

CLAIMS

1. A surgical robot comprising an articulated arm, the arm having a terminal portion comprising:

a distal segment having an attachment for a surgical instrument;

an intermediate segment; and

a basal segment whereby the terminal portion is attached to the remainder of the arm;

a first articulation between the distal segment and the intermediate segment, the first articulation permitting relative rotation of the distal segment and the intermediate segment about a first axis; and

a second articulation between the intermediate segment and the basal segment, the second articulation permitting relative rotation of the intermediate segment and the basal segment about a second axis;

wherein:

the intermediate segment comprises a third articulation permitting relative rotation of the distal segment and the basal segment about third and fourth axes;

the first, second and third articulations are arranged such that in at least one configuration of the third articulation:

the first and second axes are ~~collinear~~ parallel;

the third and fourth axes are transverse to each other; ~~and~~

the third and fourth axes are transverse to the first axis; ~~and~~

the third and fourth axes intersect each other.

2. A surgical robot as claimed in claim 1, wherein in the said configuration the third and fourth axes are perpendicular to the first axis.

~~3. A surgical robot as claimed in claim 1 or 2, wherein in the said configuration the first and second axes are collinear.~~

~~4. A surgical robot as claimed in of claims 1 to 3, wherein the third and fourth axes intersect each other.~~

35. A surgical robot as claimed in ~~any of claims 1 or 2 to 4~~, wherein the third and fourth axes are perpendicular to each other.

46. A surgical robot as claimed in any of claims 1 to 35, wherein the first articulation is a revolute joint.

57. A surgical robot as claimed in any of claims 1 to 46, wherein the second articulation is a revolute joint.

68. A surgical robot as claimed in any of claims 1 to 57, wherein the third articulation is a spherical joint or a pair of revolute joints.

79. A surgical robot as claimed in claim 68, wherein the third articulation is a universal joint.

840. A surgical robot as claimed in any of claims 1 to 79, wherein the only means of articulating the attachment for a surgical instrument relative to the basal segment are the first, second and third articulations.

944. A surgical robot as claimed in any of claims 1 to 840, wherein the attachment for a surgical instrument is located on the first axis.

102. A surgical robot as claimed in any of claims 1 to 944, comprising a surgical instrument attached to the attachment.

113. A surgical robot as claimed in any of claims 1 to 102, wherein the surgical instrument extends in a direction substantially along the first axis.

124. A surgical robot as claimed in of claims 1 to 113, wherein the arm comprises:
a base; and
a proximal portion extending between the base and the basal segment of the terminal portion of the arm, the proximal portion being articulated along its length and being rigidly connected to the basal segment.

135. A surgical robot as claimed in claim 124, wherein the proximal portion comprises:
a first arm segment;

a second arm segment coupled to the first arm segment by a first arm articulation whereby the second arm segment can rotate relative to the first arm segment about a first arm axis;

a third arm segment coupled to the second arm segment by a second arm articulation whereby the third arm segment can rotate relative to the second arm segment about a second arm axis;

a fourth arm segment coupled to the third arm segment by a third arm articulation whereby the fourth arm segment can rotate relative to the third arm segment about a third arm axis; and

a fifth arm segment coupled to the fourth arm segment by a fourth arm articulation whereby the fifth arm segment can rotate relative to the fourth arm segment about a fourth arm axis;

wherein

the second arm axis is transverse to the first arm axis, the third arm axis is transverse to the second arm axis and the fourth arm axis is transverse to the third arm axis; and

the second and third arm segments together form an elongate limb that extends in a direction along the third arm axis.

146. A surgical robot as claimed in claim 135, wherein the second arm axis is perpendicular to the first arm axis.

157. A surgical robot as claimed in claim 135 or 146, wherein the third arm axis is perpendicular to the second arm axis.

168. A surgical robot as claimed in any of claims 135 to 157, wherein the fourth arm axis is perpendicular to the third arm axis.

179. A surgical robot as claimed in any of claims 135 to 168, wherein the first arm segment is rigidly attached to the base.

1820. A surgical robot as claimed in any of claims 135 to 179, wherein the first, second, third and fourth arm articulations are revolutes joints and the only means of articulating the fifth arm segment relative to the base are the first, second, third and fourth arm articulations.

1924. A surgical robot as claimed in any of claims 135 to 1820, having a first additional articulation between the first arm segment and the base, the first additional articulation permitting relative rotation of the first arm segment and the base about a first additional axis transverse to the first arm axis.

202. A surgical robot as claimed in claim 1924, having a second additional articulation between the first arm segment and the base, the second additional articulation permitting relative rotation of the first arm segment and the base about a second additional axis transverse to the first additional axis.

213. A surgical robot as claimed in any of claims 135 to 168, 1924 or 202, wherein the second arm segment comprises a third additional articulation whereby the second arm segment can flex about an axis transverse to the third arm axis.

224. A surgical robot as claimed in any of claims 135 to 213, wherein the second arm axis is offset from the first arm axis in a direction perpendicular to the first arm axis.

235. A surgical robot as claimed in any of claims 135 to 224, wherein the second arm axis is offset from the third arm axis in a direction perpendicular to the third arm axis.

246. A surgical robot as claimed in any of claims 135 to 235, wherein the fourth arm axis is offset from the third arm axis in a direction perpendicular to the third arm axis.

257. A surgical robot as claimed in any of claims 135 to 246, wherein the base is arranged such that the first axis is offset from vertical by at least 20°.

268. A surgical robot as claimed in any of claims 135 to 257, wherein the fifth arm segment is rigidly attached to the basal segment of the terminal portion of the arm.

279. A surgical robot as claimed in claim 268, wherein the fifth arm segment and the basal segment together form an elongate limb that extends in a direction along the second axis.

2830. A surgical robot as claimed in claim 279, wherein the second axis is transverse to the fourth arm axis.

2934. A surgical robot as claimed in claim 2830, wherein the second axis is perpendicular to the fourth arm axis.

302. A surgical robot as claimed in any of claims 268 to 2934, wherein the fourth arm axis is offset from the second axis in a direction perpendicular to the second axis.

313. A surgical robot as claimed in any of claims 1 to 302, wherein the arm comprises eight revolute joints by means of which the distal end of the arm may be rotated relative to the proximal end of the arm, the eight revolute joints providing the distal end of the arm with six degrees of freedom relative to the proximal end of the arm.

324. A surgical robot as claimed in any of claims 1 to 313, wherein the third articulation is constituted by a joint having an intermediate member capable of moving about a first spherical joint with respect to the basal segment and about a second spherical joint with respect to the distal segment, the first and second spherical joints being constrained to move in a plane with respect to the intermediate member.

335. A surgical robot as claimed in claim 324, comprising a follower captive within the intermediate member and coupled by the first and second spherical joints to the basal segment and the distal segment respectively, the follower being constrained to move linearly with respect to the intermediate member.

346. A surgical robot as claimed in claim 324 or 335, comprising a plurality of linear actuators arranged between the basal segment and the intermediate member for causing relative rotation of the distal segment and the basal segment about third and fourth axes.