



(51) International Patent Classification:

G01S 5/00 (2006.01) G01S 7/40 (2006.01)

G01S 5/02 (2010.01) G01S 13/46 (2006.01)

G01S 7/02 (2006.01) A61B 19/00 (2006.01)

(21) International Application Number:

PCT/US2014/028005

(22) International Filing Date:

14 March 2014 (14.03.2014)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

13/834,553 15 March 2013 (15.03.2013) US

(71) Applicant: MEDTRONIC NAVIGATION, INC.

[US/US]; 826 Coal Creek Circle, Louisville, Colorado 80027 (US).

(72) Inventors: JACOBSEN, Brad; 2840 Prince Circle, Erie,

Colorado 80516 (US). BZOSTEK, Andrew; 5757 Rim Rock Court, Boulder, Colorado 80301 (US). HARTMANN, Steven L.; 2535 Andrew Drive, Superior, Colorado 80027 (US).

(74) Agents: WARNER, Richard W. et al.; Harness, Dickey &

Pierce, P.L.C., P.O. Box 828, Bloomfield Hills, Michigan 48303 (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, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

— as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

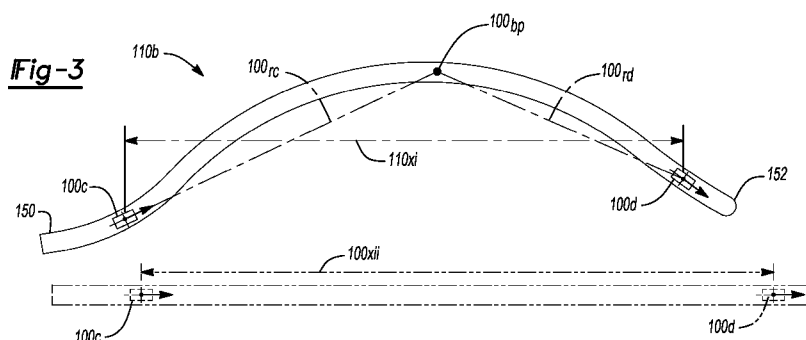
Published:

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

— with amended claims (Art. 19(1))

Date of publication of the amended claims: 11 December 2014

(54) Title: NAVIGATION FIELD DISTORTION DETECTION



(57) Abstract: Disclosed is a method and system for navigating an instrument relative to a patient that can be near a field distorting feature. A localizer can generate an electromagnetic field that is sensed by a tracking device to determine a location of the tracking device with the sensed electromagnetic field. The system and related method can assist in determining whether a navigation field is distorted near a tracking device of the instrument.

AMENDED CLAIMS

received by the International Bureau on 24 October 2014 (24.10.2014)

1. A method to determine proper navigation of an instrument in a
5 navigation field, comprising:

receiving a first signal from a first tracking device fixed to the
instrument at a first instrument position;

receiving a second signal from a second tracking device fixed to the
instrument at a second instrument position that is spaced a distance along the
10 instrument from to the first instrument position, wherein the instrument is able to
flex to change at least one of a relative distance or orientation between the first
instrument position and the second instrument position;

determining a first three-dimensional position of the first tracking
device based on the first received signal;

15 determining a second three-dimensional position of the second
tracking device based on the second received signal;

determining a relative position of the first tracking device and the
second tracking device based on the determined first three-dimensional position
and the determined second three-dimensional position;

20 recalling at least one instrument constraint from a memory system;
and

determining whether the determined relative position of the first
tracking device and the second tracking device is probable based on the recalled
at least one instrument constraint.

25

2. The method of Claim 1, wherein determining whether the
determined relative position of the first tracking device and the second tracking
device is probable includes determining a parameterizable energy of the
instrument between the first tracking device and the second tracking device.

30

3. The method of Claim 2, wherein the parameterizable energy is an
energy of bending and a higher energy of bending is related to a less probable
position of the instrument.

4. The method Claim 3, wherein the determined first three-dimensional position includes at least a first three-dimension location and a first three-dimension orientation;

5 wherein determined second three-dimensional position includes at least a second three-dimension location and a second three-dimension orientation.

5. The method of Claim 2, further comprising:
a third tracking device;

10 wherein the energy of bending is calculated between at least three of the first, second, and third tracking devices.

6. The method of Claim 3, wherein the energy of bending has a maximum that is related to a physical constraint of a volume in which the instrument is currently placed when the first signal is received and the second signal is received.

7. The method of Claim 1, wherein receiving the first signal occurs substantially simultaneously with receiving the second signal.

20

8. The method of Claim 1, further comprising:

navigating the instrument within a space based at least on the determined first three-dimensional position and the determined second three-dimensional position.

25

9. The method of Claim 8, further comprising:

stopping a user navigation while continuing a system navigation if it is determined that the determined relative position of the first tracking device and the second tracking device is improbable;

30

wherein user navigation is restarted when, based on the system navigation, it is determined that the relative position of the first tracking device and the second tracking device is probable.

10. The method of Claim 9, further comprising:
mitigating an interference caused by an interfering object, wherein
the interfering object is causing the interference.

5 11. The method of Claim 2, further comprising:
determining the position of the instrument relative to a space; and
illustrating an icon representing a model of at least a portion of the
instrument based on the determined energy of bending of the instrument between
the first tracking device and the second tracking device superimposed on an
10 image of the space.

12. The method of Claim 2, wherein the parameterizable energy
includes at least one of a torsion energy, a compression energy, extension
energy, or a rotation energy;
15 wherein determining the parameterizable energy includes
determining a parameterizable physical constraint of the instrument related to the
parameterizable energy.

13. The method of Claim 1, wherein determining whether the
20 determined relative position of the first tracking device and the second tracking
device is probable includes determining a calibrated position of the first tracking
device relative to the second tracking device when the instrument is at-rest and
comparing the determined relative position of the first tracking device and the
second tracking device based on the determined first three-dimensional position
25 and the determined second three-dimensional position.

14. The method of Claim 1, wherein determining the first three-
dimensional position of the first tracking device based on the first received signal
and determining the second three-dimensional position of the second tracking
30 device based on the second received signal includes accounting for at least one
known error in at least one of the first received signal or the second received
signal.

15. The method of Claim 14, wherein accounting for at least one known error includes accounting for an uncertainty in a tracked three dimensional position of at least one of the first tracking device or the second tracking device.

5 16. A method to determine proper navigation of an instrument in a navigation field, comprising:

 evaluating physical constraints of a flexible instrument;

 storing with a first storage device the evaluated physical constraints;

10 determining a calibrated position of a first tracking device and a second tracking device fixed to the flexible instrument; and

 storing with a second storage device the calibrated position of the first tracking device and the second tracking device fixed to the flexible instrument;

 wherein the stored evaluated physical constraints and stored calibrated position are accessible by a processor to execute an algorithm to
15 determine an energy of bending of the flexible instrument based on the accessed stored evaluated physical constraints and accessed stored calibrated position.

17. The method of Claim 16, further comprising:

 determining the energy of bending based on a current tracked
20 position of the first tracking device and the second tracking device and the saved physical constraints and the determined calibrated position of the first tracking device and the second tracking device; and

 based on the determined energy, determine whether the determined energy of bending is probable based on the stored evaluated physical constraints
25 and the determined calibrated position of the first tracking device and the second tracking device.

18. The method of Claim 17, further comprising:

 executing the algorithm with the processor to determine the energy
30 of bending based on at least one of a distances between a tracked location of the first tracking device and the second tracking device or determining an estimated arc length of the flexible instrument between the first tracking device and the second tracking device.

19. The method of Claim 18, wherein the evaluated physical constraints include at least one of a wire constant, a modulus of elasticity, a dimension of the instrument, or combinations thereof.

5 20. The method of Claim 19, wherein the probable energy of bending is at or below a threshold energy value.

 21. The method of Claim 20, further comprising:
 determining a probability value of the energy of bending based on
10 whether the value of the energy of bending is greater than the threshold energy value.

 22. The method of Claim 21, further comprising:
 stopping a current user tracking of the first tracking device and a
15 current user tracking of the second tracking device if the determined energy of bending is determined to have a determined probability value less than a selected threshold probability value while maintaining a system tracking to determine if the determined energy of bending changes to have a determined probability value greater than a selected threshold probability value.

20

 23. The method of Claim 22, further comprising:
 providing an output to a user that the current user tracking is stopped.

25 24. The method of Claim 18, further comprising:
 positioning the instrument within a space during a procedure;
 determining an intra-procedure physical constraint based at least on a physical feature of the space;
 accessing the determined intra-procedure physical constraint;
30 determining a maximum energy of bending based on the accessed determined intra-procedure physical constraint; and
 comparing the maximum energy of bending to the determined energy of bending.

25. The method of Claim 18, further comprising:
generating an electromagnetic field; and
tracking the first tracking device and the second tracking device by
sensing the generated electromagnetic field in a navigation space.

5

26. The method of Claim 25, further comprising:
determining that a distortion is present in the generated
electromagnetic field if a probability value of the energy of bending based on the
determined value of the energy of bending is greater than a threshold energy
value.

10

27. The method of Claim 16, further comprising:
creating a user defined physical constraint on the flexible instrument
different from the evaluated physical constraints;
wherein determining the energy of bending is further based on the
used defined physical constraint of the flexible instrument.

15

28. The method of Claim 16, providing a single storage device as the
first storage device and the second storage device.

20

29. A system to determine proper navigation of an instrument in a
navigation field, comprising:

a localizer to generate an electromagnetic field as the navigation
field;

25

a flexible instrument configured to be moved relative to the
navigation field;

a first tracking device fixed to the flexible instrument at a first
position;

30

a second tracking device fixed to the flexible instrument at a second
position spaced apart from the first position;

a navigation processor configured for:

receiving a first signal from the first tracking device;

receiving a second signal from the second tracking device;

determining a relative position of the first tracking device and the second tracking device based on the respective received first single and second signal;

5 recalling at least one instrument constraint from a memory system;

determining whether the determined relative position of the first tracking device and the second tracking device is probable based on the recalled at least one instrument constraint.

10 30. The system of Claim 29, wherein the navigation processor is further configured for determining whether the determined relative position of the first tracking device and the second tracking device is probable by:

15 determining a geometry of the flexible instrument based on the determined relative position of the first tracking device and the second tracking device; and

determining a physical parameterizable energy of the flexible instrument based on the geometry of the flexible instrument.

20 31. The system of Claim 30, further comprising:
a notification system configured to notify a user that the determined physical parameterizable energy is improbable.

25 32. The system of Claim 31, further comprising:
a display device configured to illustrate a model of the flexible instrument representing the determined geometry of the flexible instrument and the physical parameterizable energy.

30 33. The system of Claim 30, wherein the flexible instrument is configured to change geometry based on the at least one instrument constraint during a procedure.

34. The system of Claim 30, wherein the physical parameterizable energy includes at least one of an energy of bending, a torsion energy, a compression energy, extending energy, or a rotation energy.

- 5 35. The system of Claim 34, wherein the physical parameterizable energy further includes at least one associated physical parameterizable constraint.