

EXHIBIT A



US008965598B2

(12) **United States Patent
Kruglick**

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(45) **Date of Patent:** Feb. 24, 2015

(54) **AUTOMATIC FLIGHT CONTROL FOR UAV
BASED SOLID MODELING**

USPC 701/2, 3, 13, 24, 36, 31.4, 300;
244/75.1

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See application file for complete search history.

(73) Assignee: **Empire Technology Development LLC**,
Wilmington, DE (US)

(56) **References Cited**

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 97 days.

U.S. PATENT DOCUMENTS

4,504,914 A 3/1985 Hofmann
4,613,899 A 9/1986 Kuwano et al.

(Continued)

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FOREIGN PATENT DOCUMENTS

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AU 2010219335 9/2010
EP 2112630 10/2009

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OTHER PUBLICATIONS

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(51) **Int. Cl.**

G05D 3/00 (2006.01)
B64C 19/00 (2006.01)

(Continued)

(57) **ABSTRACT**

Technologies are generally described for controlling a flight path of a UAV based image capture system for solid modeling. Upon determining an initial movement path based on an estimate of a structure to be modeled, images of the structure to be modeled may be captured and surface hypotheses formed for unobserved surfaces based on the captured images. A normal vector and a viewing cone may be computed for each hypothesized surface. A set of desired locations may be determined based on the viewing cones for the entire structure to be modeled and a least impact path for the UAV determined based on the desired locations and desired flight parameters.

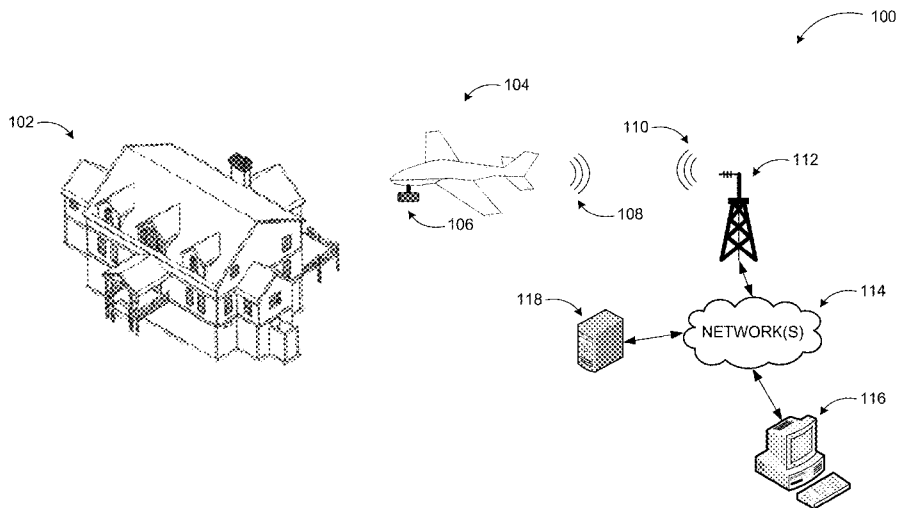
(52) **U.S. Cl.**

CPC **B64C 19/00** (2013.01); **B64C 39/024**
(2013.01); **G05D 1/0094** (2013.01); **G05D**
1/101 (2013.01); **G06T 17/05** (2013.01); **G06T**
17/10 (2013.01); **B64C 2201/127** (2013.01);
B64C 2201/146 (2013.01)
USPC **701/2**; 701/3; 701/13; 244/75.1

(58) **Field of Classification Search**

CPC B64C 19/00; B64C 2201/127; B64C
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17/05

21 Claims, 11 Drawing Sheets



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G05D 1/00 (2006.01)
G05D 1/10 (2006.01)
G06T 17/05 (2011.01)
G06T 17/10 (2006.01)

FOREIGN PATENT DOCUMENTS

WO 2006/037237 4/2006
 WO 2009/125304 10/2009

OTHER PUBLICATIONS

- (56) **References Cited**
 U.S. PATENT DOCUMENTS

| | | | | |
|--------------|-----|---------|---------------------|--------|
| 4,628,354 | A | 12/1986 | Nagura | |
| 4,802,757 | A | 2/1989 | Pleitner et al. | |
| 5,104,217 | A | 4/1992 | Pleitner et al. | |
| 5,289,185 | A | 2/1994 | Ramier et al. | |
| 5,602,586 | A | 2/1997 | Schauer et al. | |
| 6,272,404 | B1 | 8/2001 | Amano et al. | |
| 6,972,696 | B2 | 12/2005 | Rogers et al. | |
| 7,009,638 | B2 | 3/2006 | Gruber et al. | |
| 7,339,614 | B2 | 3/2008 | Gruber et al. | |
| 7,342,670 | B2 | 3/2008 | Teichman | |
| 7,509,241 | B2 | 3/2009 | Gou et al. | |
| 7,630,797 | B2 | 12/2009 | Garceau et al. | |
| 8,355,834 | B2* | 1/2013 | Duggan et al. | 701/24 |
| 8,768,555 | B2* | 7/2014 | Duggan et al. | 701/24 |
| 2003/0014224 | A1 | 1/2003 | Guo et al. | |
| 2008/0125920 | A1 | 5/2008 | Miles et al. | |
| 2009/0256909 | A1 | 10/2009 | Nixon | |
| 2009/0263009 | A1 | 10/2009 | Krishnaswamy et al. | |
| 2010/0004802 | A1 | 1/2010 | Bodin et al. | |
| 2010/0013927 | A1 | 1/2010 | Nixon | |

Punchcard VideoTrace, Modelling a House, <http://punchcard.com.au/wordpress/?p=12>.
 Punchcard: VideoTrace, Image-based Modelling for All, <http://tinyurl.com/y96q52c>.
 Andert, et al., Online World Modeling and Path Planning for an Unmanned Helicopter, Autonomous Robot (2009) 27: 147-164.
 Metni et al., A UAV for Bridge Inspection: Visual Serving Control Law with Orientation Limits, Automation in Construction, vol. 17, #1, (2007) pp. 3-10.
 Favi et al., Techniques for Fully Integrated Intra-/Inter-Chip Optical Communication, Proceedings of the 45th annual Design Automation Conference, Anaheim, California (2008) 2 pages.
 Fischler et al., Random Sample Consensus: A Paradigm for Model Fitting with Applications to Image Analysis and Automated Cartography. Commun. ACM, 24(6):381-395, 1981.
 Quirk et al., RANSAC-Assisted Display Model Reconstruction for Projective Display, Department of Computer Science University of North Carolina at Chapel Hill, 4 pages.
 International Search Report & Written Opinion dated Jan. 4, 2011 in PCT/US10/050829.

* cited by examiner

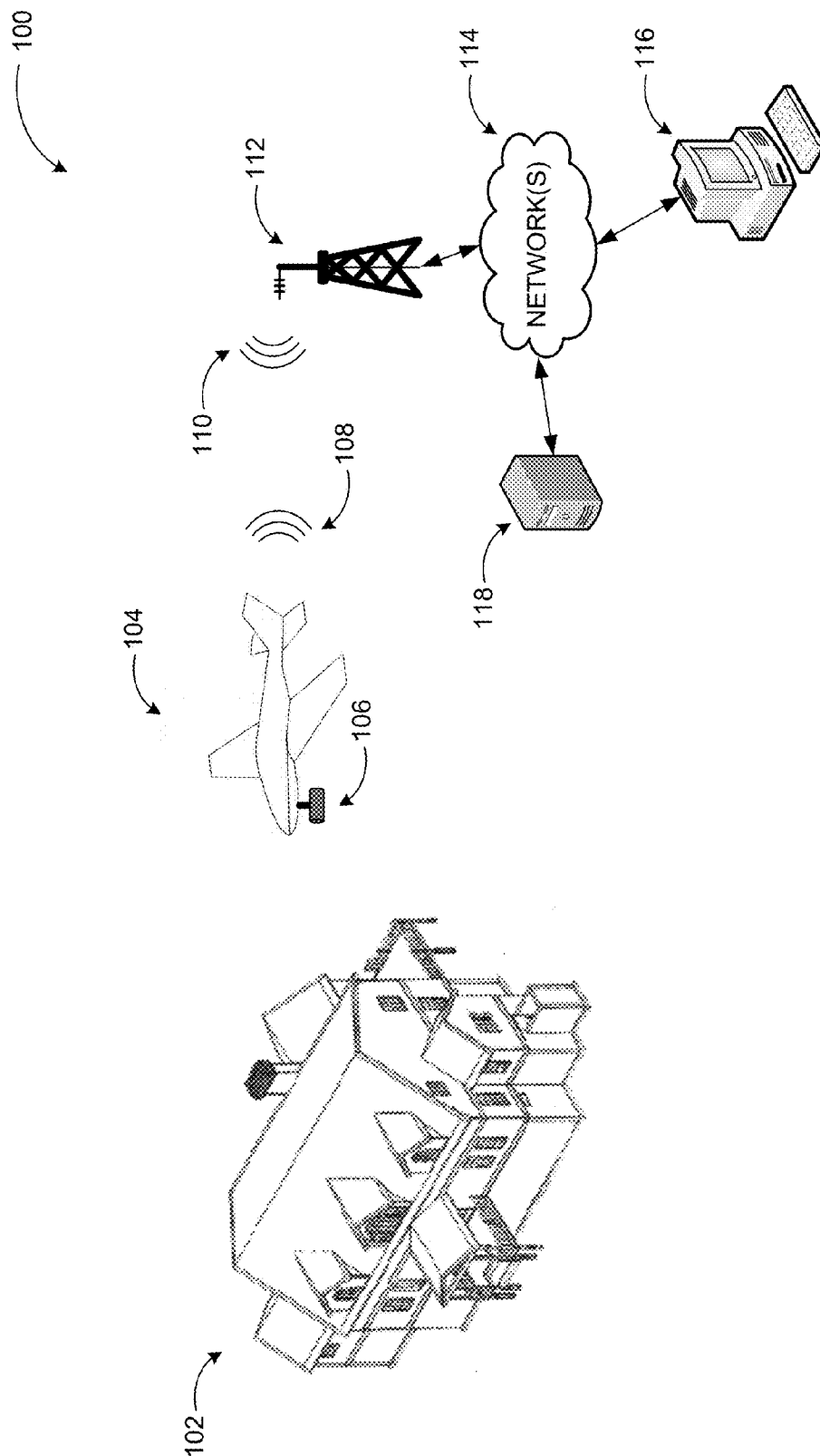


FIG. 1

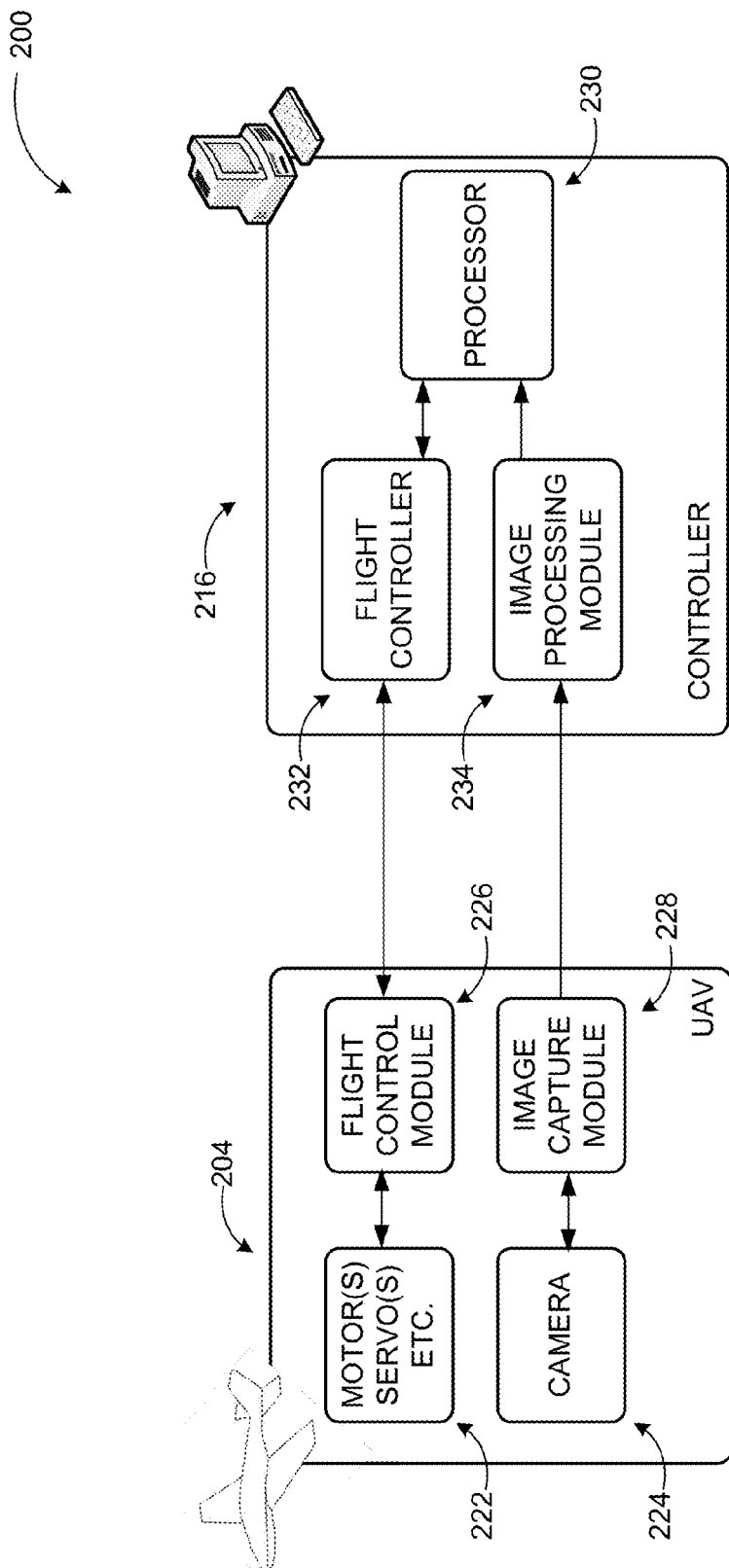


FIG. 2

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