



(51) International Patent Classification:

G01C 17/38 (2006.01) G01C 21/18 (2006.01)
G01C 21/20 (2006.01) G01D 18/00 (2006.01)
G01C 21/08 (2006.01) G01V 3/08 (2006.01)
G01C 21/04 (2006.01)

(21) International Application Number:

PCT/US2013/045435

(22) International Filing Date:

12 June 2013 (12.06.2013)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/658,883 12 June 2012 (12.06.2012) US
61/783,908 14 March 2013 (14.03.2013) US

(71) Applicant: TRXS SYSTEMS, INC. [US/US]; 7500 Greenway Center Drive, Suite 420, Greenbelt, MD 20770 (US).

(72) Inventors: FUNK, Benjamin, E.; c/o Trxs Systems, Inc., 7500 Greenway Center Drive, Suite 420, Greenbelt, MD 20770 (US). HAKIM, Daniel; c/o Trxs Systems, Inc., 7500 Greenway Center Drive, Suite 420, Greenbelt, MD 20770 (US). KARVOUNIS, John; c/o Trxs Systems, Inc., 7500 Greenway Center Drive, Suite 420, Greenbelt, MD 20770 (US). YOUNG, Travis; c/o Trxs Systems, Inc., 7500 Greenway Center Drive, Suite 420, Greenbelt, MD 20770 (US). TEOLIS, Carole; c/o Trxs Systems, Inc., 7500 Greenway Center Drive, Suite 420, Greenbelt, MD 20770 (US).

(74) Agent: CASEY, Timothy, D.; Baker & Hostetler LLP, Cira Centre, 12th Floor, 2929 Arch Street, Philadelphia, PA 19104-2891 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,

[Continued on next page]

(54) Title: METHODS FOR IMPROVED HEADING ESTIMATION

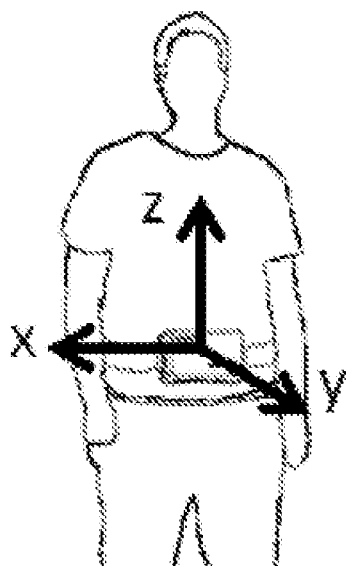


FIG. 13

(57) Abstract: Methods for calibrating a body-worn magnetic sensor by spinning the magnetic sensor 360 degrees to capture magnetic data; if the spin failed to produce a circle contained in an x-y plane fit a sphere to the captured data; determining offsets based on the center of the sphere; and removing the offsets that are in the z-direction. Computing a magnetic heading reliability of a magnetic sensor by determining an orientation of the sensor at one location; transforming the orientation between two reference frames; measuring a first vector associated with the magnetic field of Earth at the location; processing the first vector to generate a virtual vector when a second location is detected; measuring a second vector associated with the magnetic field of Earth at the second location; and calculating the magnetic heading reliability at the second location based on a comparison of the virtual vector and the second vector.





MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

(88) Date of publication of the international search report:

17 April 2014

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

Group I: Claim 1; Group II: Claims 2-4; Group III: Claims 5-11; Group IV: Claims 12-15

-Please see Supplemental Page-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
1-11
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G01C 17/38, 21/20, 21/08, 21/04, 21/18; G01D 18/00; G01V 3/08 (2014.01)

USPC - 701/489, 501, 512, 525; 702/150, 92; 33/356

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): G01C 17/38, 21/20, 21/08, 21/04, 21/18; G01D 18/00; G01V 3/08 (2014.01)

USPC: 701/489, 501, 512, 525; 702/150, 92; 33/356

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

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

MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); ProQuest; IEEE/IEEEExplore;
Google/Google Scholar; Search Terms Used: calibrat*, adjust*4, tun*3, correct*4, align*4, compensate*3, mov*5, rotat*3, transducer,
compass, gyroscope, navigate*3, position*3, locat*3, concurrent, con-current, ad hoc, continu*, realtime, real-time, vector, magnet*, axis

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/0312509 A1 (PATEL, P et al.) December 9, 2010; figures 1, 2, 4; paragraphs [0021]-[0029], [0033], [0044].	1
X	US 7587277 B1 (WELLS) September 8, 2009; abstract; figures 1, 3, 4, 5; column 3, lines 32-33 and lines 38-52; column 4, lines 25-45; column 5, lines 8-1; column 8, lines 18-19, lines 30-38 and lines 50-55; column 9, lines 65-67; column 10, lines 9-29 and lines 34-43; column 11, lines 35-36 and lines 50-52; column 12, lines 15-30.	2-4
A		5-11
A	US 2012/0130632 A1 (BANDYOPADHYAY, A et al.) May 24, 2012; the entire document.	5-11
A	US 2009/0254294 A1 (DUTTA, G) October 8, 2009; the entire document.	1-11
A	BANJANOVIĆ-MEHMEDOVIĆ, L et al. Hough Transform based Correction of Mobile Robot Orientation. IEEE ICIT '04. 2004 IEEE International Conference on Industrial Technology [online], December 2004 [retrieved on 2014-02-05]. Retrieved from the Internet: <URL: http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=1490801&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F9977%2F32037%2F01490801 >.	1-11
A	DONG, W et al. A Low-cost Motion Tracker and Its Error Analysis. IEEE International Conference on Robotics and Automation [online] May 2008 [retrieved on 2014-02-05]. Retrieved from the Internet: <URL: http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=4543226&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxppls%2Fabs_all.jsp%3Farnumber%3D4543226 >.	1-11

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

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

06 February 2014 (06.02.2014)

Date of mailing of the international search report

14 FEB 2014

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-3201

Authorized officer:

Shane Thomas

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

-----Continued from Box No. III - Observations where lack of unity is lacking-----

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fee must be paid.

Group I: Claim 1 is directed towards a method for calibrating in real-time a body worn magnetic sensor.

Group II: Claims 2-4 are directed toward a computing system for computing an indicator of a magnetic heading reliability of a magnetic sensor.

Group III: Claims 5-11 are directed toward calculating a gyro heading drift associated with a magnetic sensor and a gyro sensor.

Group IV: Claims 12-15 are directed toward a global rotation estimation.

The inventions listed as Groups I-IV do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I include capturing magnetic data from the magnetic sensor when the sensor moves along a 360 degree spun path; determining x-axis, y-axis and z-axis offsets; removing the z-axis offsets; and using the x-axis offsets and y-axis offsets to calibrate the magnetic sensor, which are not present in Groups II-IV.

The special technical features of Group II include determining an orientation of the magnetic sensor at a first location; generate a filter; measure a first vector and a second vector; calculate the indicator of magnetic heading reliability at the second location, which are not present in Groups I, III and IV.

The special technical features of Group III include transforming gyro data and compass data into a navigation frame; computing a compass heading and a gyro heading; determining a first drift; sorting the compass data; determining a second drift; and calculating the gyro heading drift, which are not present in Groups I, II, and IV.

The special technical features of Group IV include determining a path of a magnetic sensor and gyro sensor in motion in an environment based on magnetic data received from the magnetic sensor and gyro data received from the gyro sensor; breaking the path into a plurality of grids; computing a heading based on magnetic headings and gyro headings at locations within the path in each grid; determining an average heading; and setting the global rotation estimation as a value that minimizing the average heading, which are not present in Groups I-III.

The common technical feature shared by Groups I-IV is calculating a magnetic sensor path. However, this common feature is previously disclosed by US 7,587,277 B1 (Wells). Wells discloses calculating data movement using a magnetic sensor and gyro sensor (estimate pitch, roll, and heading using a magnetometer and gyro information; Abstract).

Since the common technical feature is previously disclosed by the Wells reference, this common feature is not special and so Groups I-IV lack unity.