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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
62/263,496	12/04/2015		130	PAILP003P		

CONFIRMATION NO. 5000

FILING RECEIPT



0000000079751049

19694
Kwan & Olynick LLP
2000 Hearst Avenue, Suite 305
Berkeley, CA 94709

Date Mailed: 01/07/2016

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**

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Permission to Access Search Results: Yes

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If Required, Foreign Filing License Granted: 01/06/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/263,496**

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 IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS

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

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Title 37, Code of Federal Regulations, 5.11 & 5.15

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PAILP003P
		Application Number	
Title of Invention	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2:

☐	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
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Inventor Information:

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	Elliot		English			
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PAILP003P
		Application Number	
Title of Invention	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS		

City	Stanford	State/Province	CA	Country of Residence	US
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Inventor 4					Remove
Legal Name					
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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
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Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).			
☐ An Address is being provided for the correspondence Information of this application.			
Customer Number	19694		
Email Address	docket@kwanip.com	Add Email	Remove Email

Application Information:

Title of the Invention	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS		
Attorney Docket Number	PAILP003P	Small Entity Status Claimed	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	5	Suggested Figure for Publication (if any)	

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PAILP003P
		Application Number	
Title of Invention	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS		

Filing By Reference:

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For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

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When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PAILP003P
		Application Number	
Title of Invention	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS		

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)ⁱ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

			Remove
Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Access Code ⁱ (if applicable)
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Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) 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. NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PAILP003P
		Application Number	
Title of Invention	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS		

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

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B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PAILP003P
		Application Number	
Title of Invention	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS		

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.			
Applicant 1			
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.			
Clear			
☒ Assignee		☐ Legal Representative under 35 U.S.C. 117	
☐ Person to whom the inventor is obligated to assign.		☐ Person who shows sufficient proprietary interest	
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:			
Name of the Deceased or Legally Incapacitated Inventor:			
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Assignee Information including Non-Applicant Assignee Information:

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PAILP003P
		Application Number	
Title of Invention	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS		

Assignee 1			
Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.			
If the Assignee or Non-Applicant Assignee is an Organization check here. ☒			
Organization Name	Pilot AI Labs, Inc.		
Mailing Address Information For Assignee including Non-Applicant Assignee:			
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Address 2			
City	Sunnyvale	State/Province	CA
Country ⁱ	US	Postal Code	94085
Phone Number		Fax Number	
Email Address			
Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.			

Signature:

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This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Joshua Chang/		Date (YYYY-MM-DD)	2015-12-04
First Name	Joshua	Last Name	Chang	Registration Number
70831				
Additional Signature may be generated within this form by selecting the Add button.				

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PAILP003P
		Application Number	
Title of Invention	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS		

This collection of information is required by 37 CFR 1.76. 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 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet 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.**

U.S. PATENT APPLICATION
FOR
SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION
OF DETECTED OBJECTS

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System and Method for Improved Distance Estimation of Detected Objects

TECHNICAL FIELD

[0001] The present disclosure relates generally to machine learning algorithms, and more specifically to distance estimation of detected objects.

BACKGROUND

[0002] It is often useful to know the distance one is from a particular object or target. Systems have attempted to estimate the distance of an object using a camera using a variety of methods, e.g. lasers. However, lasers may have limited range and also may not be accurate for really close objects. Thus, there is a need for distance estimation of an object no matter how far the object is from the observer, as long as the object appears in a camera used by the observer.

SUMMARY

[0003] The following presents a simplified summary of the disclosure in order to provide a basic understanding of certain embodiments of the present disclosure. This summary is not an extensive overview of the disclosure and it does not identify key/critical elements of the present disclosure or delineate the scope of the present disclosure. Its sole purpose is to present some concepts disclosed herein in a simplified form as a prelude to the more detailed description that is presented later.

[0004] In general, certain embodiments of the present disclosure provide techniques or mechanisms for improved object detection by a neural network. According to various embodiments, a method for distance and velocity estimation of detected objects is provided. The method includes receiving an image that includes a minimal bounding box around an object of interest. The method also includes calculating a noisy estimate of the physical position of the object of interest relative to a source of the image. Last,

the method includes producing a smooth estimate of the physical position of the object of interest using the noisy estimate.

[0005] In another embodiment, a system for distance and velocity estimation of detected objects is provided. The system includes one or more processors, memory, and one or more programs stored in the memory. The one or more programs comprise instructions to receive an image. The image includes a minimal bounding box around an object of interest. The one or more programs also comprise instructions to calculate a noisy estimate the physical position of the object of interest to a source of the image and produce a smooth estimate of the physical position of the object of interest using the noisy estimate.

[0006] In yet another embodiment, a non-transitory computer readable medium is provided. The computer readable medium storing one or more programs comprising instructions to receive an image. The image includes a minimal bounding box around an object of interest. The one or more programs also comprise instructions to calculate a noisy estimate the physical position of the object of interest to a source of the image and produce a smooth estimate of the physical position of the object of interest using the noisy estimate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The disclosure may best be understood by reference to the following description taken in conjunction with the accompanying drawings, which illustrate particular embodiments of the present disclosure.

[0008] Figure 1 illustrates a particular example of distance and velocity estimation by a neural network, in accordance with one or more embodiments.

[0009] Figure 2 illustrates an example of object recognition by a neural network, in accordance with one or more embodiments.

[0010] Figure 3 illustrates an example of a method for distance and velocity estimation of detected objects, in accordance with one or more embodiments.

[0011] Figure 4 illustrates one example of a neural network system that can be used in conjunction with the techniques and mechanisms of the present disclosure in accordance with one or more embodiments.

DETAILED DESCRIPTION OF PARTICULAR EMBODIMENTS

[0012] Reference will now be made in detail to some specific examples of the present disclosure including the best modes contemplated by the inventors for carrying out the present disclosure. Examples of these specific embodiments are illustrated in the accompanying drawings. While the present disclosure is described in conjunction with these specific embodiments, it will be understood that it is not intended to limit the present disclosure to the described embodiments. On the contrary, it is intended to cover alternatives, modifications, and equivalents as may be included within the spirit and scope of the present disclosure as defined by the appended claims.

[0013] For example, the techniques of the present disclosure will be described in the context of particular algorithms. However, it should be noted that the techniques of the present disclosure apply to various other algorithms. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. Particular example embodiments of the present disclosure may be implemented without some or all of these specific details. In other instances, well known process operations have not been described in detail in order not to unnecessarily obscure the present disclosure.

[0014] Various techniques and mechanisms of the present disclosure will sometimes be described in singular form for clarity. However, it should be noted that some embodiments include multiple iterations of a technique or multiple instantiations of a mechanism unless noted otherwise. For example, a system uses a processor in a variety of contexts. However, it will be appreciated that a system can use multiple processors while remaining within the scope of the present disclosure unless otherwise noted. Furthermore, the techniques and mechanisms of the present disclosure will sometimes describe a connection between two entities. It should be noted that a connection between two entities does not necessarily mean a direct, unimpeded connection, as a variety of other entities may reside between the two entities. For example, a processor

may be connected to memory, but it will be appreciated that a variety of bridges and controllers may reside between the processor and memory. Consequently, a connection does not necessarily mean a direct, unimpeded connection unless otherwise noted.

[0015] Overview

[0016] According to various embodiments, a method for distance and velocity estimation of detected objects is provided. The method includes receiving an image that includes a minimal bounding box around an object of interest. The method also includes calculating a noisy estimate of the physical position of the object of interest relative to a source of the image. Last, the method includes producing a smooth estimate of the physical position of the object of interest using the noisy estimate.

[0017] Example Embodiments

[0018] In various embodiments, a system is provided for estimating the physical distance and velocities of objects within a sequence of images relative to the camera which took the sequence of images. In some embodiments, it is assumed that for each image, there is a minimal bounding box around all objects of interest (e.g. a people's heads). The system must also be told the approximate physical, diagonal size of the objects within the boxes (e.g. the diagonal across a minimal bounding box of an average person's head is 0.25 meters). In some embodiments, the sequence of boxes around the objects of interest is produced by neural networks. In addition, the system provides tracking between the sequence of frames, so that the system can keep track of which box belongs to which instance of the object from one frame to the next. Because these boxes come from a neural network, there is inherently some noise associated with the box's size and position. The system produces smooth position and velocity estimates even if the sequence of boxes is noisy.

[0019] In various embodiments, an overview of the system for determining smooth position estimates is as follows. First, given a single image, the system produce a noisy estimate of the relative physical position (relative to the camera) of the each object within the image (for all the bounding boxes that are given). This noisy estimate is

computed using the orientation of the camera, the size of the box within the image, and the known physical box size of that type of object.

[0020] Second, the noisy estimate is fed into the dynamical systems estimator which is able to produce accurate, smooth object positions and velocities given a sequence of noisy estimates. The sequence of noisy estimates is handled separately for each unique instance of an object within a sequence of images (e.g. for each individual person).

[0021] Calculating a noisy estimate of the physical position

[0022] The diagram below shows a sketch of a camera pointed at a physical object. Given the angle of the camera with the ground (denoted as θ), the field of view of the camera (denoted as α), the physical length of the diagonal across the box for an average instance of the object (denoted as s), the area of the box in pixels (denoted as A), and the height (H) and width (W) of the image in pixels, the system compute the straight-line distance d between the object and the camera as:

$$d = s/2 * \tan(A/2 * \alpha/H)$$

[0023] Once the system has the straight-line object distance d , the system computes the relative position (denoted as $[(x)]_0, x_1, x_2$) using the horizontal and vertical position of the box center within the image (in pixels) (denoted as δ_w, δ_h):

$$(x_0, x_1, x_2) = (\cos(\theta - \delta_h) * d, \sin(\delta_w) * d, -\sin(\theta - \delta_h) * d)$$

[0024] Computing smooth estimates of object position and velocity

[0025] In various embodiments, as stated above, the position estimates which are computed purely based on the size and orientation of the box plus the geometry of the camera configuration are inherently noisy. This noise is due to noise in the box size and position, as well as noise in the camera angle (that measurement is only accurate to the nearest whole degree). To compensate for the noise in the system, the system uses a dynamical model of the object position and input the noisy estimates from above into the model to produce a smooth function which estimates the position and velocity which approximately fit the noisy data.

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[0026] The model of the system is that the position of the object, as a function of time, is given by the equation:

$$\underline{x}(t) = \underline{x}_i + \underline{(v_i)} * t$$

where $\underline{x}(t)$ is the vector of position of the object as a function of time, t is time, $\underline{x}_i$ is the position of the object at some initial time, and $\underline{(v_i)}$ is the velocity vector of the object at some initial time. If the system has n camera frames, the previous section gives a sequence of n measurements of the position $\underline{x}(t)$ at times $t_0, t_1, \dots, t_n$. Substituting this data into the model provides a system of n equations which we can solve for the constants $\underline{x}_i$ and $\underline{v}_i$. Having solved the system for the constants, we can then determine the position and velocity of the object at any time t , so long as $t_0 \leq t \leq t_n$.

[0027] Application of the model

[0028] In practice, the model is used in the following way. As new frames are received, the system stores a sequence of the previous n noisy position estimates (from above, based only on the box size and location and the geometry of the camera). Every time a new frame is received, the system computes the noisy estimate above and appends it to the list of position estimates, and discards the oldest estimate. After updating the list of estimates, the model is refitted using the new list. Then, until a new frame is received, the model is used to estimate the position.

[0029] Figure 1 illustrates some of the variables that are fed into the distance estimation algorithm. The input image 100 may be an image of a person 102. The input image 100 is passed through a neural network to produce a bounding box 108. The image pixels within bounding box 108 is also passed through a neural network to associate each box with a unique identifier, so that the identity of each object within the box is coherent from one frame to the next (although only a single frame is illustrated in Figure 1). The location from the center of the bounding box to the center of the image is measured, for both the horizontal coordinate (δ_w) and the vertical coordinate (δ_h). The image 100 may be recorded by a camera 104. In some embodiments, camera 104 may be a camera attached to a drone. The angle θ that the camera makes with a

horizontal line is depicted, as well as the straight-line distance d between the camera lens and the center of the image.

[0030] Figure 2 illustrates an example of output boxes around objects of interest generated by a neural network 200, in accordance with one or more embodiments. According to various embodiments, the pixels of image 202 are input into neural network 200 as a third-order tensor. Once the pixels of image 202 have been processed by the computational layers within neural network 200, neural network 300 outputs a first order tensor with five dimensions corresponding to the smallest bounding box around the object of interest, including the x and y coordinates of the center of the bounding box, the height of the bounding box, the width of the bounding box, and a probability that the bounding box is accurate. As depicted in Figure 2, neural network 200 has output boxes 204, 206, and 208. Boxes 204 and 206 each identify the face of a person. Box 208 identifies a car and may be a box from output by a separate recurrent step.

[0031] Figure 3 illustrates an example of a method 300 for distance and velocity estimation of detected objects. At 301, an image is received. In some embodiments, the source of the image may comprise a camera 302. The image includes a minimal bounding box 303 around an object of interest. In some embodiments, the minimal bounding box 303 may be produced by a neural network 304, such as neural network 200 described in Figure 2. Alternatively, the image may include multiple minimal bounding boxes 305 around multiple objects of interest. Such minimal bounding boxes may also be produced by a neural network 306, such as neural network 200 described in Figure 2.

[0032] At 307, a noisy estimate 309 of the physical position of the object of interest relative to a source of the image is calculated. In some embodiments, the source of the image may be camera 302. In various embodiments, calculating the noisy estimate 309 may include using the following values: the orientation of the source of the image, the size of the bounding box within the image, a known physical box size of the object of interest's type of object, the angle of the source of the image relative to the ground, the field of view of the source of the image, the physical length of a diagonal across the bounding box for an average instance of the object of interest, the area of the box in

pixels, and the height and width of the image in pixels. In other embodiments, other values or fewer values may be used in calculating noisy estimate 309 of the physical position of the object of interest relative to the source of the image.

[0033] Noisy estimate 309 is then stored in a list of noisy estimates at 311. A subsequent image is then received at 301 and another noisy estimate 309 is calculated for the subsequent image and stored in the list of noisy estimate at 311. In some embodiments, steps 301 to 311 are repeated as long as an image is being captured by a source, such as camera 302, and sent to step 301.

[0034] Using the noisy estimates 309, a smooth estimate of the physical position of the object of interest is produced at 313. Additionally, using a sequence of images of the object of interest, a smooth estimate of the velocity of the object of interest is produced at 319. In some embodiments producing a smooth estimate at steps 313 and 319 includes passing a plurality of noisy estimates, including the noisy estimate, into a dynamical system estimator 315. In some embodiments, producing a smooth estimate at steps 313 and 319 further includes calculating the position 317 of the object of interest as a function of time.

[0035] Figure 4 illustrates one example of a neural network system 400, in accordance with one or more embodiments. According to particular embodiments, a system 400, suitable for implementing particular embodiments of the present disclosure, includes a processor 401, a memory 403, an interface 411, and a bus 415 (e.g., a PCI bus or other interconnection fabric) and operates as a streaming server. In some embodiments, when acting under the control of appropriate software or firmware, the processor 401 is responsible for various processes, including processing inputs through various computational layers and algorithms. Various specially configured devices can also be used in place of a processor 401 or in addition to processor 401. The interface 411 is typically configured to send and receive data packets or data segments over a network.

[0036] Particular examples of interfaces supports include Ethernet interfaces, frame relay interfaces, cable interfaces, DSL interfaces, token ring interfaces, and the like. In addition, various very high-speed interfaces may be provided such as fast Ethernet interfaces, Gigabit Ethernet interfaces, ATM interfaces, HSSI interfaces, POS

interfaces, FDDI interfaces and the like. Generally, these interfaces may include ports appropriate for communication with the appropriate media. In some cases, they may also include an independent processor and, in some instances, volatile RAM. The independent processors may control such communications intensive tasks as packet switching, media control and management.

[0037] According to particular example embodiments, the system 400 uses memory 403 to store data and program instructions for operations including training a neural network, object detection by a neural network, and distance and velocity estimation. The program instructions may control the operation of an operating system and/or one or more applications, for example. The memory or memories may also be configured to store received metadata and batch requested metadata.

[0038] Because such information and program instructions may be employed to implement the systems/methods described herein, the present disclosure relates to tangible, or non-transitory, machine readable media that include program instructions, state information, etc. for performing various operations described herein. Examples of machine-readable media include hard disks, floppy disks, magnetic tape, optical media such as CD-ROM disks and DVDs; magneto-optical media such as optical disks, and hardware devices that are specially configured to store and perform program instructions, such as read-only memory devices (ROM) and programmable read-only memory devices (PROMs). Examples of program instructions include both machine code, such as produced by a compiler, and files containing higher level code that may be executed by the computer using an interpreter.

[0039] While the present disclosure has been particularly shown and described with reference to specific embodiments thereof, it will be understood by those skilled in the art that changes in the form and details of the disclosed embodiments may be made without departing from the spirit or scope of the present disclosure. It is therefore intended that the present disclosure be interpreted to include all variations and equivalents that fall within the true spirit and scope of the present disclosure. Although many of the components and processes are described above in the singular for convenience, it will be appreciated by one of skill in the art that multiple components

and repeated processes can also be used to practice the techniques of the present disclosure.

CLAIMS:

What is claimed is:

1. A method for distance and velocity estimation of detected objects, the method comprising:
 - receiving an image, the image includes a minimal bounding box around an object of interest;
 - calculating a noisy estimate of the physical position of the object of interest relative to a source of the image; and
 - producing a smooth estimate of the physical position of the object of interest using the noisy estimate.
2. The method of claim 1, further comprising producing a smooth estimate of the velocity of the object of interest using a sequence of images of the object of interest.
3. The method of claim 1, wherein producing a smooth estimate includes passing a plurality of noisy estimates, including the noisy estimate, into a dynamical system estimator.
4. The method of claim 3, wherein calculating the noisy estimate includes using the orientation of the source of the image, the size of the bounding box within the image, and a known physical box size of the object of interest's type of object.
5. The method of claim 3, wherein calculating the noisy estimate includes using the angle of the source of the image relative to the ground, the field of view of the source of the image, the physical length of a diagonal across the bounding box for an average instance of the object of interest, the area of the box in pixels, and the height and width of the image in pixels.
6. The method of claim 1, wherein producing a smooth estimate includes calculating the position of the object of interest as a function of time.
7. The method of claim 1, further comprising:
 - storing the noisy estimate of the position of the object of interest in a list of noisy estimates;

receiving a new image, the new image including the object of interest;
calculating a new noisy estimate of the position of the object of interest using
the new image; and
appending the new noisy estimate to the list of noisy estimates to be used for
producing the smooth estimate.

8. The method of claim 1, wherein the image includes multiple minimal bounding boxes around multiple objects of interest.

9. The method of claim 1, wherein the source of the image comprises a camera.

10. The method of claim 1, wherein the minimal bounding box is produced by a neural network.

11. A system for distance and velocity estimation of detected objects, comprising:
one or more processors;
memory; and
one or more programs stored in the memory, the one or more programs
comprising instructions to:
receive an image, the image including a minimal bounding box around an object
of interest;
calculate a noisy estimate the physical position of the object of interest to a
source of the image; and
produce a smooth estimate of the physical position of the object of interest
using the noisy estimate.

12. The system of claim 11, wherein the one or more programs further comprises instructions to produce a smooth estimate of the velocity of the object of interest using a sequence of images of the object of interest.

13. The system of claim 11, wherein producing a smooth estimate includes passing a plurality of noisy estimates, including the noisy estimate, into a dynamical system estimator.

14. The system of claim 13, wherein calculating the noisy estimate includes using the orientation of the source of the image, the size of the bounding box within the image, and a known physical box size of the object of interest's type of object.
15. The system of claim 13, wherein calculating the noisy estimate includes using the angle of the source of the image relative to the ground, the field of view of the source of the image, the physical length of a diagonal across the bounding box for an average instance of the object of interest, the area of the box in pixels, and the height and width of the image in pixels.
16. The system of claim 11, wherein producing a smooth estimate includes calculating the position of the object of interest as a function of time.
17. The system of claim 11, wherein the one or more programs further comprises instructions to:
- store the noisy estimate of the position of the object of interest in a list of noisy estimates;
 - receive a new image, the new image including the object of interest;
 - calculate a new noisy estimate of the position of the object of interest using the new image; and
 - append the new noisy estimate to the list of noisy estimates to be used for producing the smooth estimate.
18. The system of claim 11, wherein the image includes multiple bounding boxes around multiple objects of interest.
19. The system of claim 11, wherein the source of the image comprises a camera.
20. The system of claim 11, wherein the minimal bounding box is produced from a neural network.
21. A non-transitory computer readable storage medium storing one or more programs configured for execution by a computer, the one or more programs comprising instructions to:
- receive an image, the image including a minimal bounding box around an object of interest;

calculate a noisy estimate the physical position of the object of interest to a source of the image; and
produce a smooth estimate of the physical position of the object of interest using the noisy estimate.

22. The non-transitory computer readable medium of claim 21, wherein the one or more programs further comprises instructions to produce a smooth estimate of the velocity of the object of interest using a sequence of images of the object of interest.

23. The non-transitory computer readable medium of claim 21, wherein producing a smooth estimate includes passing a plurality of noisy estimates, including the noisy estimate, into a dynamical system estimator.

24. The non-transitory computer readable medium of claim 23, wherein calculating the noisy estimate includes using the orientation of the source of the image, the size of the bounding box within the image, and a known physical box size of the object of interest's type of object.

25. The non-transitory computer readable medium of claim 23, wherein calculating the noisy estimate includes using the angle of the source of the image relative to the ground, the field of view of the source of the image, the physical length of a diagonal across the bounding box for an average instance of the object of interest, the area of the box in pixels, and the height and width of the image in pixels.

26. The non-transitory computer readable medium of claim 21, wherein producing a smooth estimate includes calculating the position of the object of interest as a function of time.

27. The non-transitory computer readable medium of claim 21, wherein the one or more programs further comprises instructions to:

store the noisy estimate of the position of the object of interest in a list of noisy estimates;

receive a new image, the new image including the object of interest;

calculate a new noisy estimate of the position of the object of interest using the new image; and

append the new noisy estimate to the list of noisy estimates to be used for producing the smooth estimate.

28. The non-transitory computer readable medium of claim 21, wherein the image includes multiple bounding boxes around multiple objects of interest.

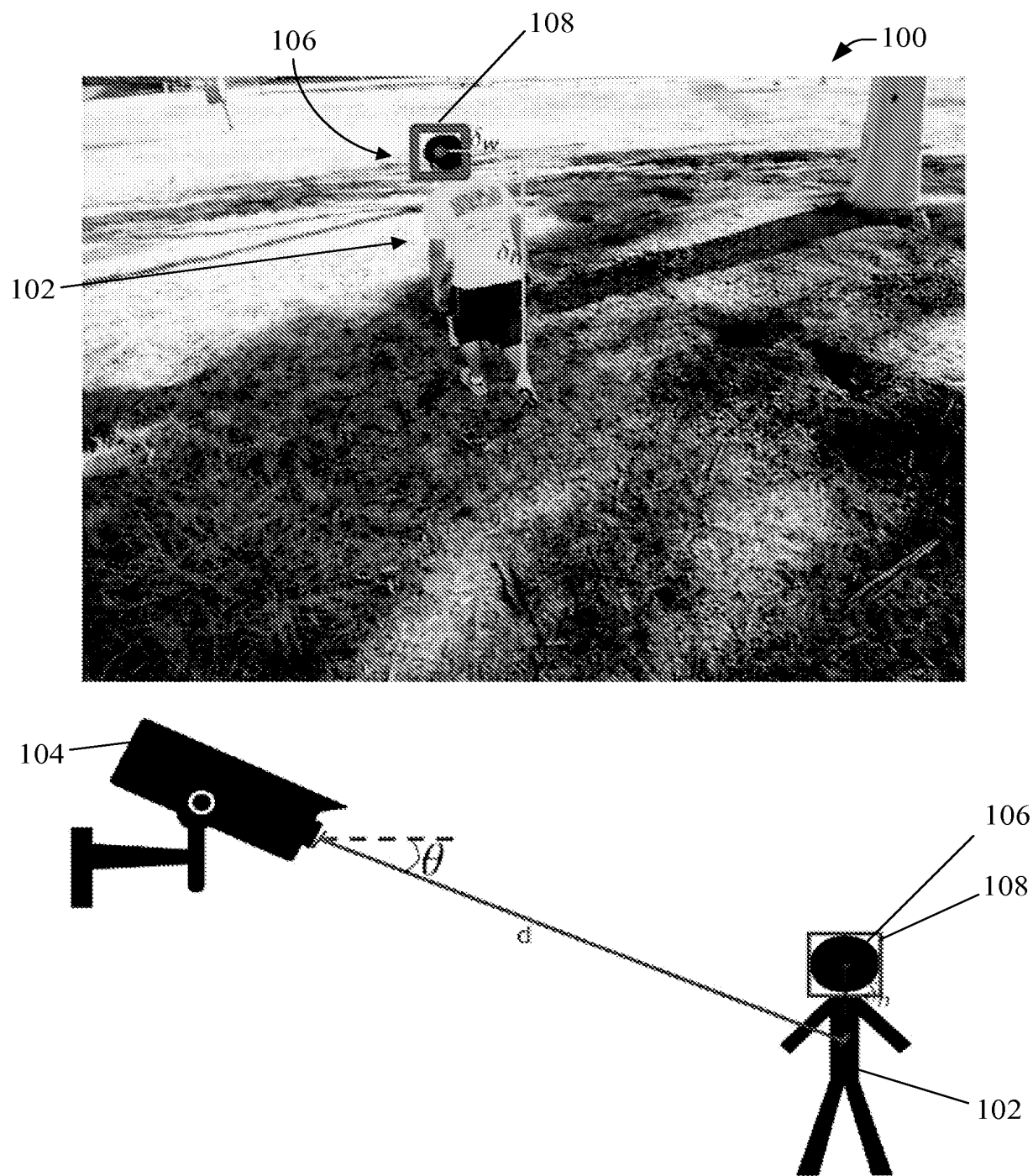
29. The non-transitory computer readable medium of claim 21, wherein the source of the image comprises a camera.

30. The non-transitory computer readable medium of claim 21, wherein the minimal bounding box is produced from a neural network.

ABSTRACT

SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS

According to various embodiments, a method for distance and velocity estimation of detected objects is provided. The method includes receiving an image that includes a minimal bounding box around an object of interest. The method also includes calculating a noisy estimate of the physical position of the object of interest relative to a source of the image. Last, the method includes producing a smooth estimate of the physical position of the object of interest using the noisy estimate.



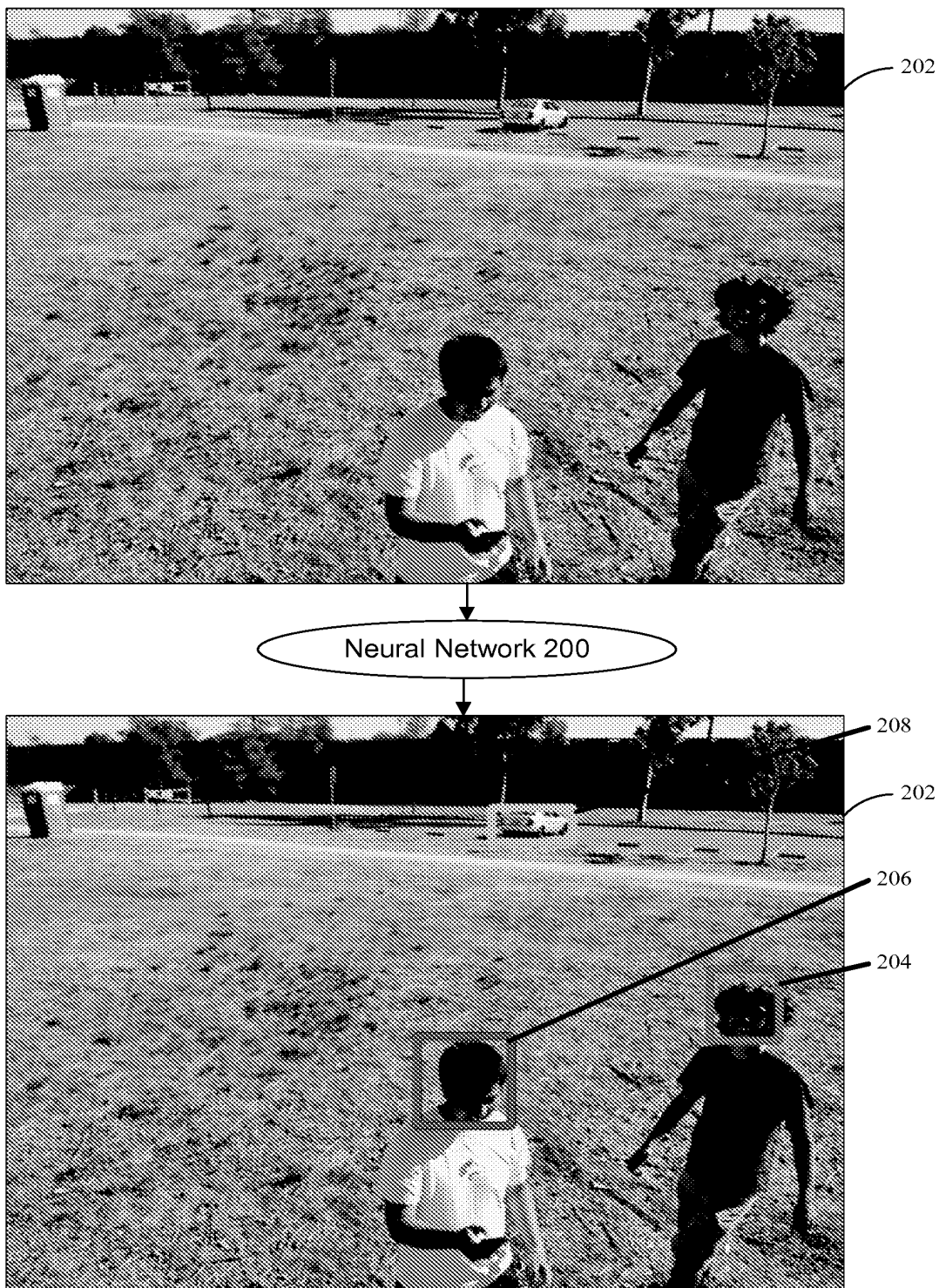


FIG. 2

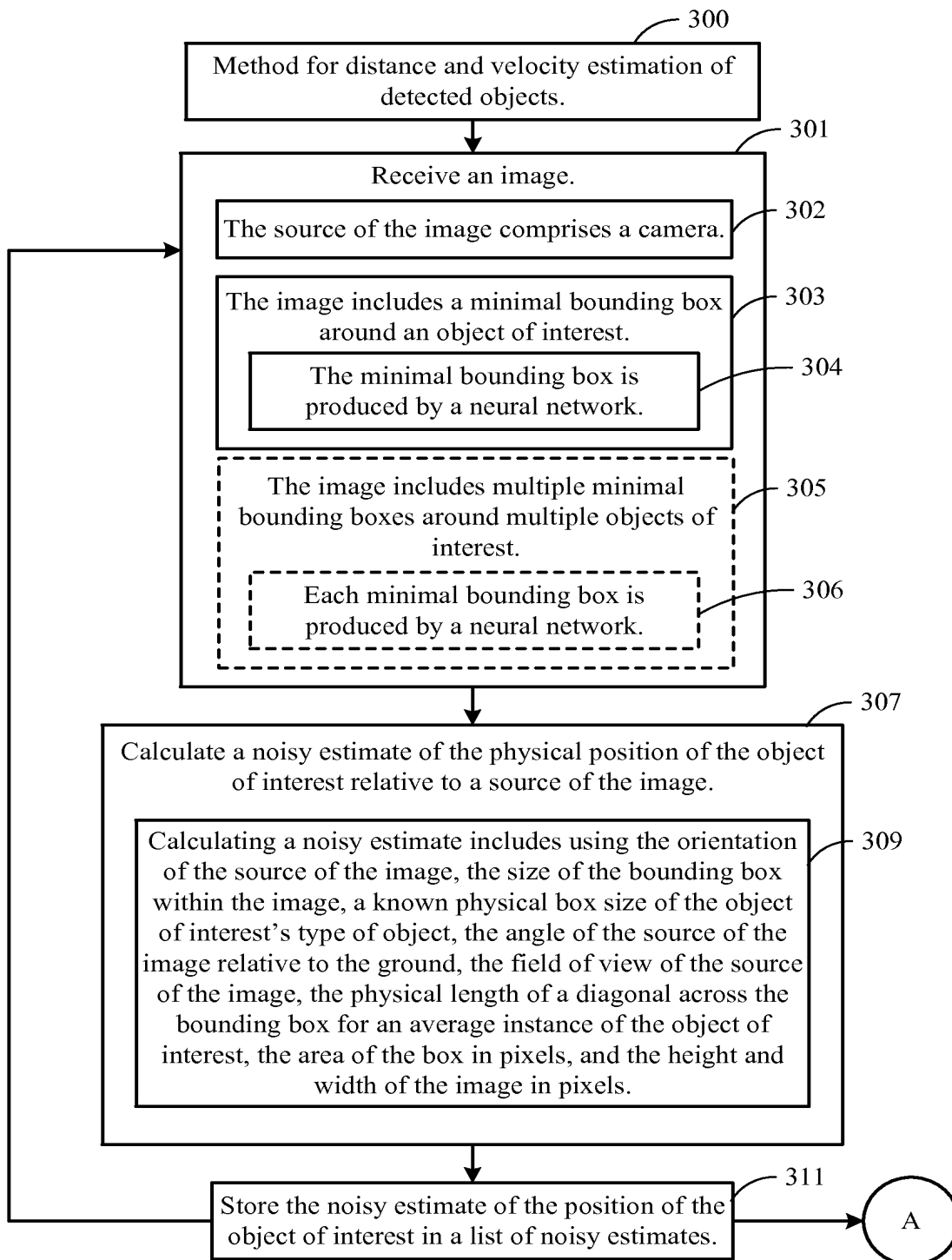


FIG. 3A

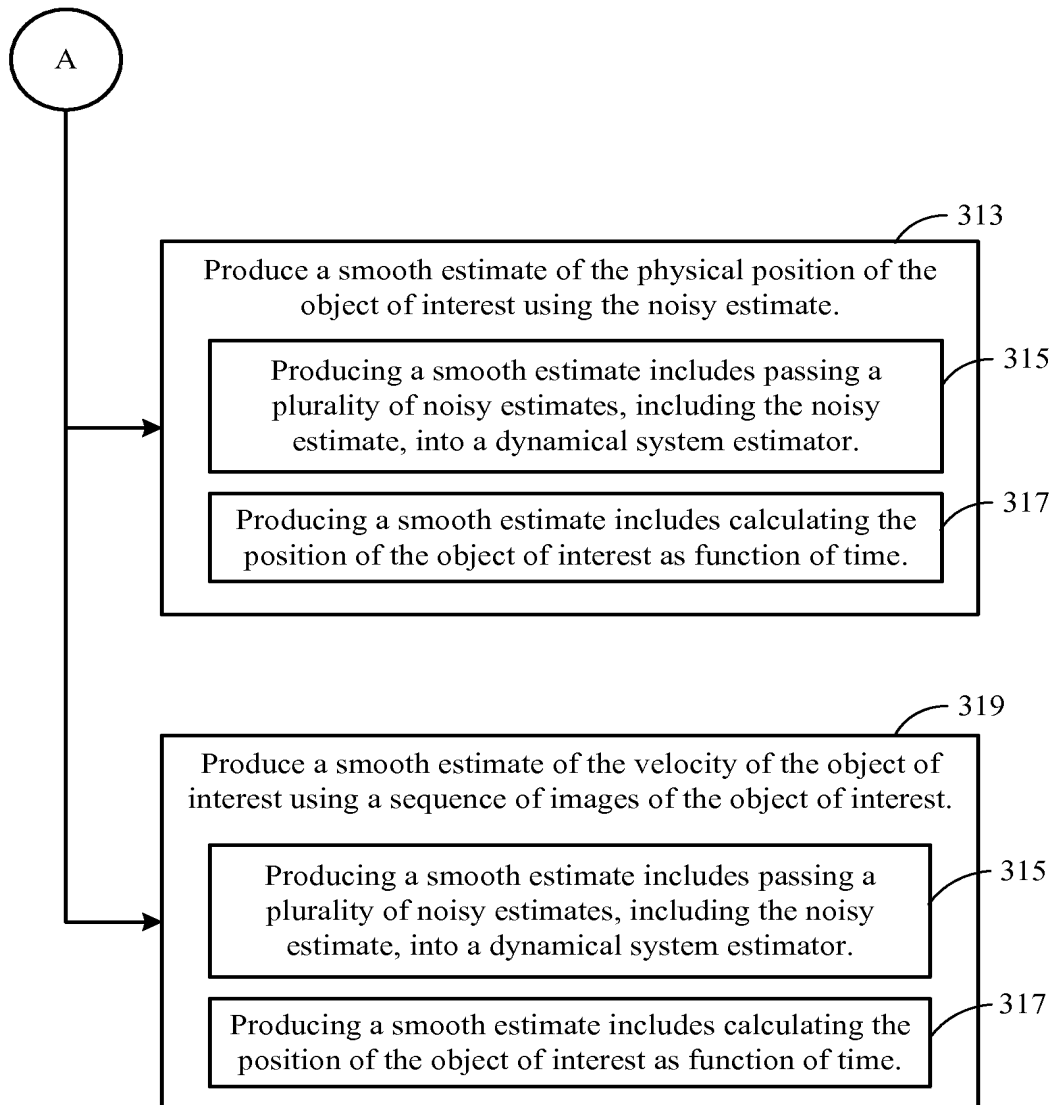


FIG. 3B

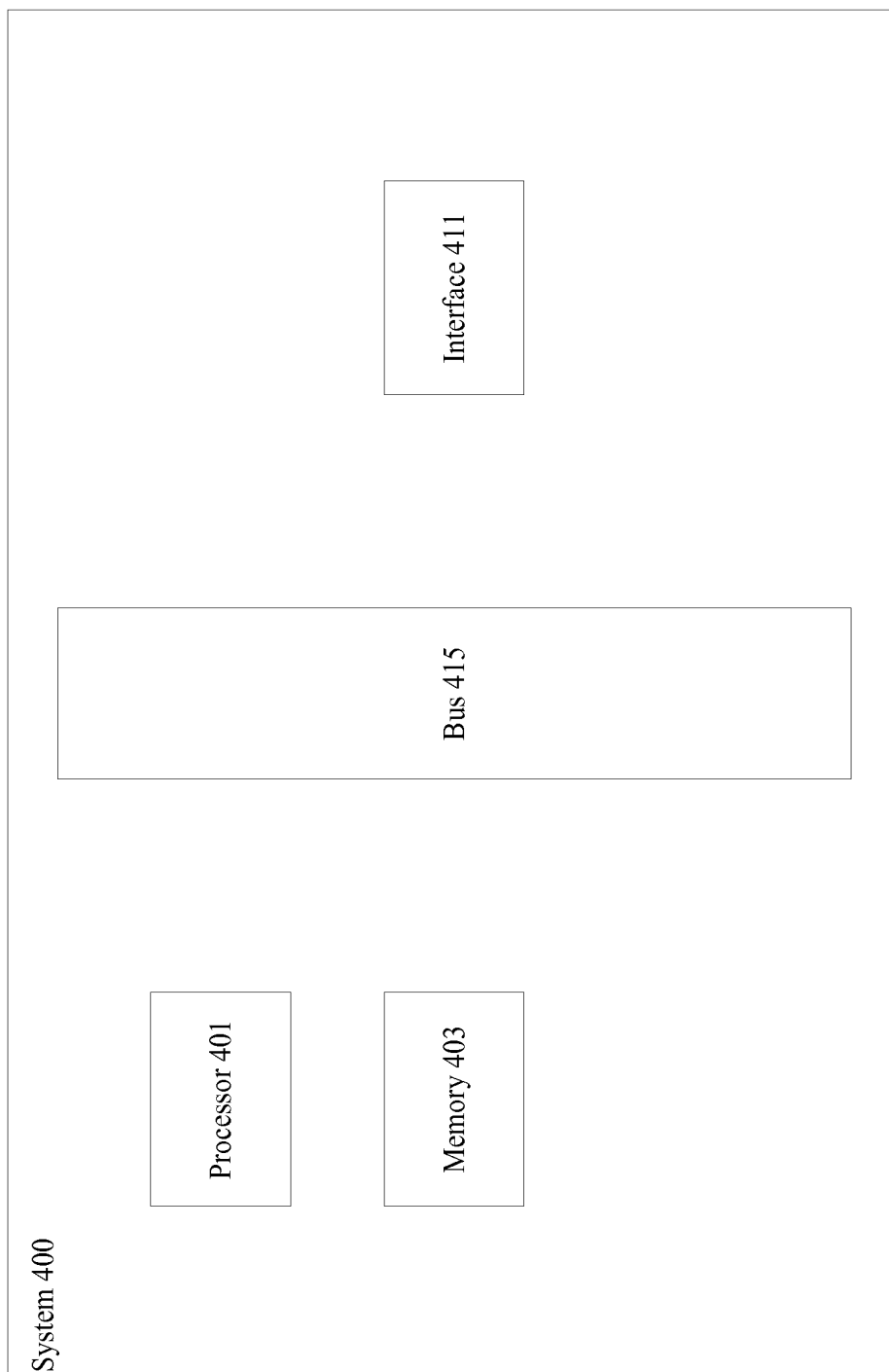


FIG. 4

Electronic Patent Application Fee Transmittal

Application Number:				
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Title of Invention:	SYSTEM AND METHOD FOR IMPROVED DISTANCE ESTIMATION OF DETECTED OBJECTS			
First Named Inventor/Applicant Name:	Ankit Kumar			
Filer:	Joshua Chang/Sally Austin			
Attorney Docket Number:	PAILP003P			
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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:				
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Total in USD (\$)				130

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1		PAILP003P_APLN_filed_120415.pdf	1334090	yes	30
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	Application Data Sheet		1	7	
	Specification		8	19	
	Claims		20	24	
	Abstract		25	25	
	Drawings-only black and white line drawings		26	30	
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	29777	no	2
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