Supplementary data for

A High-Precision US-Guided Robot-Assisted HIFU Treatment System for Breast Cancer

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Algorithm of 3D US image reconstruction

The algorithm that reconstructs the 3D US image from the stack of 2D images is summarized below.

Algorithm 1
3D US image reconstruction from linear scans.

Data: Image stacks $I(u,v,f)$; speed vector $\boldsymbol{v}$ that specifies the scan motion; initial end-effector pose ${}^{B}\xi_{E(1)}$;

Result: Volume data $V(i,j,k)$ of 3D US image;

Begin

1 Form the spatial transformation matrix $T1$: $(u,\ v,\ f) \Leftrightarrow ({}^{I}x,\ {}^{I}y,\ f)$ by utilizing ${}^{I}\xi_{U}$;

2 Determine the bounding box of the volume in $\{B\}$ by utilizing $T1$ and the input information;
3 Determine the volume dimension (Dim1, Dim2, Dim3) by using the bounding box and predefined voxel size;

4 Form the inverse spatial transformation matrix $T2$: $({}^{I}x,\ {}^{I}y,\ f) \Leftarrow ({}^{B}x,\ {}^{B}y,\ {}^{B}z)$;

Begin

/* $\boldsymbol{n}$ is the normal vector of the first frame in coordinate system $\{B\}$, which is along the z axis of $\{I\}$ */

/* ${}^{B}\boldsymbol{x}_{I}$ is the unit vector along the x axis of coordinate system $\{I\}$, with respect to $\{B\}$ */

/* ${}^{B}\boldsymbol{y}_{I}$ is the unit vector along the y axis of coordinate system $\{I\}$, with respect to $\{B\}$ */

$\forall\, {}^{B}\boldsymbol{p} \sim ({}^{B}x,\ {}^{B}y,\ {}^{B}z)$;

$f = \left[{}^{B}\boldsymbol{p} - {}^{B}\boldsymbol{o}(1)\right] \cdot \boldsymbol{n} \big/ \| \boldsymbol{s} \| + 1$;

${}^{I}x = \left[{}^{B}\boldsymbol{p} - {}^{B}\boldsymbol{o}(f)\right] \cdot {}^{B}\boldsymbol{x}_{I}$; /* inner product */

${}^{I}y = \left[{}^{B}\boldsymbol{p} - {}^{B}\boldsymbol{o}(f)\right] \cdot {}^{B}\boldsymbol{y}_{I}$

end

5 Form the spatial transformation matrix $T3$: $({}^{B}x,\ {}^{B}y,\ {}^{B}z) \Leftrightarrow (i,\ j,\ k)$; /* user defined transformation */

/* Do the calculation */

for $i \leftarrow 1$ to Dim1 **do**
for $j \leftarrow 1$ to Dim2 **do**
for $k \leftarrow 1$ to Dim3 **do**

6 Retrieve the frame index f;

7 $(u,\ v)^{\mathrm{T}} = \left[T3 \cdot T2(f) \cdot T1\right]^{-1} \cdot (i,\ j,\ k)^{\mathrm{T}}$; */

/* Assign value to the voxel

8 $V(i,\ j,\ k) \leftarrow$ **Interpolate** on $I(u,\ v,\ f)$;

end
end
end

end
