SUMMARY

[0006] According to a first aspect of the present invention, there is provided a system for determining a trajectory of an elongated tool into a body of a patient, the system comprising:

a memory module configured to receive imaging data of a preliminary 3-dimensional (3D) image of ~~a~~ the body from a 3D imaging device, the body comprising an opaque body surface, a target and at least one occlusion between the body surface and the target;

a processor communicatively coupled with the memory module, wherein the processor is configured to:

process the preliminary 3D image of the body from the 3D imaging device to obtain location data of the ~~target,~~ body surface and at least one occlusion; ~~and~~

determine a 3D voxel grid based on a volume of the target to calculate coordinates of a centroid of the target;

using the coordinates of the centroid, determine one or more sets of coordinates of locations around the centroid in the 3D voxel grid for striking the target; and

based on ~~a location~~ the sets of coordinates around the centroid of the target relative to the body surface and at least one occlusion, determine at least one trajectory for the elongated tool to strike the target.

[0007] The processor may further be configured to determine at least one tool insertion point on the body surface to determine the at least one trajectory for the elongated tool to strike the target.

[0008] The processor may further be configured to determine the insertion point on the body surface having the shortest distance between the body surface and the target.

[0009] The processor may further be configured to determine the insertion point on the body surface such that a line between the insertion point and the target bypasses the at least one occlusion.

[0010] ~~The processor may further be configured to determine coordinates of a centroid of the target to obtain location data of the target.~~

[0011] The system may further comprise a display device coupled to the processor, wherein the processor may further be configured to simulate a trajectory of the elongated tool based on the determined at least one trajectory for display on the display device.

[0012] According to a second aspect of the present invention, there is provided a system for striking a target in a body of a patient using an elongated tool, the system comprising;

a 3D imaging device;

the system as defined in the first aspect connected to the 3D imaging device;

an adjustment mechanism configured to adjust an angular orientation of the elongated tool relative to the insertion point; and

an actuator coupled to the adjustment mechanism for moving the adjustment mechanism according to signals received from the processor,

wherein the 3D imaging device is further configured to capture a real-time 3D image of the body and the elongated tool,

wherein the processor is further configured to control the adjustment mechanism to align a longitudinal axis of the elongated tool with a selected trajectory based on the real-time 3D image, the processor further configured to calculate a striking distance between the insertion point and the target based on location data of the insertion point and the ~~target~~ sets of coordinates around the centroid; and

wherein the actuator is configured to drive the elongated tool toward the target based on the angular orientation of the elongated tool at alignment and the calculated striking distance.

[0013] The processor may further be configured to associate the real-time 3D image with the preliminary 3D image, to align the elongated tool to the selected trajectory.

[0014] The 3D imaging device may comprise at least one selected from a group consisting of a magnetic resonance imaging (MRI) machine, a computerized tomography (CT) scanner and a fluoroscope.

[0015] The adjustment mechanism may comprise a base and a platform, wherein the platform is configured to be parallel to the base.

[0016] The adjustment mechanism may further comprise a plurality of arms linking the base with the platform, the plurality of arms being configured to move the platform along a plane parallel to the base to adjust the angular orientation of the elongated tool relative to the insertion point.

[0017] The platform may comprise a ball joint compliance for supporting the elongated tool, the ball joint compliance comprising a hole configured to allow sliding movement of the elongated tool therethrough.

[0018] The adjustment mechanism may further comprise a tool holder detachable from the platform.

[0019] According to a third aspect of the present invention, there is provided a method for determining a trajectory of an elongated tool into a body of a patient, the method comprising the steps of:

receiving a preliminary 3-dimensional (3D) image of ~~a~~ the body, the body comprising an opaque body surface, a target and at least one occlusion between the body surface and the target;

processing the preliminary 3D image of the body from the 3D imaging device to obtain location data of the ~~target,~~ body surface and at least one occlusion; ~~and~~

determine a 3D voxel grid based on a volume of the target to calculate coordinates of a centroid of the target;

using the coordinates of the centroid, determine one or more sets of coordinates of locations around the centroid in the 3D voxel grid for striking the target; and

based on ~~a location of~~ the sets of coordinates around the centroid the target relative to the body surface and at least one occlusion, determining at least one trajectory for the elongated tool to strike the target.

[0020] The step of determining the at least one trajectory for the elongated tool to strike the target may comprise determining at least one tool insertion point on the body surface.

[0021] The step of determining the at least one tool insertion point on the body surface may comprise determining the insertion point having the shortest distance between the body surface and the target.

[0022] The step of determining the at least one tool insertion point on the body surface may comprise determining the insertion point on the body surface such that a line between the insertion point and the target bypasses the at least one occlusion.

[0023] ~~The step of processing the preliminary 3D image of the body to obtain location data of the target may comprise determining coordinates of a centroid of the target.~~

[0024] The method may further comprise the step of simulating a trajectory of the elongated tool based on the determined at least one trajectory for display on a display device.

[0025] According to a fourth aspect of the present invention, there is provided a method of striking a target in a body of a patient using an elongated tool, the method comprising the steps of:

determining at least one trajectory for the elongated tool to strike the target using the method as defined in the third aspect;

receiving a real-time 3D image of the body and the elongated tool;

aligning a longitudinal axis of the elongated tool with a selected trajectory based on the real-time 3D image;

calculating a striking distance between the insertion point and the target based on location data of the insertion point and the ~~target~~ sets of coordinates around the centroid; and

advancing the elongated tool toward the target according to the calculated distance.

[0026] The step of aligning the longitudinal axis of the elongated tool with the selected trajectory may comprise associating the real-time 3D image with the preliminary 3D image.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] Embodiments of the invention are provided by way of example only, and will be better understood and readily apparent to one of ordinary skill in the art from the following written description and the drawings, in which:

[0028] Figure 1A shows a schematic diagram illustrating a set-up for determining a trajectory of an elongated tool according to an example embodiment.

[0029] Figure 1B shows the connections between components of the set-up of Figure 1A.

[0030] Figure 2A shows a perspective view of an adjustment mechanism suitable for use in the system of Figures 1A and 1B.

CLAIMS

1. A system for determining a trajectory of an elongated tool into a body of a patient, the system comprising:

a memory module configured to receive imaging data of a preliminary 3-dimensional (3D) image of ~~a~~ the body from a 3D imaging device, the body comprising an opaque body surface, a target and at least one occlusion between the body surface and the target;

a processor communicatively coupled with the memory module, wherein the processor is configured to:

process the preliminary 3D image of the body from the 3D imaging device to obtain location data of the ~~target,~~ body surface and at least one occlusion; ~~and~~

determine a 3D voxel grid based on a volume of the target to calculate coordinates of a centroid of the target;

using the coordinates of the centroid, determine one or more sets of coordinates of locations around the centroid in the 3D voxel grid for striking the target; and

based on ~~a location~~ the sets of coordinates around the centroid of the target relative to the body surface and at least one occlusion, determine at least one trajectory for the elongated tool to strike the target.

2. The system as claimed in claim 1, wherein the processor is further configured to determine at least one tool insertion point on the body surface to determine the at least one trajectory for the elongated tool to strike the target.

3. The system as claimed in claim 2, wherein the processor is further configured to determine the insertion point on the body surface having the shortest distance between the body surface and the target.

4. The system as claimed in claim 2 or 3, wherein the processor is further configured to determine the insertion point on the body surface such that a line between the insertion point and the target bypasses the at least one occlusion.

~~5. The system as claimed in any one of the preceding claims, wherein the processor is further configured to determine coordinates of a centroid of the target to obtain location data of the target.~~

~~6~~5. The system as claimed in any one of the preceding claims, further comprising a display device coupled to the processor, wherein the processor is further configured to simulate a trajectory of the elongated tool based on the determined at least one trajectory for display on the display device.

~~7~~6. A system for striking a target in a body of a patient using an elongated tool, the system comprising:

a 3D imaging device;

the system as claimed in any one of claims 2 to 4 connected to the 3D imaging device;

an adjustment mechanism configured to adjust an angular orientation of the elongated tool relative to the insertion point; and

an actuator coupled to the adjustment mechanism for moving the adjustment mechanism according to signals received from the processor,

wherein the 3D imaging device is further configured to capture a real-time 3D image of the body and the elongated tool,

wherein the processor is further configured to control the adjustment mechanism to align a longitudinal axis of the elongated tool with a selected trajectory based on the real-time 3D image, the processor further configured to calculate a striking distance between the insertion point and the target based on location data of the insertion point and the ~~target~~ sets of coordinates around the centroid; and

wherein the actuator is configured to drive the elongated tool toward the target based on the angular orientation of the elongated tool at alignment and the calculated striking distance.

~~8~~7. The system as claimed in claim ~~7~~6, wherein the processor is further configured to associate the real-time 3D image with the preliminary 3D image, to align the elongated tool to the selected trajectory.

~~9~~8. The system as claimed in claim ~~7~~6 or ~~8~~7, wherein the 3D imaging device comprises at least one selected from a group consisting of a magnetic resonance imaging (MRI) machine, a computerized tomography (CT) scanner and a fluoroscope.

~~10~~9. The system as claimed in any one of claims ~~7~~6 to ~~9~~8, wherein the adjustment mechanism comprises a base and a platform, wherein the platform is configured to be parallel to the base.

~~11~~10. The system as claimed in claim ~~10~~9, wherein the adjustment mechanism further comprises a plurality of arms linking the base with the platform, the plurality of arms being configured to move the platform along a plane parallel to the base to adjust the angular orientation of the elongated tool relative to the insertion point.

~~12~~11. The system as claimed in claim ~~10~~9 or ~~11~~10, wherein the platform comprises a ball joint compliance for supporting the elongated tool, the ball joint compliance comprising a hole configured to allow sliding movement of the elongated tool therethrough.

~~13~~12 The system as claimed in any one of claims ~~10~~9 to ~~12~~11, wherein the adjustment mechanism further comprises a tool holder detachable from the platform.

~~14~~13. A method for determining a trajectory of an elongated tool into a body of a patient, the method comprising the steps of:

receiving a preliminary 3-dimensional (3D) image of ~~a~~ the body, the body comprising an opaque body surface, a target and at least one occlusion between the body surface and the target;

processing the preliminary 3D image of the body from the 3D imaging device to obtain location data of the ~~target,~~ body surface and at least one occlusion; ~~and~~

determine a 3D voxel grid based on a volume of the target to calculate coordinates of a centroid of the target;

using the coordinates of the centroid, determine one or more sets of coordinates of locations around the centroid in the 3D voxel grid for striking the target; and

based on ~~a location~~ the sets of coordinates around the centroid of the target relative to the body surface and at least one occlusion, determining at least one trajectory for the elongated tool to strike the target.

~~15~~14. The method as claimed in claim ~~14~~13, wherein determining the at least one trajectory for the elongated tool to strike the target comprises determining at least one tool insertion point on the body surface.

~~16~~15. The method as claimed in claim ~~15~~14, wherein determining the at least one tool insertion point on the body surface comprises determining the insertion point having the shortest distance between the body surface and the target.

~~17~~16. The method as claimed in claim ~~15~~14 or ~~16~~15, wherein determining the at least one tool insertion point on the body surface comprises determining the insertion point on the body surface such that a line between the insertion point and the target bypasses the at least one occlusion.

~~18. The method as claimed in any one of claims 14 to 17, wherein processing the preliminary 3D image of the body to obtain location data of the target comprises determining coordinates of a centroid of the target.~~

~~19~~17. The method as claimed in any one of claims ~~14~~13 to ~~18~~16, further comprising the step of simulating a trajectory of the elongated tool based on the determined at least one trajectory for display on a display device.

~~20~~18. A method of striking a target in a body of a patient using an elongated tool, the method comprising the steps of:

determining at least one trajectory for the elongated tool to strike the target using the method as claimed in any one of claims ~~15~~14 to ~~17~~16;

receiving a real-time 3D image of the body and the elongated tool;

aligning a longitudinal axis of the elongated tool with a selected trajectory based on the real-time 3D image;

calculating a striking distance between the insertion point and the target based on location data of the insertion point and the sets of coordinates around the centroid~~target~~; and

advancing the elongated tool toward the target according to the calculated distance.

~~21~~19. The method as claimed in claim ~~20~~18, wherein aligning the longitudinal axis of the elongated tool with the selected trajectory comprises associating the real-time 3D image with the preliminary 3D image.