection (AOI) to its picking objects (e.g. trays 84, 88, 90, cups 294, 296, 300). The AOI can visually scan surfaces of the objects when the objects are lit by several light sources. This enables the monitoring of all external areas of the picking objects, even those hidden in one direction by other components. Common defects of the food and non-food items include scratches, cut, water stain, food debris, deformation, liquid spillage and dirt attachment and discolouring.

[0081] The machine vision enabled stations/robots 32, 42, 43, 44, 78, 82, 86, 214, 216, 218 are connected together such that they can perform neural net processing, enabling them to conduct weighted and self-training multi-variable decision makings.

[0082] Fig. 16 illustrates the robotic arm 292 that twists for shaking off an attached cup 296. In particular, the suction cup 298 both rotates and swings when lifting the first cup 294. The second cup 296 is thus shook off from the first cup 294.

[0083] Fig. 17 illustrates the robotic arm 292 that vibrates for shaking off an attached cup 296. The suction cup 298 holds the first cup 294 together such that they both vibrate vertically, horizontally or both. The second cup 296 is thus dropped onto the third cup 300 below.

[0084] Fig. 18 illustrates the robotic arm 292 that heats up for removing an attached cup 296. The suction cup 298 has embedded heating elements (not shown) that transmit heat onto a picked cup 294. The first cup 294 is thus easily removed from the second cup 296 due to its thermal expansion. According to Figs. 15-18, the cups 294,

296, 300 have their openings facing top or the end effector 298. The robotic arm 292 can equally pick and shake these cups 294, 296, 300 if they face down.

[0085] The end effector 298, similar to other end effectors of other industrial robots or machine stations 32, 34, 36, 38, 62, 74, 78, 82, 86, 214, 216, 218, 234, 236, 238, 250 is washable or repeatedly washable when in tray packaging operation. In practice, a cleaning and sterilization station (not shown) is provided next any of these industrial robots or machine stations 32, 34, 36, 38, 62, 74, 78, 82, 86, 214, 216, 218, 234, 236, 238, 250. For example, the cleaning and sterilization station comprises a water tank with an inlet and outlet. Clean water is injected into the water tank, whilst dirty/used water is discharged from the water tank. The end effector 298 is periodically dipped into the water tank and blown dry when in packaging operation, such that the robotic arm 292 is kept clean throughout continuously packaging operation. The water washing of the end effector may be complimented or replaced by rinsing/spraying the end effector 298 with a sanitizer. The cleaning of the end effector may be further enhanced by having projecting ultraviolet light onto the end effector 298.

[0086] Conveyors 46, 232, 242 of the flexible assemblies 30, 210, 212, 276 may be cleaned continuously or periodically when packaging the tray assemblies. For example, the belt 60 is sprayed with water from below so that rinsed water of the belt 60 is collected by a drain pan below. The conveyors 46, 232, 242 or the belt 60 may be further exposed to infrared light, ultraviolet light or brushes such that the conveyors 46, 232, 242 or the belt 60 are kept clean and hygiene throughout tray packaging operation. Cleaning devices (e.g. spray head, sanitizer nozzle/pump, light bulb and brushes) may be individually or collectively installed with any machine station of the flexible assembly line 30, 210, 212, 276.

[0087] Throughout the description, some similar parts or operation steps labeled with similar or identical reference numerals. Descriptions of the similar parts or steps are hereby incorporated by reference where appropriate.

[0088] In the application, unless specified otherwise, the terms "comprising", "comprise", and grammatical variants thereof, intended to represent "open" or

"inclusive" language such that they include recited elements but also permit inclusion of additional, non-explicitly recited elements.

[0089] As used herein, the term "about", in the context of concentrations of components of the formulations, typically means +/- 5% of the stated value, more typically +/- 4% of the stated value, more typically +/- 3% of the stated value, more typically, +/- 2% of the stated value, even more typically +/- 1% of the stated value, and even more typically +/- 0.5% of the stated value.

[0090] Throughout this disclosure, certain embodiments may be disclosed in a range format. The description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

[0091] It will be apparent that various other modifications and adaptations of the application will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the application and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Reference Numerals

30	flexible assembly line
32	tray dispenser
34	first loading station
36	second loading station
38	third loading station
40	manual loading station
42	inspection and rejection station
43	auto reject station
44	tray-to-cart loading station
46	conveyor
48	main computer
50	first display
52	second display
54	first bin stacker
56	second bin stacker
58	vibratory bowl sorter
60	belt
62	trolley
64	front end
66	back end
68	carts
70	first operator
72	second operator
74	arm
76	empty tray
78	first four-axis robot
80	clean empty tray
82	second four-axis robot
84	tray
86	third four-axis robot
88	tray
90	tray

91 carousel shelves
92 longitudinal direction
100 method
102 enter
104 retrieve
106 upload
108 move
110 inspect
112 compare
114 catch
116 place
118 drop
119 allow
120 proceed
122 identify
124 detect
126 capture
128 put
130 scan
132 compare
134 replace
136 ascertain
138 stretch
140 seize
141 cutlery tray pack
142 lift
144 take
146 move
148 replace
150 sense
152 examine
154 extend
156 grab
158 shifted

160 deposit
162 shot
164 process
166 depart
168 take off
170 replace
172 pick
174 place
176 scrutinize
178 take off
180 look
182 intervene
184 take
186 compare
188 withhold
190 stack
192 receive
194 reach
196 hold
198 identify
200 insert
202 transmit
204 show
206 label
210 second flexible assembly line
212 third flexible assembly line
214 fourth loading station
216 fifth loading station
218 sixth loading station
220 reject conveyor
222 first bin
224 second bin
226 third bin
228 fourth bin

230 conveyor
232 conveyor
234 non-food vision robotic module
236 non-food vision robotic module
238 food vision robotic module
240 conveyor
242 food items
244 conveyor 244
246 quality con-complaint food items
248 reject bin
250 food vision robotic module
252 auto food items dispenser
254 rotatable food hopper
256 diverter
258 conveyor
260 top sprocket gear
262 bottom sprocket gear
264 chain
266 roller chain
268 loading trays
270 one side
272 another side
274 automatically guided vehicle
276 flexible assembly line
278 auto bin stacker and carousel
280 bin
282 method
284 first step
286 second step
288 third step
290 fourth step
292 robotic arm
294 first cup
296 second cup

298 suction cup

300 third cup

Claims

1. A Flexible assembly line (30, 210, 212, 276) for tray packaging comprising
   - a tray dispenser (32, 62) for providing a tray (76, 80, 84, 88, 90), and
   - a loading station (34, 36, 38, 214, 216, 218, 234, 236, 238, 250) adjacent to the tray dispenser (32, 62) for placing food or non-food items onto the tray (76, 80, 84, 88, 90) automatically.

2. The flexible assembly line (30, 210, 212, 276) of Claim 1 further comprising a tray-to-cart loading station (44, 68) connected to the loading station (34, 36, 38, 218, 234, 236, 238) for removing a completed tray package away from the loading station (34, 36, 38, 218, 234, 236, 238).

3. The flexible assembly line (30, 210, 212, 276) of Claim 1 or 2 further comprising
a conveyor (46) that connects the tray dispenser (32, 62), the loading station (34, 36, 38, 218, 234, 236, 238), the tray-to-cart loading station (44, 68) or a combination of any of these.

4. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims further comprising
an inspection and reject station (42, 43) for checking quality of food and non-food items (242).

5. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims further comprising
at least one sorter (54, 56, 58) for organizing the food or non-food items.

6. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims, wherein the tray dispenser (32, 62), the loading station (34, 36, 38, 214, 216, 218, 234, 236, 238), the tray-to-cart loading station (44, 68), the conveyor (46), the inspection and reject station (42, 43) or a combination of any of these comprise an industrial robot (32, 78, 82, 86, 292) for picking the food or non-food items (242).

7. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims, wherein the tray dispenser (32, 62), the loading station (34, 36, 38, 214, 216, 218, 234, 236, 238), the tray-to-cart loading station (44, 68), the conveyor (46), the inspection and reject station (42, 43), the industrial robot (32, 78, 82, 86, 292) or a combination of any of these have machine vision for recognizing shapes of various objects.

8. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims, wherein the tray dispenser (32, 62), the loading station (34, 36, 38, 214, 216, 218, 234, 236, 238), the tray-to-cart loading station (44, 68), the conveyor (46), the inspection and reject station (42, 43), the industrial robot (32, 78, 82, 86, 292) or a combination of any of these have machine vision for surface texture of various objects.

9. The flexible assembly line (30, 210, 212, 214, 216, 218) of any of the preceding Claims,
Wherein at least two of the tray dispenser (32, 62), the loading station (34, 36, 38, 214, 216, 218, 234, 236, 238), the tray-to-cart loading station (44, 68), the conveyor (46), the inspection and reject station (42, 43), the industrial robot (32, 78, 82, 86, 292) or a combination of any of these are connected for neural net processing.

10. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims, wherein the tray dispenser (32, 62), the loading station (34, 36, 38, 214, 216, 218, 234, 236, 238), the tray-to-cart loading station (44, 68), the conveyor (46), the inspection and reject station (42, 43), the industrial robot (32, 78, 82, 86, 292) or a combination of any of these are modularly connected to the flexible assembly line (30, 210, 212, 214, 216, 218) such that it can be disconnected to other parts of the flexible assembly line (30, 210, 212, 214, 216, 218) without affecting others.

11. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims, wherein

the loading station (34, 36, 38, 214, 216, 218, 234, 236, 238) comprises a conveyor (232) for feeding bins (222, 224) with food or non-food items (242), and another conveyor (230) for removing empty bins (226, 228).

12. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims further comprising
a manual loading station (40) for manually loading, unloading or checking food or non-food items (242).

13. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims further comprising
a shelving carousel that has movable loading trays (268) for transferring food or non-food items (242).

14. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims further comprising
a touch screen display (50, 52) connected to a main computer (48) of the flexible assembly line (30, 210, 212, 214, 216, 218) for controlling.

15. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims further comprising
an automatically guided vehicle (274) for fetching packaged tray assemblies or empty trays (76, 84, 88, 90).

16. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims further comprising
an auto food items dispenser (252) that comprises a rotatable food hopper (254), a diverter (256) and a conveyor (46, 258), the rotatable food hopper (254) having at least one compartments for storing food items (242).

17. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claim 6 to 10, wherein
the industrial robot (32, 78, 82, 86, 292) has an end effector (298) for rotating.

18. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claim 6 to 10 or 17, wherein
the industrial robot (32, 78, 82, 86, 292) has an end effector (298) for shaking.

19. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claim 6 to 10 and 17 to 18, wherein
the industrial robot (32, 78, 82, 86, 292) has an end effector (298) for heating.

20. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims, further comprising
a cleaning and sterilization station for cleaning an end effector (298) of the industrial robot (32, 78, 82, 86, 292).

21. The flexible assembly line (30, 210, 212, 276) of any of the preceding Claims, further comprising
a cleaning and drying station for cleaning a belt (60) of the conveyors (46, 220, 230, 232, 240, 258).

22. A catering center having one or more of the flexible assembly line (30, 210, 212, 276).

23. Method (100) of using a flexible assembly line for tray packaging comprising
receiving a tray (76, 80, 84, 88, 90),
providing a food or non-food item (242), and
loading the food or non-food item (242) onto the tray (76, 80, 84, 88, 90) automatically.

24. Method (100) of Claim 23 further comprising
inspecting the tray (76, 80, 84, 88, 90), the food or non-food item (242), a loaded tray (84, 88, 90) by machine vision.

25. Method (100) of Claim 23 or 24 further comprising
transferring a loaded tray (84, 88, 90) into a cart (68) for transporting.

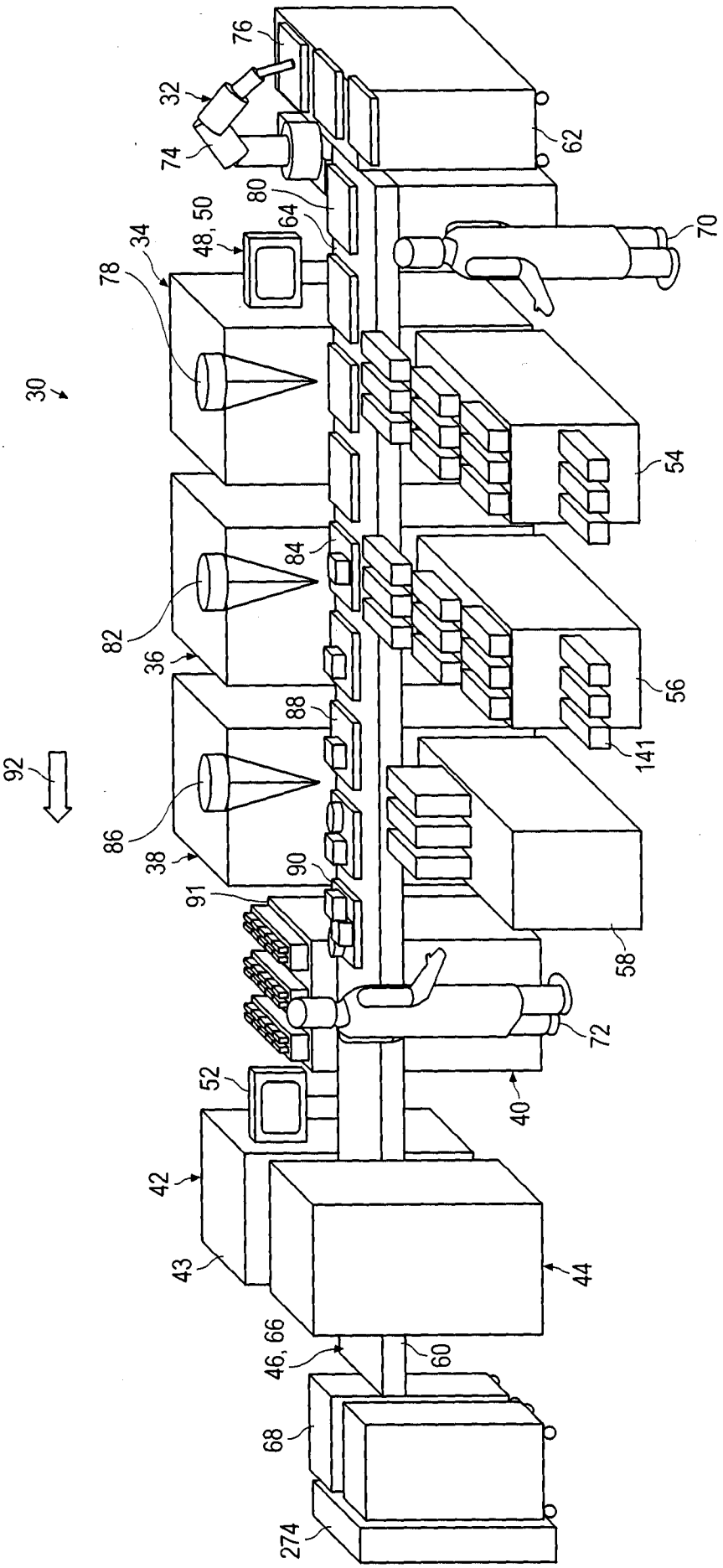
26. Method (100) of installing a flexible assembly line for tray packaging (30, 210, 212, 276), the method comprising

providing a tray dispenser (32, 62) for presenting a tray (76, 80, 84, 88, 90), and

presenting a loading station (34, 36, 38, 214, 216, 218, 234, 236, 238, 250) adjacent to the tray dispenser (32, 62) (with a fixing tool) for placing food or non-food items onto the tray (76, 80, 84, 88, 90) automatically.

27. Method (100) of configuring a flexible assembly line for tray packaging (30, 210, 212, 276) comprising

loading a software package for image processing of machine vision.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46, 66
48, 50
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141
274

FIG. 1

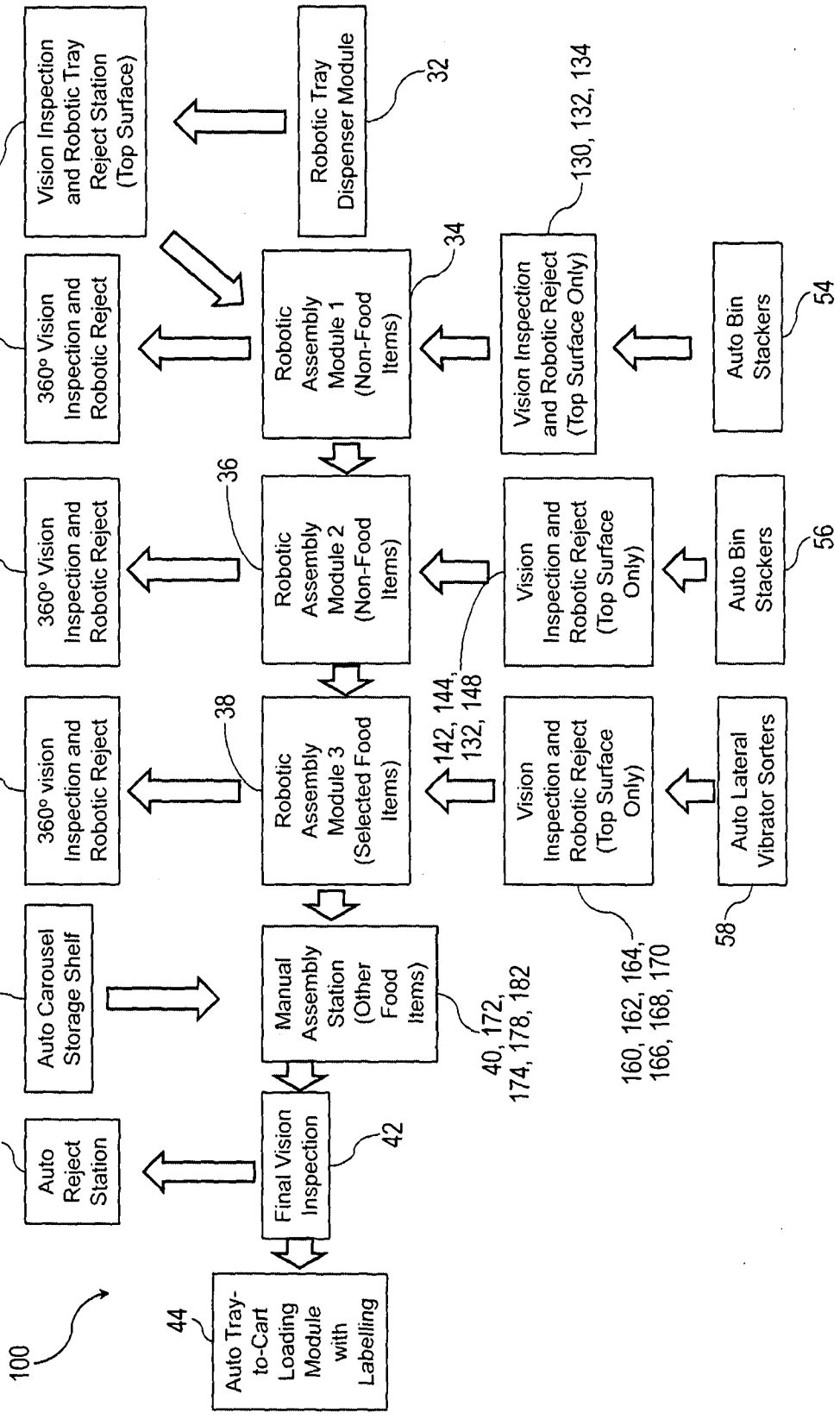
100
Auto Tray-to-Cart Loading Module with Labelling
44
Auto Reject Station
43
Final Vision Inspection
42
Auto Carousel Storage Shelf
91
Manual Assembly Station (Other Food Items)
40, 172, 174, 178, 182
360° vision Inspection and Robotic Reject
150, 152, 154, 156
Robotic Assembly Module 3 (Selected Food Items)
38
360° Vision Inspection and Robotic Reject
136, 138, 140
Robotic Assembly Module 2 (Non-Food Items)
36
360° Vision Inspection and Robotic Reject
122, 124, 126, 128
Robotic Assembly Module 1 (Non-Food Items)
34
Vision Inspection and Robotic Tray Reject Station (Top Surface)
110, 112
Robotic Tray Dispenser Module
32
Auto Lateral Vibrator Sorters
58
Vision Inspection and Robotic Reject (Top Surface Only)
160, 162, 164, 166, 168, 170
142, 144, 132, 148
Vision Inspection and Robotic Reject (Top Surface Only)
Auto Bin Stackers
56
Vision Inspection and Robotic Reject (Top Surface Only)
130, 132, 134
Auto Bin Stackers
54

FIG. 2

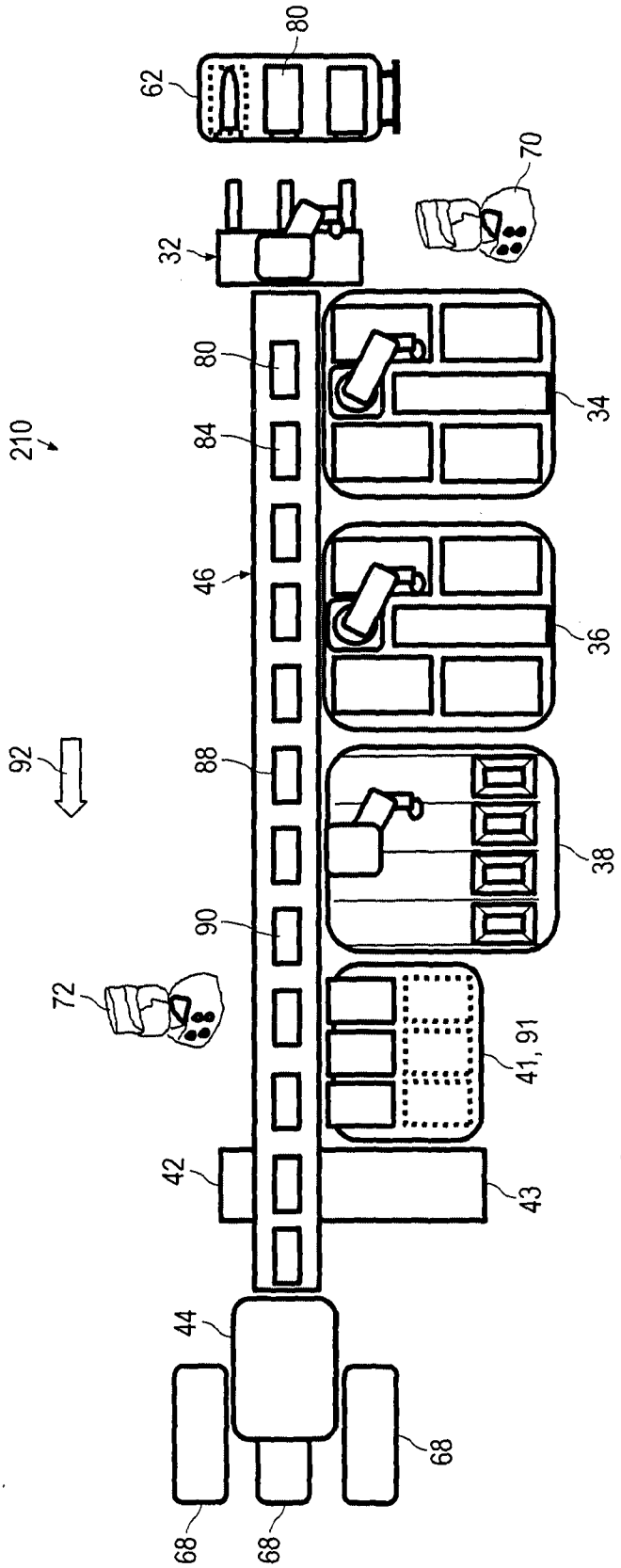

FIG. 3

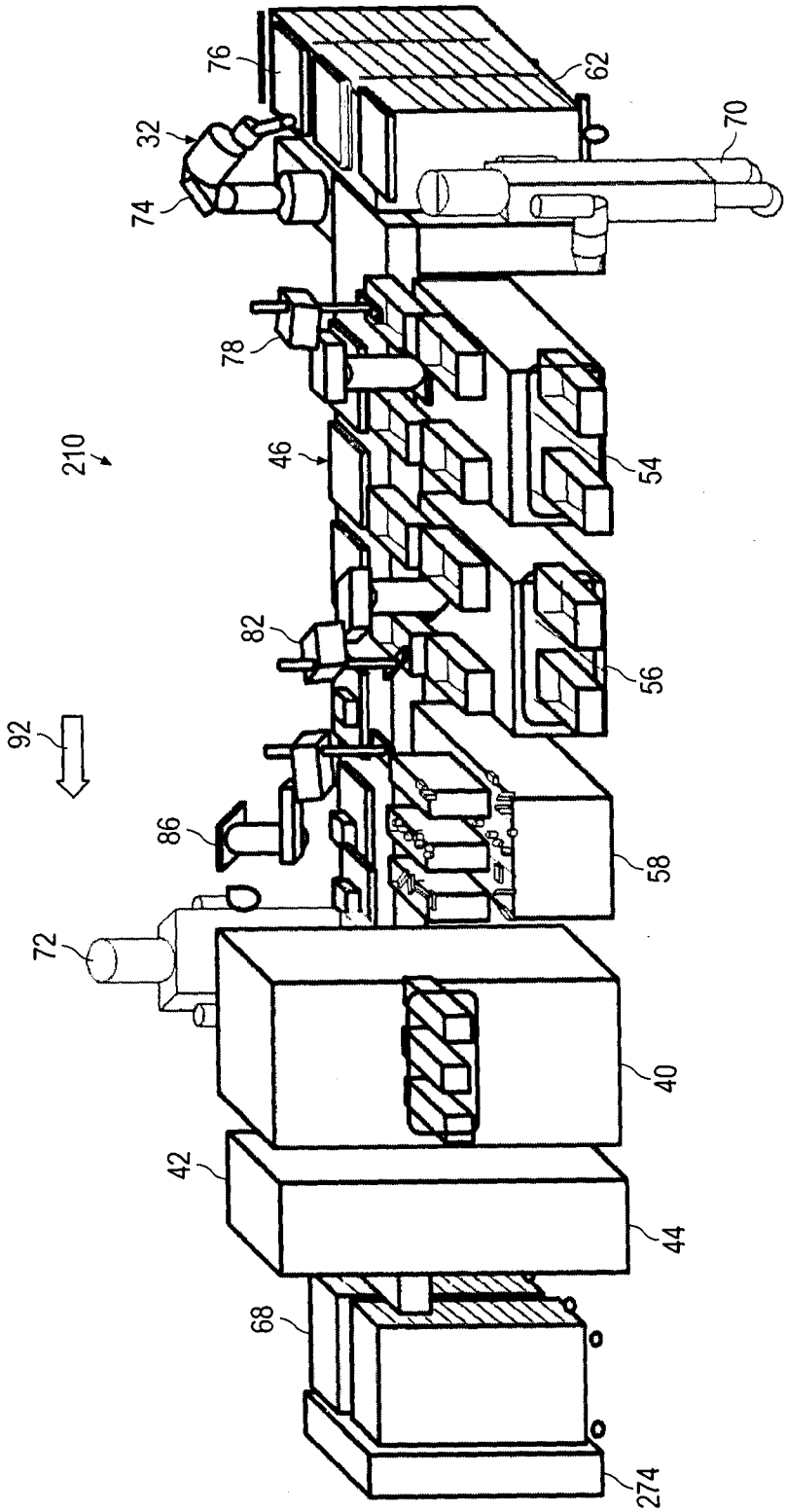

FIG. 4

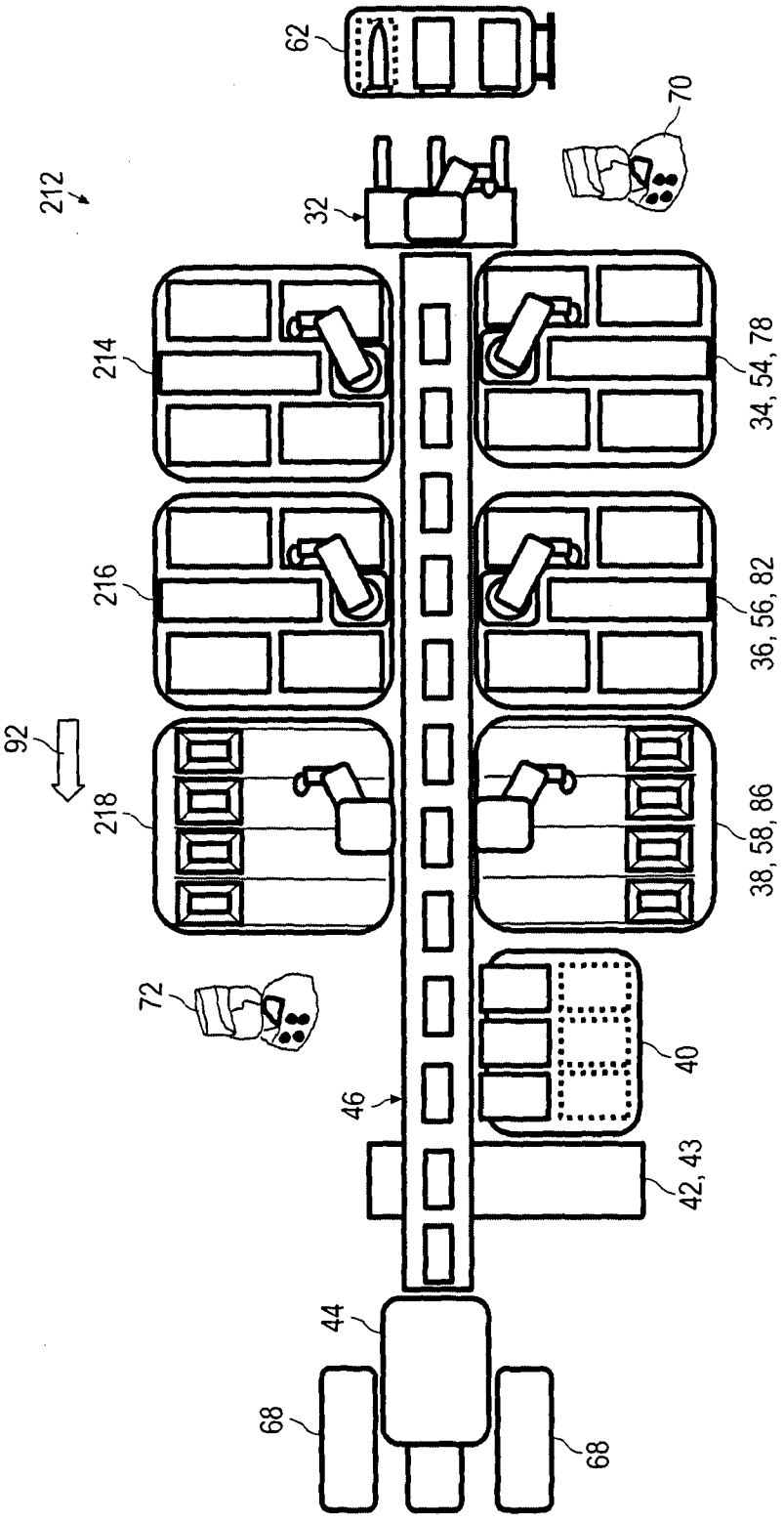
62
70
212
32
214
34, 54, 78
216
36, 56, 82
92
218
38, 58, 86
72
40
46
42, 43
44
68
68

FIG. 5

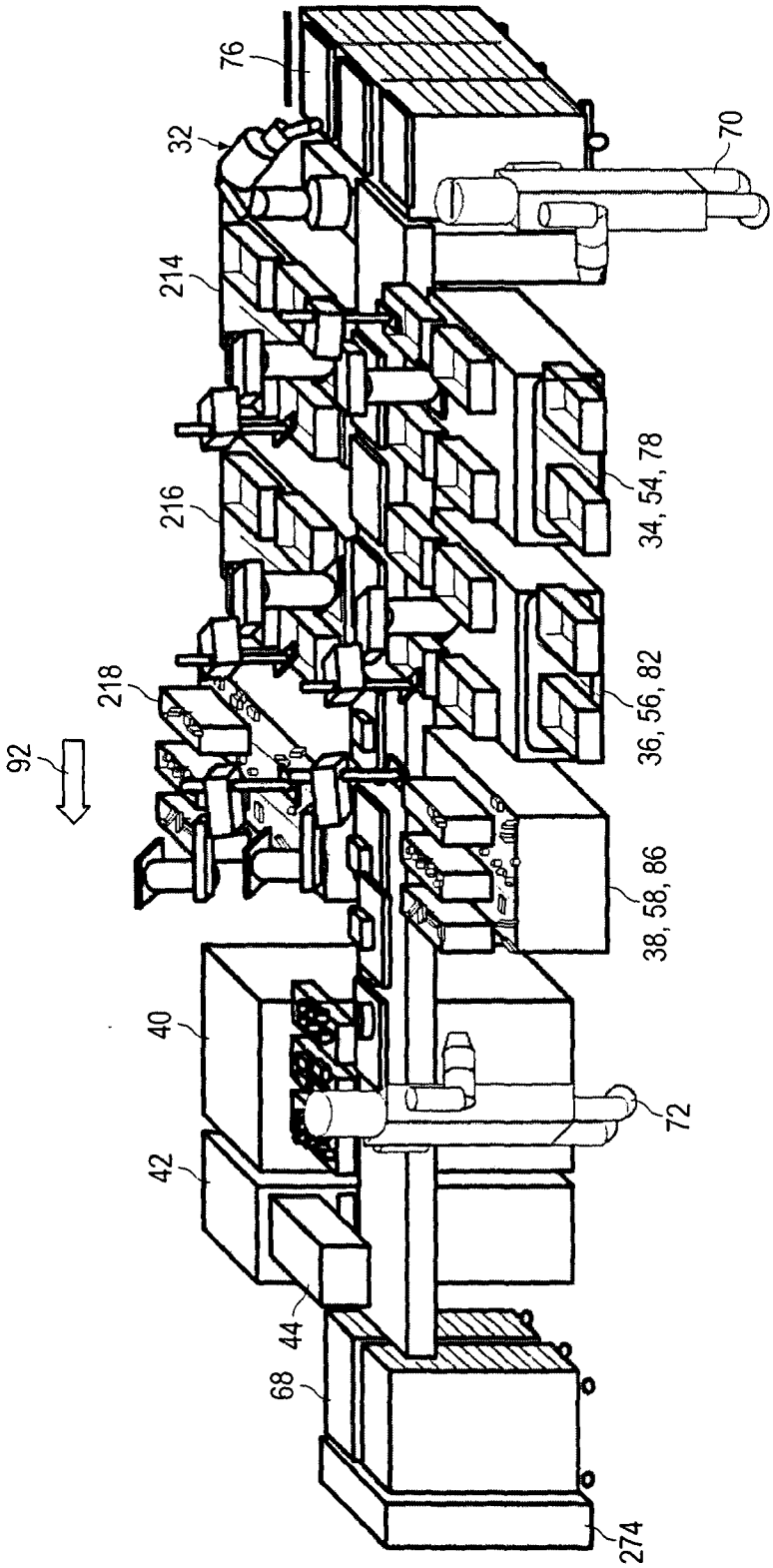

FIG. 6

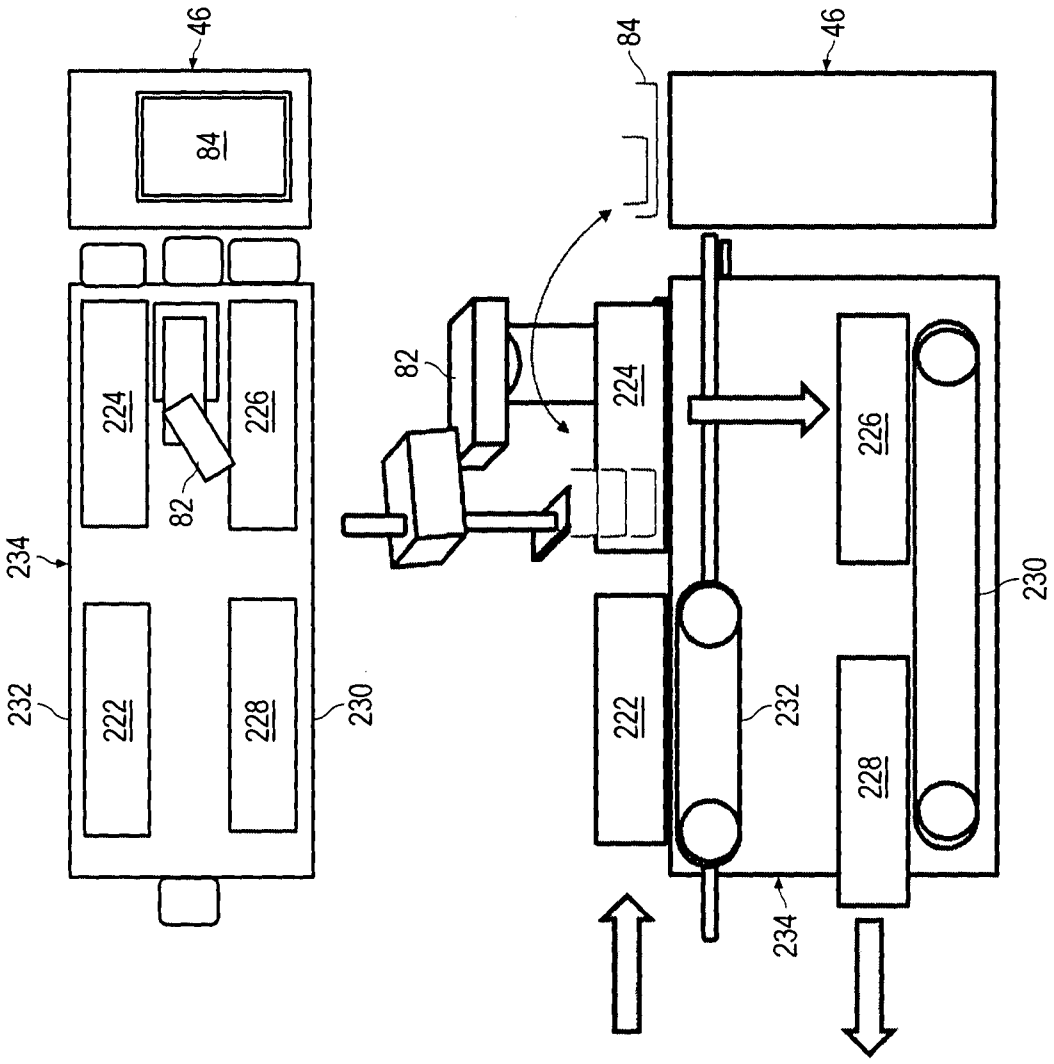
46
84
224
226
82
234
232
222
228
230
84
46
82
224
226
222
232
228
230
234

FIG. 7

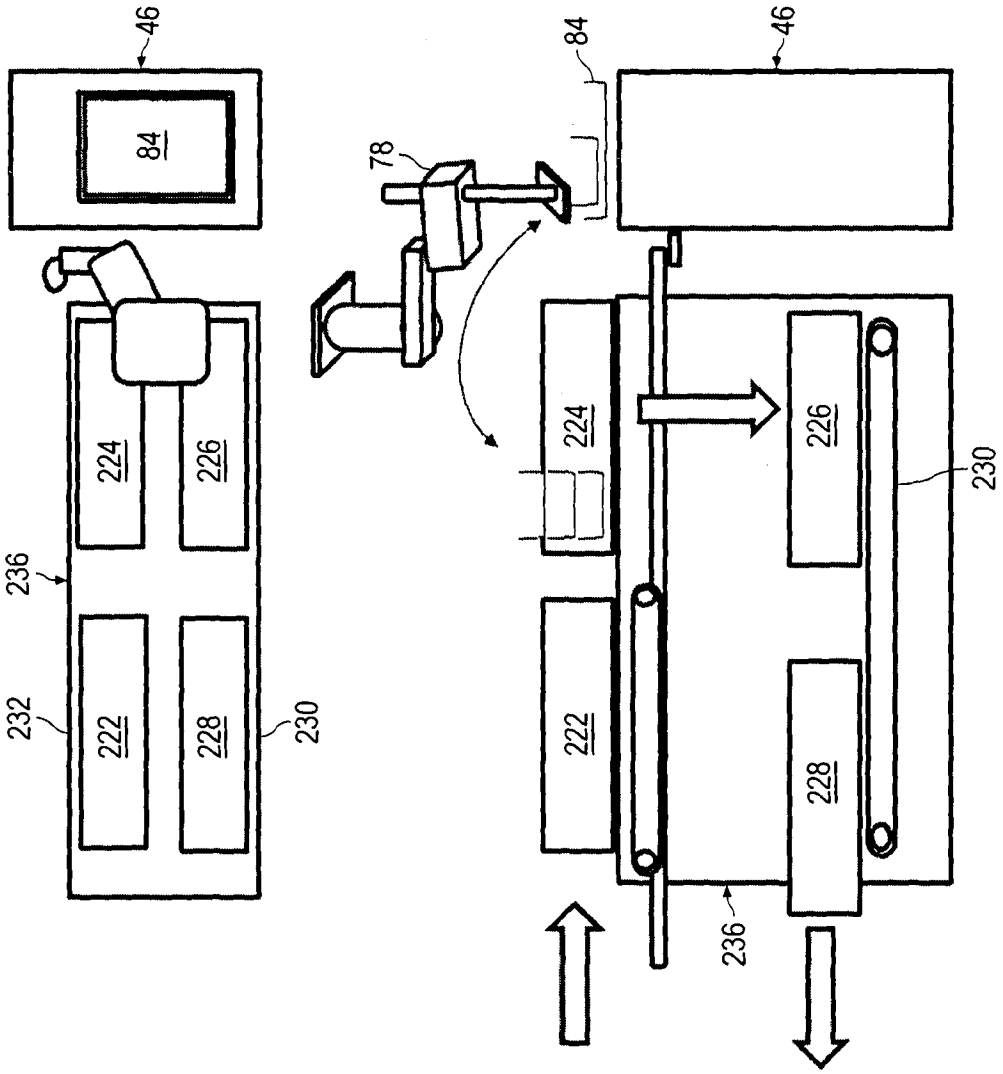

FIG. 8

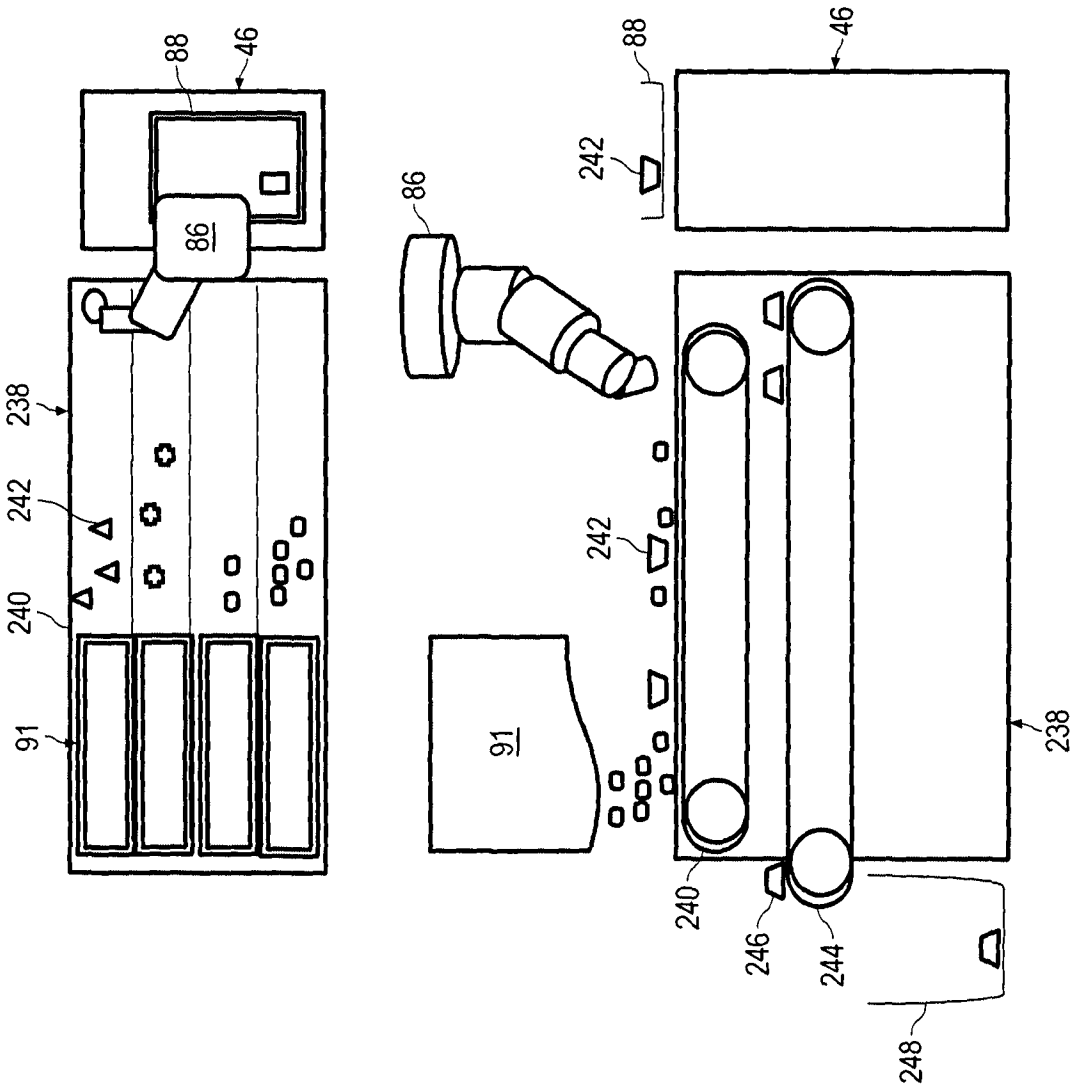

FIG. 9

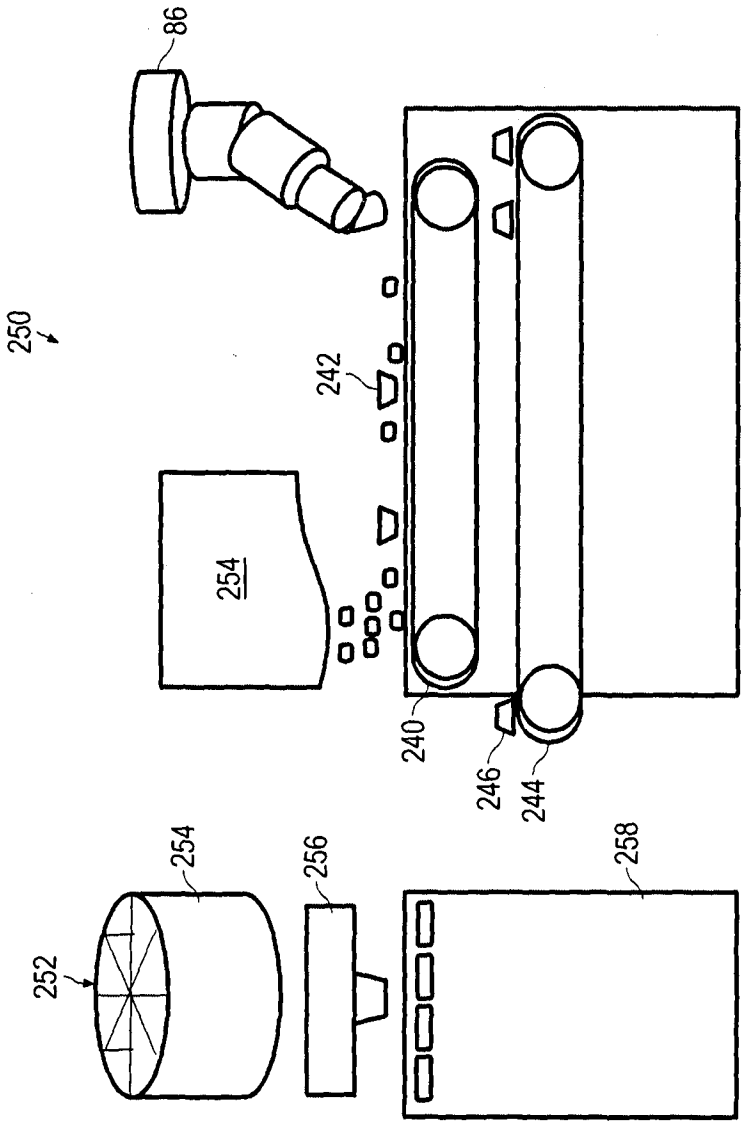

FIG. 10

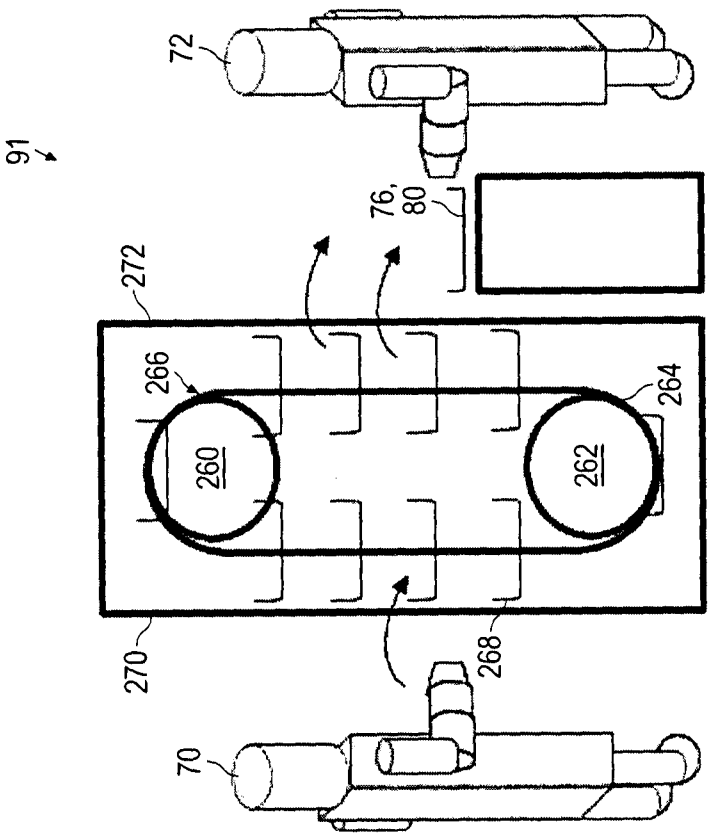

FIG. 11

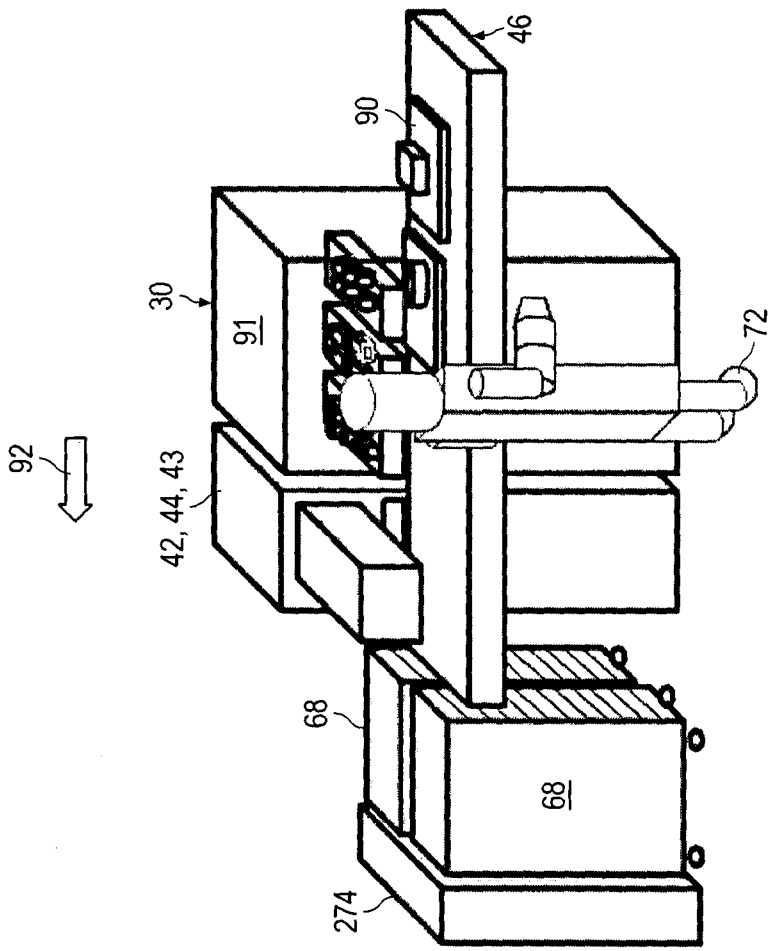

FIG. 12

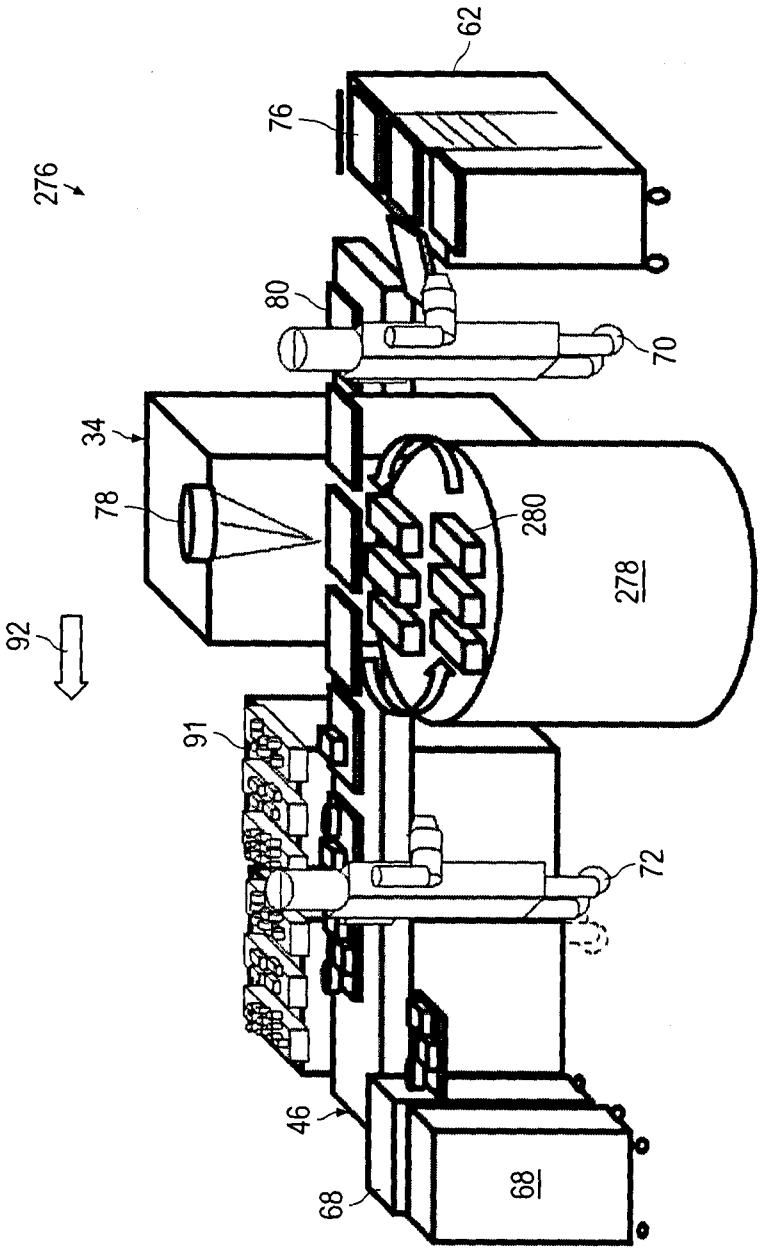

FIG. 13

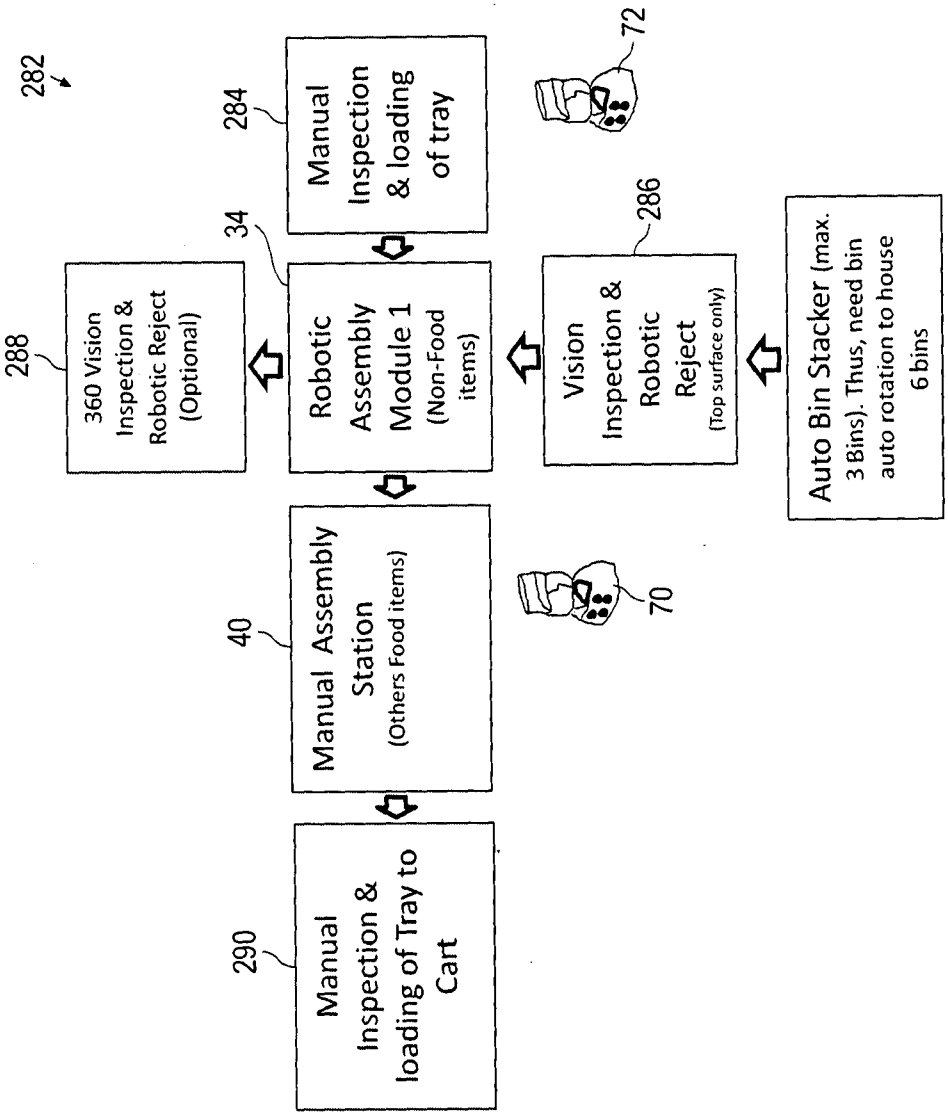
282
290
Manual Inspection & loading of Tray to Cart
40
Manual Assembly Station (Others Food items)
70
34
Robotic Assembly Module 1 (Non-Food items)
288
360 Vision Inspection & Robotic Reject (Optional)
284
Manual Inspection & loading of tray
72
286
Vision Inspection & Robotic Reject (Top surface only)
Auto Bin Stacker (max. 3 Bins). Thus, need bin auto rotation to house 6 bins

FIG. 14

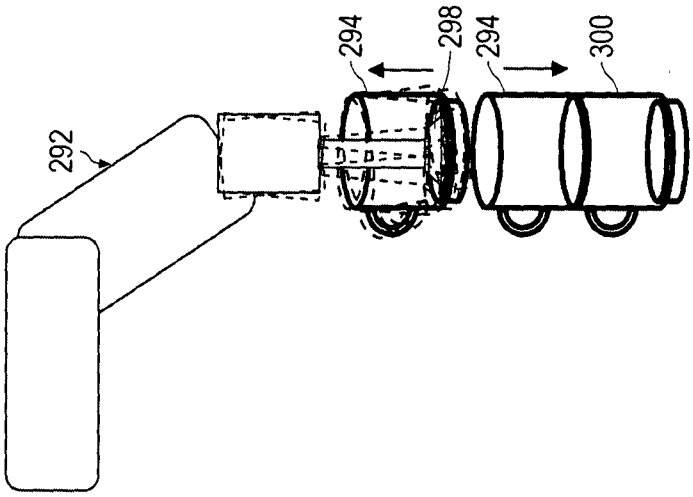

FIG. 16

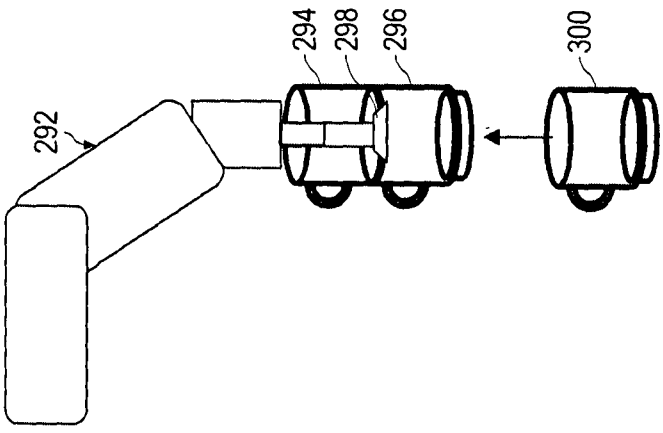

FIG. 15

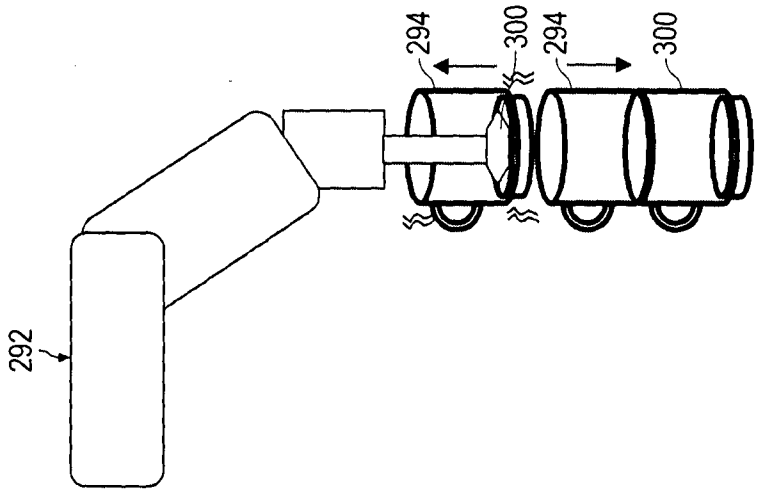

FIG. 18

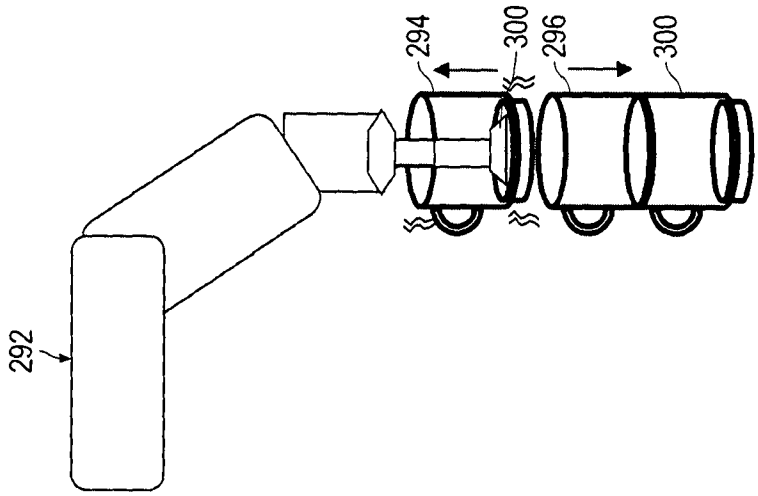

FIG. 17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2013/000011

A. CLASSIFICATION OF SUBJECT MATTER

B65B 5/10(2006.01)i, B65G 47/22(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B65B 5/10; B65B 11/02; B65B 11/00; B65B 55/04; B65B 35/30; B65B 5/02; B65B 43/04; B65B 19/34; B65B 21/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: flexible, line, tray, dispenser, loading, inspect and station

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0841247 B1 (MAX DORR GMBH) 27 June 2001 See abstract; paragraphs [0015]-[0017]; claims 1-8 and figures 1-3.	1-3,22-27
A	US 6698572 B2 (HORST LOEWENTHAL et al.) 02 March 2004 See abstract; column 3, line 4 - column 4, line 60 and figures 1-6.	1-3,22-27
A	US 2006-0032191 A1 (REBECCA A. HEILMAN et al.) 16 February 2006 See abstract; claims 14-18 and figures 11-16.	1-3,22-27
A	US 2010-0212266 A1 (ROBERT ELSAESSER et al.) 26 August 2010 See abstract; claims 1-17 and figures 1-4.	1-3,22-27
A	US 2003-0029139 A1 (MARTIN B. H. NG et al.) 13 February 2003 See abstract and figures 1-8.	1-3,22-27

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 April 2013 (29.04.2013)	**30 April 2013 (30.04.2013)**

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

CHOI, Sang Won

Telephone No. 82-42-481-8291

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2013/000011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0841247 B1	27.06.2001	DE 19645682 C1	30.10.1997
		EP 0841247 A1	13.05.1998
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		JP 2003-160107 A	03.06.2003
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		AU 2008-306156 A1	09.04.2009
		CA 2699267 A1	09.04.2009
		EP 2230971 A1	29.09.2010
		EP 2230971 B1	04.01.2012
		WO 2009-043542 A1	09.04.2009
US 2003-0029139 A1	13.02.2003	US 2001-0015051 A1	23.08.2001
		US 6223502 B1	01.05.2001
		US 6684607 B2	03.02.2004

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2013/000011

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-21
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.