

Provisional Application for Patent Cover Sheet					
This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)					
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All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the Add button.					Add
Title of Invention		System and Method for Locating, Identifying and Counting Products on Shelves			
Attorney Docket Number (if applicable)		BOSS-00300			
Correspondence Address					
Direct all correspondence to (select one):					
☒ The address corresponding to Customer Number			☐ Firm or Individual Name		
Customer Number			34051		

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.	
☒ No.	
☐ Yes, the name of the U.S. Government agency and the Government contract number are:	

Entity Status

Applicant claims small entity status under 37 CFR 1.27

☒ Yes, applicant qualifies for small entity status under 37 CFR 1.27☐ No**Warning**

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Signature	/David R. Stevens/			Date (YYYY-MM-DD)	2016-03-29
First Name	David R.	Last Name	Stevens	Registration Number (If appropriate)	38626

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Application Data Sheet

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Application Information

Title of the Invention::	System and Method for Locating, Identifying and Counting Products on Shelves
Attorney Docket Number::	BOSS-00300
Small Entity::	Yes
Application Type::	Provisional
Subject Matter::	Utility
Total Number of Drawing Sheets::	0

Publication Information

Request Early Publication::	No
Request Not to Publish::	No

Representative Information

Customer Number::	34051
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Statement under 37 CFR 1.55 or 1.78 for AIA Transition Applications

This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.

No

Signature

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System and Method for Locating, Identifying and Counting Products on Shelves

This disclosure describes a system and method for scanning products on shelves in commercial settings including but not limited to retail stores and warehouses.

Imaging/Scanning products on shelves

The system consists of a mobile base, sensors and a computing device as follows:

- The mobile base may be actuated or passive; it could move itself or be moved manually.
- The mobile base is equipped with at least one image capture sensor (shelf camera) to scan the shelves
- The mobile base is equipped with one or more sensors to determine its location. The sensors may measure absolute location or relative motion from a starting point. The sensors may be onboard the mobile base, or located externally to the mobile base.
- The mobile base is equipped with an onboard computing device that communicates with the sensors through wired or wireless communication.

In some embodiments, the system further consists of at least one range finding sensor to measure distance between the at least one image capture sensor and the shelves and products on shelves.

In some embodiments, the system has more than one camera arranged at different heights along the height of the system. These cameras are synchronized so they can capture images simultaneously.

The method consists of:

- Informing the computing device about the starting position of the mobile base. This information can be programmed into the computing device if the start position is known through manual measurements; or it could be computed from analysis of sensor information, e.g. by use of absolute location sensors, or by triangulation to a known landmark in the sensor's field of view, or to known locations in a blueprint or a previously built map.
- The mobile base either moving or being moved along a path generally parallel to a shelving unit
- The computing device updating its estimate of the mobile base location from information received from localization sensors. Localization may utilize external markers and fiducials or may not need any special localization feature or require any modification of the environment. Sensors may use optical, sonar, radar, or other means of measuring distance between the mobile base and the environment, or incremental distance traveled by the mobile base, using techniques that include but are not limited to triangulation, visual flow, visual odometry and wheel odometry. If the location sensors are external to the mobile base, the mobile base's position is communicated to it via remote communication.
- Imaging /scanning the shelves with the at least one image capture sensor

- Locating and identifying products and labels through one or more of the following methods: Segmenting Images or Utilizing a Product Library. These methods are described below.

An example system is shown in FIG. 1

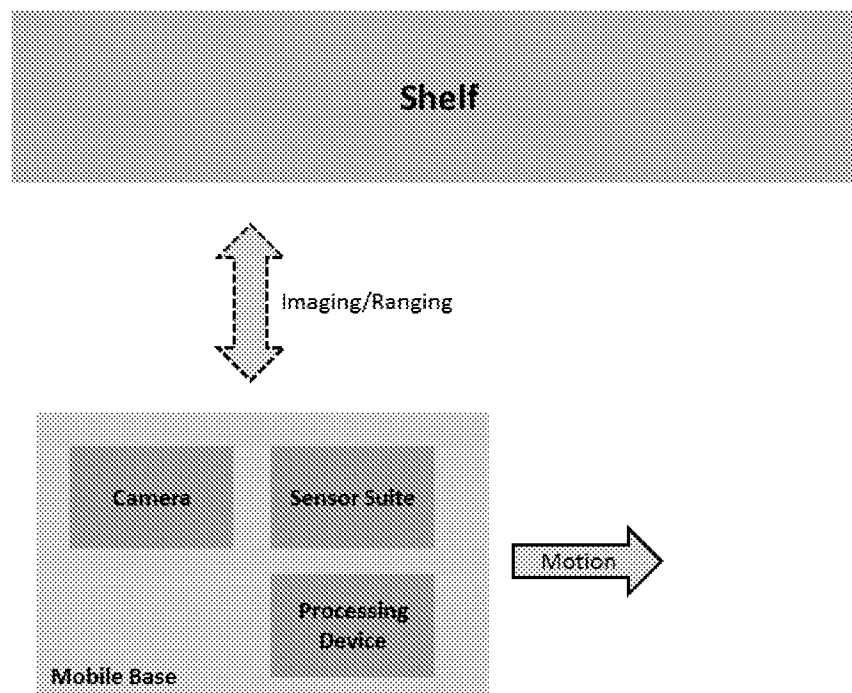


FIG. 1 Example of a mobile base configured to image or scan products on a shelf

Some methods further consist of measuring distances between the shelf cameras to the shelves and products on the shelves by means of the at least one range finding sensor or by means of analysis of consecutive images captured by the shelf cameras using algorithms such as structure from motion.

Some methods further consist of constructing a depth map of the shelves and products by aggregating distances from the shelf cameras to the shelves and products over the length of the shelving unit.

Some methods further consist of inferring the location of the beginning and/or end of each shelving unit. Inference may use, but is not limited to, the location of the mobile base, the location of the image capture sensor on the mobile base, the distance between the image capture sensor and the shelf, information provided by the location sensors, and information provided by the one or more imaging sensors.

Stitching images into shelf unit-wide panoramas

This method consists of stitching consecutive images capture by the shelf cameras into a panorama that spans the entire shelving unit.

For embodiments with more than one camera, the images are first stitched vertically among all the cameras, and then horizontally and incrementally with each new consecutive set of vertical images.

Learning product features

This method builds automatic correspondences between one or multiple images of a product and the product identifier to enable image-based product recognition.

A product space is defined as the horizontal space on the shelf occupied by one or more copies (facings) of the same product, and the vertical space spanning the distance between the current shelf and the shelf above it. When the current shelf is the top shelf, the vertical space is a heuristic number generally corresponding to the distance to top of the fixture.

In one method, the product space is determined by the planogram. A planogram specifies the location of each product on the shelf, its number of facings, and the height of each shelf. These numbers are sufficient to calculate the product space.

In another method, the product space is inferred from sensor measurements without the use of the planogram as follows:

1. Detect shelf labels either in individual shelf images, or in the stitched panorama, using classification algorithms such as template matching or HAAR cascades.
2. Analyze each shelf label to obtain one or more product identifiers. Analysis may include but is not limited to: optical character recognition; bar code scanning; QR code scanning; AR code scanning; hologram code scanning. Product identifiers may be a collection of letters, numbers, or a combination, as read on the price tag or label. Examples include product name and UPC code. In the case of more than one identifier, use a heuristic to consistently select one identifier such as the UPC code.
3. Register the image location of the shelf label to the depth map to recover its 3D location in space.
4. Group labels by height, where a group contains labels whose height is smaller than a heuristic number, typically equal to the thickness of the shelf lip.
5. Within each group, the horizontal distance between consecutive shelf labels defines the horizontal product space.
6. The height of the product space is derived from the detection of shelf heights. Shelf heights are detected using one or more of the following methods:
 - a. Analyze the depth map to identify horizontal indentations corresponding to the distance between the bottom of a shelf and products stacked below it. These horizontal indentations correspond to shelf lips and measure shelf height. The height of the bottom shelf is a heuristic that's generally known and constant for a specific store.

- b. Filter label groups by horizontal span defined as the horizontal distance between the first and last label of the group, according the following criteria:
 - i. A label group passes the filter if its horizontal span overlaps with the current label group span.
 - ii. A label group passes the filter if its horizontal span is distant from the current label group span by no more than a heuristic number generally representing a bay's width. Generally, bay widths are standard and known within a store. For example, US stores typically use 4-ft wide or 3-ft wide shelves.
 - iii. Order filtered label groups by height and select the label group that is next highest after the current label group.
 - c. Probabilistically combine the above two methods through estimating a confidence measure for each method and adding their results.
 - 7. The height difference between the selected label group and the current label group defines the vertical product space. The product space is now fully defined.

Next, consistently associate each product space to an identifier based on a label location heuristic. The heuristic may determine the identifier to originate from the left or the right shelf label.

From the planogram determine the number F of facings in the product space corresponding to the identifier.

Register the product space on the stitched image and compute image descriptors on the portion of the stitched image corresponding to the product space (product space image). Methods for generating image descriptors include but are not limited to: image templates, the Scale Invariant Feature Transform, Binary Robust Independent Elementary Features, Maximally Stable Extremal Regions, Binary Robust Invariant Scalable Keypoints, Fast Retina Keypoints, Kaze features, and variations thereof.

Next, classify the image descriptors into F classes and label them with the identifier. Classification algorithms that can be used include but are not limited to Support Vector Machine.

Repeat this process for every image of the product space associated to the same identifier, whether the image is captured in the same store at different times, or in different stores.

Automatically build a library of descriptors as described below in the "Building Library of Products"

Segmenting Images to Detect Products and Labels

This method consists of analyzing the shelf images to detect products and product labels as follows:

- Segmenting each shelf image to detect individual price tags or product labels on the shelf.
 - Analyzing the segmented price tag or product label per the method described above.
 - Segmenting each image to detect individual products and product packages.
- Segmentation may use techniques that include but are not limited to:
- Edge detection
 - Depth estimation using depth estimation techniques that include but are not limited to:
 - Stereo camera
 - Structure from motion
 - Structure from focus
 - Depth camera using time of flight
 - Depth camera using triangulation
 - Planar or 3D laser/lidar scanner
 - Color segmentation
 - Heuristics about product features including but not limited to product shapes, colors, texts, and aspect ratios.
- Consistently associating individual product images to identifiers based on a location heuristic. The heuristic may locate the identifier below a product image or in another proximal location.

The heuristic may be informed from the planogram.

Some product layout configurations consistently place the shelf label to the left or right of the leftmost or rightmost product. Other configurations place the label in the middle of the space spanned by one or more facings of the product. The heuristic uses this information to locate the identifier relatively to the product.

Some methods further consist of:

- Inferring the position of each identifier on the shelf by comparing the location of the identifier to the location of the beginning or end of the shelf on which the identifier is placed.
- Inferring the position of each product on the shelf by comparing the location of the product to the location of the beginning or end of the shelf on which the product is placed.

In some methods, an identifier's shelf location and/or product location are expressed in metric terms, i.e. measured distance from the beginning or end of a specific shelf. In other methods, an identifier's shelf location and/or product location are expressed topologically, e.g. as a sequence of identifiers from the start or the end of a specific shelf, and from the bottom of a shelf to the top. For example, a specific identifier may be third from the start of the fourth shelf.

Utilizing a Product Library to Detect Products and Labels

This method consists of detecting products and labels from a library of product and label information as follows:

- Define a product object as containing:
 - o One product identifier
 - o One or more sets of descriptors
- Extract one or more sets of descriptors from each shelf image
- Search the library for products objects with a large number of similar features
- For each potential product object match, verify the geometric consistency of the feature locations in the library with the feature locations in the shelf image (not clear)

Some methods further consist of indexing the sets of descriptor within the library for improved searching performance and/or reduced storage requirements. Indexing methods include but are not limited to: hashing techniques, tree representations, and bag-of-words encodings.

Some methods further consist of using the planogram information or product location information from the product library to reduce the number of products that must be searched to just those products contained within the imaged shelf.

Some methods further consist of verifying the identified products by segmenting and decoding the price tag or product label located proximally to each identified product and comparing it to the product object identifier.

Building Library of Products

In some embodiments, the method further consists of building a library of product descriptors and their identifiers as follows:

- Extract one set of descriptors from each product image associated to an identifier
- Increase the scope of the product object and redefine it as containing:
 - o One product identifier
 - o One or more sets of descriptors
 - o Confidence levels for each set of descriptors
 - o Dates at which each set of descriptors was generated
- Store each identifier and set of product descriptors in a database or library of product objects as follows:
 - o If the identifier does not match an existing identifier in the library, create a new object containing the identifier, the set of product descriptors, an entry confidence level for the set of product descriptors, and the date. The entry confidence level is unique.
 - o If the product's identifier matches an existing identifier in the library, compute a score for each existing set of descriptors that describes the likelihood that the new and existing sets of descriptors were extracted from the same object, and:
 - o If the highest likelihood score exceeds a heuristic value for a positive match:
 - Combine the new set of descriptors with the highest likelihood feature set

- Increase the confidence level of this set of descriptors relative to the other sets of descriptors in the object
 - Append the date to that of the existing set of descriptors
- If the highest likelihood score does not exceed a heuristic value for a positive match:
 - Add the set of descriptors to the object
 - Set the confidence to the entry level
 - Add the date

Some methods further consist of indexing the descriptor sets within the library for improved searching performance and/or reduced storage requirements. Indexing methods include but are not limited to: hashing techniques, tree representations, and bag-of-words encodings.

Some methods further increase the scope of the product object and redefine it as containing:

- One product identifier
- One or more sets of descriptors
- Confidence levels for each set of descriptors
- One or more shelf position metric estimates
- Confidence levels for each shelf position metric estimate
- One or more shelf position topological estimates
- Count number for each shelf position topological estimate

Some methods further consist of estimating the metric shelf positions of the identifiers as follows:

- Store the first metric estimate of an identifier shelf position in its product object. Set its confidence to an entry level. The entry confidence level is unique and not necessarily the same as the entry confidence level for a set of descriptors.
- Compare the second or more metric estimates generated by a second or more product scans to the existing metric position estimate that has the highest confidence level, if available:
 - If the difference in position is smaller than a proximity threshold, then
 - Replace the existing position estimate with a weighted average of the existing and new estimates. The weights are the confidence level of the existing estimate and the entry confidence level of the new estimate.
 - Incrementally increase the confidence level of the existing estimate.
 - Append the date to that of the existing measurement
 - If the difference in position is larger, then compare to the estimate with the second highest confidence level, if it exists, and repeat to the last estimate until the difference is smaller than the proximity threshold.
 - If no difference is smaller, add the new position estimate to the object, set its confidence to the entry level, and enter the date.

In some methods, the metric estimate confidence level is calculated using the accuracy of the mobile base position estimate.

Some methods further consist of estimating the topological shelf positions of the identifiers as follows:

- Store the first topological estimate of the identifier shelf position in its product object. Set its count to 1.
- Compare the second or more topological estimates generated by a second or more product scans to the existing topological position estimate that has the highest count number, if available:
 - o If the topological estimates are identical, increase the existing count level by 1, append the date to the date of the existing estimate.
 - o If the topological estimates are different, compare to the estimate with the second highest count number, if it exists, and repeat to the last estimate until the estimates are identical.
 - o If all estimates are different, add the new topological position estimate to the object, set its count number to 1, and enter the date.

Some methods further increase the scope of the product object and redefine it as containing:

- One product identifier
- One or more sets of descriptors
- Confidence levels for each set of descriptors
- One or more shelf position metric estimates
- Confidence levels for each shelf position metric estimate
- One or more shelf position topological estimates
- Count number for each shelf position topological estimate
- One or more image templates of the product

Where the one or more images templates of the product are generated from images sourced externally to the mobile base system. These images can be acquired from one or more of the following sources:

- Retailer carrying the product, where the image corresponds to the product identifier
- Manufacturer of the product, after matching the product identifier with the manufacturer's nomenclature and image
- Third-party photography of the product
- Online databases, such as searching the Internet through image search engines, or searching online retailers for product listings, or other Internet databases. Searches are conducted preferably using the manufacturer's nomenclature that corresponds to the product identifier. In some methods, this search is performed automatically and the one or more images inserted without human intervention.

The one or more images sourced externally to the mobile base system include at least one front view of the product, and optionally additional views, such as back, sides, top and bottom, or different packaging appearances of the product that correspond to the same identifier.

Some methods further consist of augmenting the product library features descriptor sets with descriptor sets generated from the one or more images sourced externally as follows.

For each image of each product:

- Compute a set of descriptors for the image
- Add the set of descriptors to the object
- Set the associated confidence to an entry level, which may be different than the entry confidence level for automatically generated descriptor sets

Some methods further consist of improving image segmentation using the one or more image templates. This enables high-confidence segmentation for products whose appearance in the mobile base image matches closely one of the images sourced externally. The method consists of matching each template with the image captured by the mobile base. If a match is positive, the matched section of the image is used as the image segmentation for that product

Some methods further consist of reducing the number of image templates that must be considered by only matching the templates that correspond to the product identifier; or to the product objects who are proximal to the shelf location being scanned.

Some methods further detect if a product is oriented differently than the externally sourced image. If a template match cannot be found, but the product descriptor does find a high-likelihood match, then this is indicative of a product orientation that is different from that of the image sourced externally to the mobile base system. If the externally sourced image is known to be a front view of the product, then this method identifies products that are improperly oriented on the shelf.

Some methods further estimate the angular deviation of the improperly oriented product by computing an affine transformation between the set of descriptors of the externally sourced image and the scanned image.

Some methods further increase the scope of the product object and redefine it as containing:

- One product identifier
- One or more sets of descriptors
- Confidence levels for each set of descriptors
- One or more shelf position metric estimates
- Confidence levels for each shelf position metric estimate
- One or more shelf position topological estimates
- Count number for each shelf position topological estimate
- One or more image templates of the product
- Dimensions of the product

For situations where template matching is successful, the product segmentation in the image is considered accurate, and the real dimensions of the product are compared to the apparent dimensions of the product in the image to extract a distance estimate between the imaging sensor and the product. Additionally, the apparent position of the product in the

image combined with the distance estimate enable the computation of the three-dimensional position and orientation between the imaging sensor and the product.

Some methods extract topological shelf positions for each product from the planogram. These methods further increase the scope of the product object and redefine it as containing:

- One product identifier
- One or more sets of descriptors
- Confidence levels for each set of descriptors
- One or more shelf position metric estimates
- Confidence levels for each shelf position metric estimate
- One or more shelf position topological estimates
- Count number for each shelf position topological estimate
- One or more image templates of the product
- Dimensions of the product
- One or more topological shelf positions from Planogram

In some embodiments, the system further consists of a plurality of mobile bases, deployed in a single retail store or warehouse. The system further comprises digital data communication among mobile bases.

In some embodiments, the system further consists of a plurality of mobile bases, deployed in two or more retail stores or warehouses, where the price tag or product label associated with the same product are identical across locations. The system further comprises optional digital data communication among mobile bases deployed in remote locations.

Some methods further consist of storing a subset of the product objects in a unified library common to two or more mobile bases. If the two or more mobile bases are in remote locations, then the subset of the product objects includes but is not limited to the product identifier, one set of descriptors, and its associated confidence level. If the two or more mobile bases are in the same location, the subset of the product object may contain the entire product object.

Some methods further consist of periodically pruning the content of each product object in the library as follows:

- *Sets of descriptors*: delete all sets whose confidence level is below a heuristic value, along with their confidence level and date entries, except if they originate from images sourced externally to the mobile base system.
- *Metric shelf positions*: delete all metric positions whose confidence level is below a heuristic value except if their date of entry is the last date on record, along with their confidence level and date entries
- *Topological shelf positions*: delete all topological positions whose count number is below a heuristic value except if their date of entry is the last date on record, along with their count number and date entries

Some alternative methods of pruning are as follows:

- *Sets of descriptors*: delete all sets except for the set with the highest confidence level, along with their confidence level and date entries, except if they originate from images sourced externally to the mobile base system.
- *Metric shelf positions*: delete all metric positions along with their confidence level and date entries, except the latest date, if its associated confidence level is higher than a heuristic value. Otherwise, keep the data from last two dates or more, until a confidence level above the heuristic value is found.
- *Topological shelf positions*: delete all topological positions along with their counter number and date entries, except the latest date, if its associated count number is higher than a heuristic value. Otherwise, keep the data from last two dates or more, until a count number above the heuristic value is found.

Limitations of the method for associating product images and identifiers described above are four fold: first, it may incorrectly segment product images; second, it does not apply to associations that fail the location heuristic; third, it suffers from association ambiguity when more than one product image fit the heuristic; and fourth, it requires the availability of price tags or product labels, which may not always be the case.

A partial remedy to these limitations is the acquisition of increasing numbers of scans of the same products and shelving units, either in the same location at different times, or at remote locations. As products are typically stocked and handled by humans, an ambiguous situation in one location may be clear in another remote location, and a heuristic failure in one day may be a success in another. Similarly, segmentations may fail in one location but work in another. Therefore, the larger the amount of product scans and library entries, the higher the percentage of products automatically included in the library.

Another method further consists of cataloguing the product images that fail to be automatically segmented, disambiguated, or associated to an identifier, and presenting them to humans for manual segmentation, identification, and association.

Planogram helps with segmentation

In some methods, the planogram is used to facilitate and confirm the accuracy of product segmentation. The planogram specifies the number of facings for each product, i.e. how many copies of a product are aligned side by side on a particular shelf. This information helps product segmentation as follows: for products with more than one facing, only the first facing needs to be segmented by one or more of the methods described above. The remaining facings repeat the same segmentation, which accelerates the product detection process. If the number of sequential segmentation for a product does not match the number of facings, then this indicates either an error in segmentation, or that one of the facings is missing.

Product Identification

Some methods further consist of utilizing the library of product objects to improve the identification of products on the shelf, missing products, and misplaced products.

Identification of products on the shelf

The first method for identifying products on the shelves is described above, and it consists of segmenting images to extract product images and identifiers and associate ones to the others.

The second method, also described above, consists of performing template matching in lieu of product segmentation.

The third method, also described above, is complementary to the first two and helps improve the overall accuracy of product identification. In situations where the first method fails to return results that meet a minimum level of confidence, if at all, the third method consists of performing vision-based product recognition by extracting features descriptors from image scans, and matching them with sets of descriptors stored in the library's product objects. The matching can be performed through an exhaustive search, or preferably by restricting the search field to the product objects whose location is proximal to the image scan. The location can be inferred from metric or topological position estimates of the image scan.

A positive match alleviates the problems of:

- a missing price tag or product label
- a product that fails the distance heuristic
- ambiguity where two products meet the heuristics of a single identifier
- segmentation errors

Identification of missing items and missing price tags and product labels

To identify a missing product, a first method consists of recognizing a location on the shelf where there is a void caused by a missing product that should have been located proximally to its identifier. The void can be detected with one or more of the following techniques:

- Recognize the color, brightness or patterns of the back of the shelf or of the void
- Detect light signature or brightness differences between the current shelf image and a previous shelf image taken at the same location
- Capture the 3D model or spatial positioning of the neighboring products using one or more of the depth estimation techniques described above

A second complementary method consists of using sets of descriptors in the library of product objects to detect a missing product as follows:

- For each identifier, match the set of descriptors from the corresponding product object to the image that fits the location heuristic proximal to the identifier
- A lack of identification is an indication of a missing product, or a product that is mis-oriented.

A third complementary method consists of using topological information in the library of product objects to detect a missing price tag or product label as follows:

- As the mobile base scans the shelf, estimate the topological location of each identifier, where the topological location is the sequence of the product on the shelf.
- Compare the estimated topological location to that stored in the library, or to that from the planogram, also stored in the library; a mismatch indicates a missing product, and the identifier of the missing product should be in the object whose topological location immediately precedes the mismatched identifier. This identifies the missing price tag or product label.

A fourth complementary method consists of using metric information in the library of product objects to detect a missing product and a missing price tag or product label as follows:

- As the mobile base scans the shelf, estimate the metric location of an area of interest in the image.
- Match the sets of descriptors from the library that correspond to the estimated location to the area of interest in the image.
- A match is an identification of a product
- A mismatch is an indication of a missing or mis-oriented product

Some methods further consist of compiling a list of identifiers of all missing products and/or their shelf position.

Identification of misplaced products

To identify products that are misplaced, the method consists of first matching the low confidence level sets of descriptors to high confidence level descriptors of all *other* identifiers. If there is a match, then the matching identifier is misplaced.

The method further consists of periodically matching high-confidence level sets of descriptors in the library to areas of the images that are along shelves and that have not been successfully segmented into product images. If there is a match, then the matching identifier is misplaced.

Some methods further consist of compiling a list of misplaced items and their location.

Estimating Product Depth and Depleted Stock

Some methods further consist of measuring the depth of each product facing, i.e. the distance between the front edge of the shelf and the products closest to that edge, or the distance between a line passing through at least two front-most products and individual products.

Techniques for sensing the depth of products and/or shelf edges include but are not limited:

- Capturing the 3D model or spatial positioning of products and shelf edges from structure from motion
- Capturing the 3D model or spatial positioning of products and shelf edges from depth from focus
- Capturing the 3D model or spatial positioning of products and shelf edges using one or more of the depth estimation techniques described above
- Estimating depth by comparing product dimensions to the apparent dimensions of the segmented product image.

Some methods use depth measurements to detect products who have depleted stock. Depleted stock typically happens when the front-most facing of a column of product is picked up from the shelf. The second product in the column becomes front facing, but positioned deeper than other product columns where the front-facing product has not been picked up. These methods detect stock depletion by detecting front facing products that are deeper than the front edge of the shelf and/or a line passing through at least two front-most products, where the depth is greater than a heuristic value.

Some methods further define the heuristic value as the thickness of the product.

Some methods further quantify the number of picked up products from a depleted column by dividing the depth by the thickness of the product, and rounding down to the closest integer.

Some methods further compile a list of identifiers that correspond to depleted product columns and/or the number of products that have been picked up.

Constructing Realogram

Some methods further consist of constructing a Realogram from the collected inventory data. A Realogram, in contrast to a Planogram, describes the actual placement of the products on the shelves. The method consists of locating the product images at their metric or topological location on a virtual representation of each shelf of a shelving category, and labeling them with their identifier. The result is an entire shelving category that visually presents the products that are available, highlights the locations of the missing products, of the misplaced products, and of discrepancies with the planogram.

Localization Using the Product Object Library

Some methods exploit the location information in the library of product objects to improve the estimate of the mobile base absolute position as follows:

- For each segmented price tag or product label from the image of the shelf, extract the highest confidence level metric position of the price tag or product label from the product database.

- Estimate the position and position confidence level of the image sensor by triangulation using the metric positions and confidences of each segmented price tag or product label.
- Update the estimated position of the image sensor and the mobile base by combining the newly derived position estimate weighted by its confidence level with the existing position estimate, also weighted by its confidence level.
- The combination of weighted position estimate may be performed with filters, including but not limited to a Kalman filter or a particle filter.

Some alternative and complementary methods exploit the location information in the library of product objects to improve the estimate of the mobile base absolute position as follows:

- For each image of the shelf, extract descriptors and match them to the descriptors from the product objects. The space of product object descriptors to be matched may be narrowed by using the mobile base's existing position estimate and only matching against proximal product objects.
- When a set of descriptors match a product object, the mobile base first derives a new estimate of its own position by combining the descriptor set's highest confidence level metric position and the relative distance and orientation between the descriptor set and the scanning sensor.
- Update the estimate position of the image sensor and the mobile base by combining the newly derived estimate weighted by its confidence level with its existing estimate, also weighted by its confidence level.
- The combination of weighted position estimate may be performed with filters, including but not limited to a Kalman filter or a particle filter.

Some methods improve the relative position estimate of the mobile base by using shelf images and one or more of the following techniques:

- Visual Servoing
 - o For each image of the shelf, extract descriptors, and derive the relative position of the scanning sensor to the descriptors.
 - o In the very next image, extract descriptors and match them to those of the preceding image. For the feature sets that match, measure the displacement between the two images.
 - o Correlate the displacement of the mobile base to the image-based displacement of the descriptor sets.
 - o This correlation may be performed with filters including but not limited to the Kalman filter and particle filters
- Optical Flow
 - o Run an optical flow algorithm on consecutive images. Optical flow algorithms measure the displacement of features in consecutive images.
 - o Correlate the motion of the mobile base to the optical flow to refine the mobile base's velocity estimate

Counting Products

In some embodiments, the mobile base system is additionally equipped with one or more RFID readers.

Some methods consist of performing an inventory count of products equipped with RFID tags as follows:

- The total number of tags for each product is communicated by an inventory management software to the mobile base computing device or RFID reader
- The RFID reader collects RFID tags while the mobile base is either stationary or moving.
- If the RFID reader does not collect all the tags for a given product, and:
 - o If the mobile base is moving, then the mobile base stops in an attempt to collect the remaining tags
 - o If the mobile base is stopped, move the mobile base in a predetermined search path in an attempt to collect the remaining tags

Autonomous Robot

In some embodiments, the mobile base is an autonomous vehicle, referred to as a robot, that has the following features:

- Locomotion mechanism to propel the robot on the ground or a flight mechanism to propel the robot in the air. The ground robot may have some ability to drive over obstacles and traverse grounds of different nature and property.
- Sensors and algorithms to detect obstacles and people and navigate around them so as to avoid a collision with obstacles, people, and the environment.

In some methods, the robot automatically plans a navigation path that positions the imaging sensors at a heuristic distance from each shelving unit.

Some methods further consist of the robot modifying its navigation plan to revisit sections of shelves depending on the performance of an earlier visit. For example, a section of the shelf could have been obstructed in an earlier visit, so the robot would generate a navigation plan at a later date to revisit that section.

Some methods further consist of the robot estimating the frequency at which products go missing or misplaced for each section of the store from consecutive scans of these sections; and modifying the navigation plan to visit more frequently and in priority sections that experience a higher frequency of missing or misplaced products than other sections.

In some embodiments, the robot is a Ballbot platform as described in patent US 7847504 B2.

Electronic Patent Application Fee Transmittal

Application Number:				
Filing Date:				
Title of Invention:	System and Method for Locating, Identifying and Counting Products on Shelves			
First Named Inventor/Applicant Name:	Sarjoun Skaff			
Filer:	David R. Stevens/TRAM RICHARDS			
Attorney Docket Number:	BOSS-00300			
Filed as Small Entity				
Filing Fees for Provisional				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Provisional Application Filing Fee	2005	1	130	130
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				130

Electronic Acknowledgement Receipt

EFS ID:	25337301
Application Number:	62314785
International Application Number:	
Confirmation Number:	2769
Title of Invention:	System and Method for Locating, Identifying and Counting Products on Shelves
First Named Inventor/Applicant Name:	Sarjoun Skaff
Customer Number:	34051
Filer:	David R. Stevens/TRAM RICHARDS
Filer Authorized By:	David R. Stevens
Attorney Docket Number:	BOSS-00300
Receipt Date:	29-MAR-2016
Filing Date:	
Time Stamp:	17:40:11
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$ 130
RAM confirmation Number	19138
Deposit Account	502421
Authorized User	STEVENS, DAVID R

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 CFR 1.16 (National application filing, search, and examination fees)

Charge any Additional Fees required under 37 CFR 1.17 (Patent application and reexamination processing fees)

Charge any Additional Fees required under 37 CFR 1.19 (Document supply fees)

Charge any Additional Fees required under 37 CFR 1.20 (Post Issuance fees)

Charge any Additional Fees required under 37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal of New Application	Transmittal_Final.pdf	34693	no	3
			299460590cf62d684c9d0b52e58d363d6806a2e8		
Warnings:					
Information:					
2	Application Data Sheet	Application_Data_Sheet.pdf	68560	no	2
			8e548723a024e50e92a436396ca1f722474e8807		
Warnings:					
Information:					
This is not an USPTO supplied ADS fillable form					
3	Specification	Specification_Final.pdf	219344	no	16
			bb17be6be883e83260b8d3e51e656abb249b7236f		
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	29716	no	2
			1f89208148303ffa28af0c4c2cc3373146638c1d		
Warnings:					
Information:					
Total Files Size (in bytes):			352313		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

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TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	62/314,785
Filing Date	3/29/2016
First Named Inventor	Sarjoun Skaff
Title	SYSTEM AND METHOD FOR LOCATING, IDENTIFYING AND COUNTING PRODUCTS ON SHELVES
Art Unit	
Examiner Name	
Attorney Docket Number	BOSS-00300

SIGNATURE of Applicant or Patent Practitioner

Signature	/David R. Stevens/	Date (Optional)	04/11/2016
Name	David R. Stevens	Registration Number	38626
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☐

*Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☒ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above:

34051

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☐ The address associated with the above-mentioned Customer Number

OR

☒ The address associated with Customer Number: 34051

OR

Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone			Email		

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

Bossa Nova Robotics IP, Inc.

- ☐ Inventor or Joint Inventor (title not required below)
- ☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)
- ☒ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)
- ☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature		Date (Optional)	
Name	Sarjoun Skaff		
Title	CTO		

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☐ Total of forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	25456716
Application Number:	62314785
International Application Number:	
Confirmation Number:	2769
Title of Invention:	System and Method for Locating, Identifying and Counting Products on Shelves
First Named Inventor/Applicant Name:	Sarjoun Skaff
Customer Number:	34051
Filer:	David R. Stevens/TRAM RICHARDS
Filer Authorized By:	David R. Stevens
Attorney Docket Number:	BOSS-00300
Receipt Date:	11-APR-2016
Filing Date:	
Time Stamp:	16:46:30
Application Type:	Provisional

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	POA_Executed.pdf	199118 04ab8fe6cde8b20e1288fae7864e779936d041a6	no	2

Warnings:

Information:

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT3824552

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT
CONVEYING PARTY DATA	
Name	Execution Date
SARJOUN SKAFF	04/11/2016
RECEIVING PARTY DATA	
Name:	BOSSA NOVA ROBOTICS IP, INC.
Street Address:	2740 SMALLMAN ST, SUITE 400
City:	PITTSBURGH
State/Country:	PENNSYLVANIA
Postal Code:	15222
PROPERTY NUMBERS Total: 1	
Property Type	Number
Application Number:	62314785
CORRESPONDENCE DATA	
Fax Number:	(408)288-7542
<i>Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.</i>	
Phone:	408-288-7588
Email:	uspto@stevenslawgroup.com
Correspondent Name:	STEVENS LAW GROUP
Address Line 1:	1754 TECHNOLOGY DRIVE
Address Line 2:	SUITE #226
Address Line 4:	SAN JOSE, CALIFORNIA 95110
ATTORNEY DOCKET NUMBER:	BOSS-00300
NAME OF SUBMITTER:	DAVID R. STEVENS
SIGNATURE:	/David R. Stevens/
DATE SIGNED:	04/11/2016
This document serves as an Oath/Declaration (37 CFR 1.63).	
Total Attachments: 2	
source=Assignment_Executed#page1.tif	
source=Assignment_Executed#page2.tif	

ASSIGNMENT-STATEMENT

WHEREAS, Sarjoun Skaff, made certain inventions or discoveries (or both) set forth in an Application for Letters Patent of the United States of America, bearing U.S. application serial number 62/314,785, entitled SYSTEM AND METHOD FOR LOCATING, IDENTIFYING AND COUNTING PRODUCTS ON SHELVES, filed 3/29/2016.

WHEREAS, Bossa Nova Robotics IP, Inc., 2740 Smallman St, Suite 400, Pittsburgh, PA 15222 US, together with its successors and assigns is hereinafter called "Assignee", is desirous of acquiring the entire right, title and interest together with the benefits and privileges hereinafter recited

NOW, THEREFORE, for valuable consideration furnished by Assignee to us, receipt and sufficiency of which I hereby acknowledge, on behalf of Assignor, I hereby, without reservation;

1. Assign, transfer and convey to Assignee any right, title and interest together with the benefits and privileges in and to said inventions and discoveries, said Application for Letters Patent or similar forms of protection of the United States of America, and all other applications for Letters Patent on said inventions and discoveries in whatsoever countries, including all conversions of provisional to non-provisional, divisional, renewal, substitute, continuation and convention applications based in whole or in part upon said inventions or discoveries, or upon said application, and any and all Letters Patent, reissues and extensions of Letters Patent or similar forms of protection granted for said inventions and discoveries or upon said applications, and every priority right that is or may be predicated upon or arise from said inventions, said discoveries, said applications and said Letters Patent;

2. Authorize Assignee to file patent applications in any or all countries or groups of countries on any or all of said inventions and discoveries in our name or in the name of Assignee or otherwise as Assignee may deem advisable, under the International Convention or any other relevant convention or treaty or otherwise;

3. Authorize and request the Commissioner of Patents and Trademarks of the United States of America and the empowered officials of all other governments to issue or transfer all said Letters Patent to Assignee, as assignee of the entire right, title and interest therein, or otherwise as Assignee may direct;

4. Warrant that we have not knowingly conveyed to others any rights in said inventions, discoveries, applications or patents or any license to use the same or to make, use or sell anything embodying or utilizing any of said inventions or discoveries; and that we have good right to assign the same to Assignee without encumbrance;

5. Bind our heirs, legal representatives and assigns, as well as ourselves, to do, upon Assignee's request and at Assignee's expense, but without additional consideration to us or them, all acts reasonable serving to assure that said inventions and discoveries, said patent applications and said Letters Patent shall be held and enjoyed by Assignee as fully and entirely as the same could have been held and enjoyed by us, our heirs, legal representatives and assigns if this assignment had not been made; and particularly to execute and deliver to Assignee all lawful application documents including petitions, specifications, and oaths, and all assignments, disclaimers, and lawful affidavits in form and substance as may be requested by Assignee; to communicate to Assignee all facts known to us relating to said inventions and discoveries or the history thereof; and to furnish Assignee with any and all documents, photographs, models, samples and other physical exhibits in our control or in the control of our heirs, legal representatives or assigns which may be useful for establishing any facts of our conceptions, disclosures, and reduction to practice of said inventions or discoveries.

Title of Invention: SYSTEM AND METHOD FOR LOCATING, IDENTIFYING AND COUNTING
PRODUCTS ON SHELVES

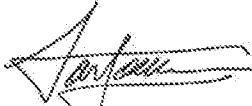
As the below named inventor, I hereby declare that:

This declaration is directed to the above-identified United States application number, filed on the above-identified date.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.



Sarjoun Skaff

_11 April 2016_____
Date



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY,DOCKET,NO	TOT CLAIMS	IND CLAIMS
62/314,785	03/29/2016		130	BOSS-00300		

CONFIRMATION NO. 2769

FILING RECEIPT



0000000082206586

34051
Stevens Law Group
1754 Technology Drive
Suite #226
San Jose, CA 95110

Date Mailed: 04/15/2016

Receipt is acknowledged of this provisional patent application. It will not be examined for patentability and will become abandoned not later than twelve months after its filing date. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Sarjoun Skaff, Pittsburgh, PA;

Applicant(s)

Sarjoun Skaff, Pittsburgh, PA;

Power of Attorney: The patent practitioners associated with Customer Number 34051

Permission to Access Application via Priority Document Exchange: No

Permission to Access Search Results: No

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 04/14/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/314,785**

Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

Early Publication Request: No

**** SMALL ENTITY ****

Title

System and Method for Locating, Identifying and Counting Products on Shelves

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

page 1 of 3

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

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