研究报告

2021 11 109 2021 12 27

Artificial Intelligence AI

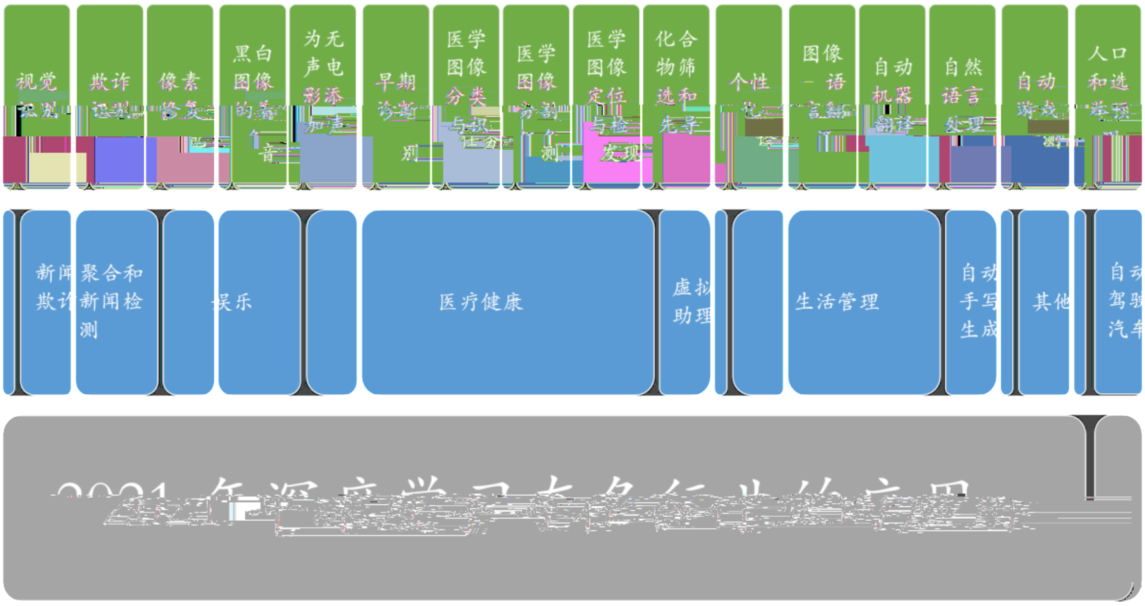
(Machine

Learning ML)

“ ”

(Deep Learning, DL)

1-1



Magnetic Resonance Imaging

MRI

Computer

Tomography CT X

X

X

X

2D X

⑤

Positron Emission Computed Tomography PET

PET

1-2

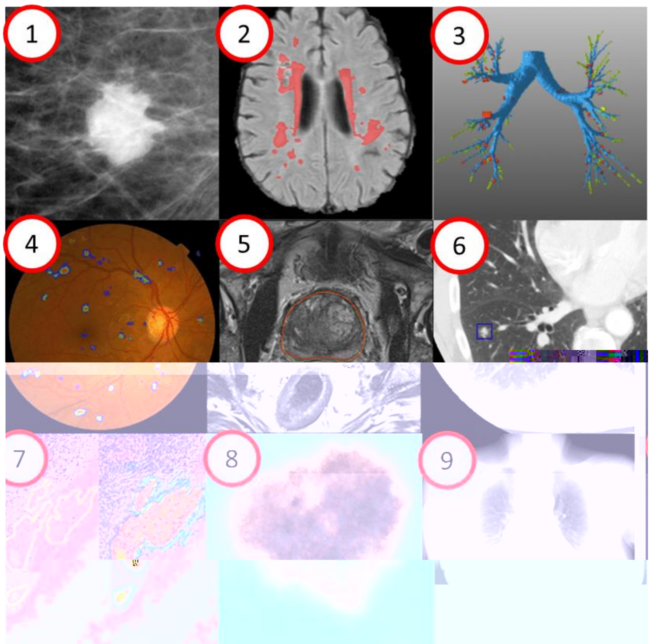
X [1] [2]

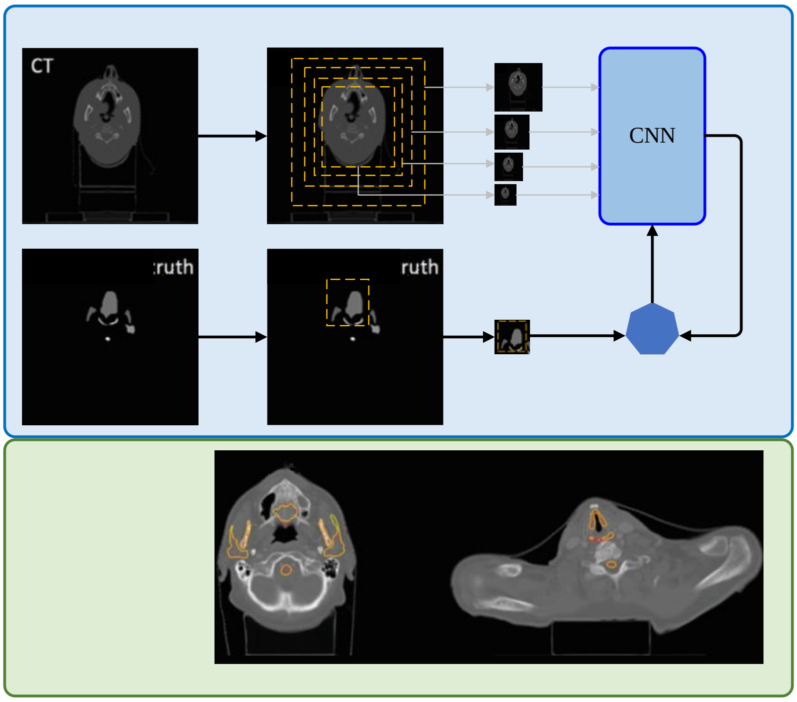
[3] [4]

[5] X

[6]

[7]





2-3 a

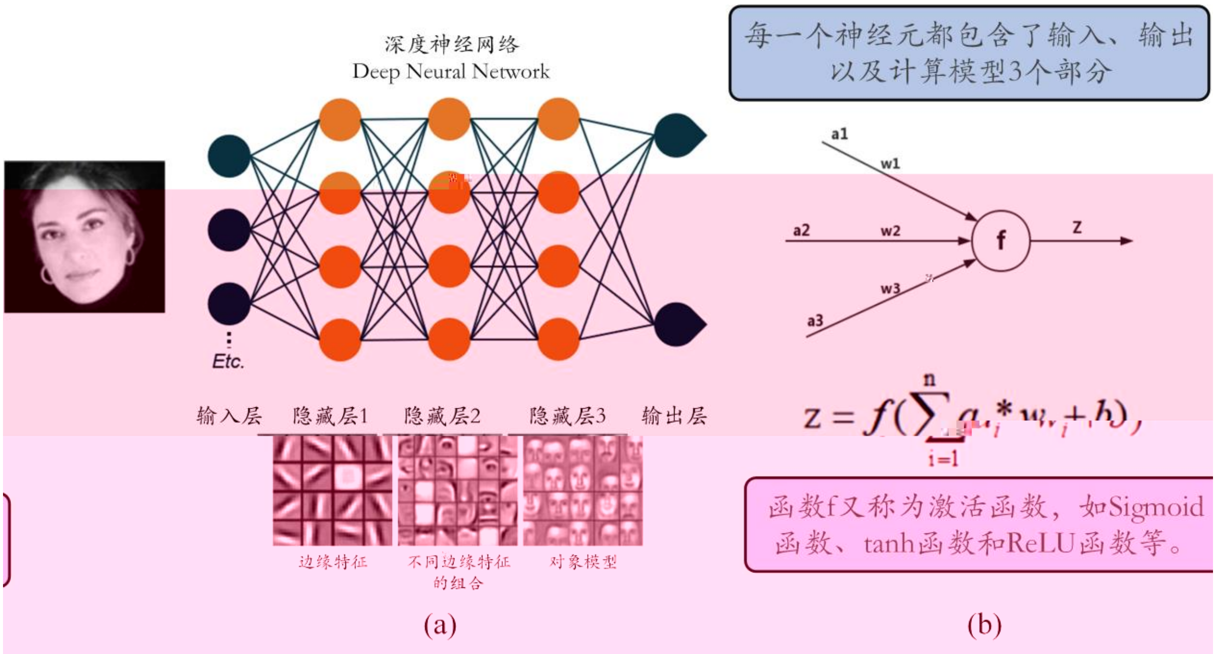
2-3 b

a_1 a_2 a_3

z 0 1

$\sum a_i w_i$ b

w_i


深度神经网络
Deep Neural Network
Etc.
输入层
隐藏层1
隐藏层2
隐藏层3
输出层
边缘特征
不同边缘特征的组合
对象模型
每一个神经元都包含了输入、输出以及计算模型3个部分
a1
w1
a2
w2
a3
w3
f
Z
$z = f(\sum_{i=1}^{n} a_i * w_i + b)$，
函数f又称为激活函数，如Sigmoid函数、tanh函数和ReLU函数等。
(a)
(b)

1

1-2

(5)

2

Multilayer Perceptron

MLP

3

2-4

2D 3D

4

2-5 GPU

GPU Intel

NVIDIA

Tensorflow Caffe Theano Torch

PyTorch Tensorflow

Torch

2 ω

2-7

3

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2-8

①

②

500Mb

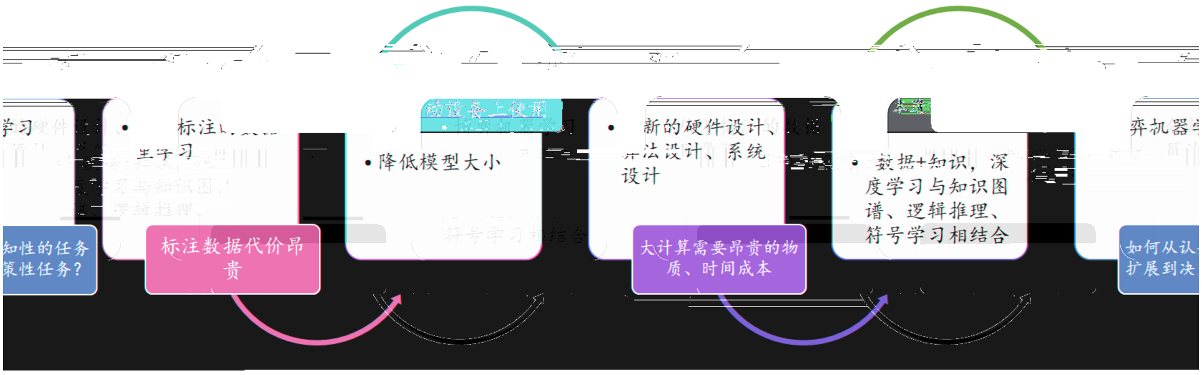
CNN

RNN

③

④

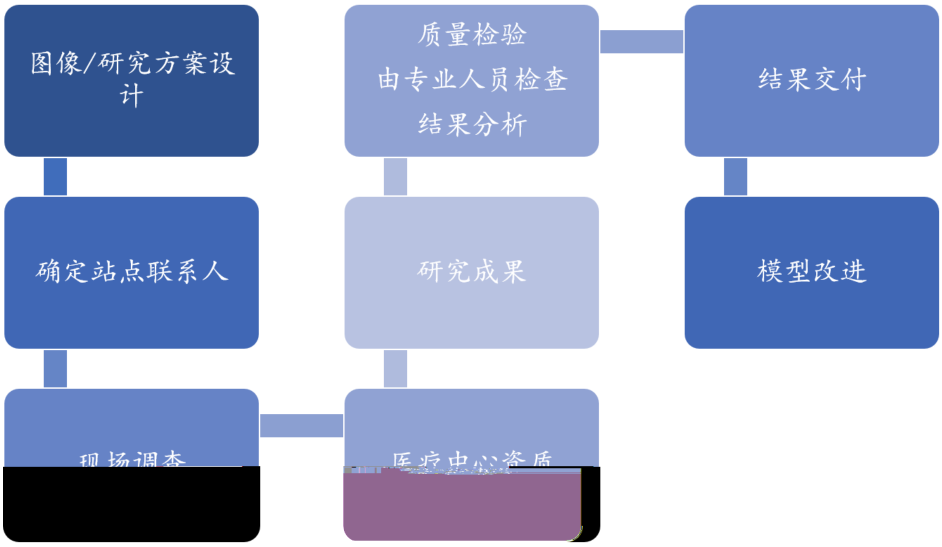
⑤


降低模型大小
新的硬件设计、
设计
数据+知识，深度学习与知识图谱、逻辑推理、符号学习相结合
标注数据代价昂贵
大计算需要昂贵的物质、时间成本

MRI CT

2-9

AI

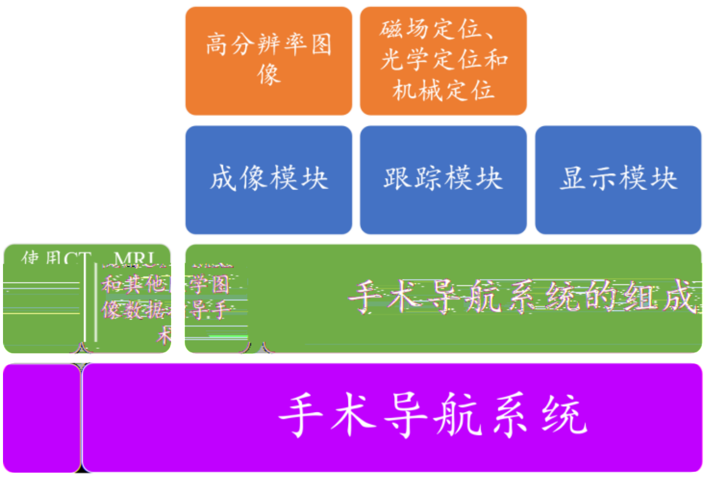


CT

Image Guided Surgery IGS

3-1

MRI



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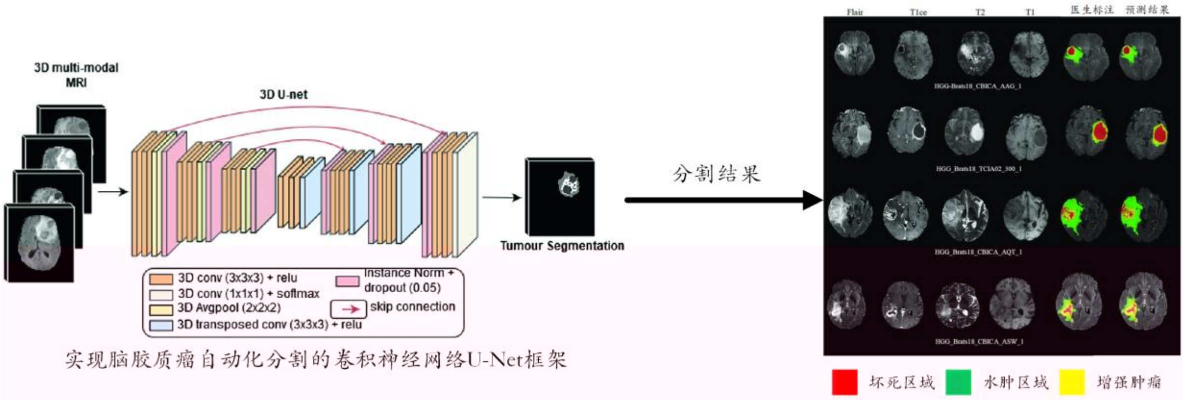
3-2

Zhou [8]

Ali [9]



实现脑胶质瘤自动化分割的卷积神经网络U-Net框架

2

3-1

[10] a	J. Weickenmeier
[11] b	A. Mohammadi
[12] c	A. Mohammadi
[13] c	M. I. Miga
[14] c	N. Hamze
[15] c	A. L. Simpson
[16] d	Kay Sun
[17] c	N. D. Serej
GPU [18] b	G. R. Joldes
[19] e	Chenxi Zhang
[20] d	M. Bucki

D.-X. Zhuang

[21] d 3DIMAGE

a- b- c- d-

e-

BrainLAB Stryker

Medtronic GE

Medtronic Xion Karl Storz Stryker BrainLAB

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3-2

Da Vinci [22]	Intuitive Surgical
NeuroArm [23]	G. R. Sutherland

Excelim-04	
DigiPointeur	

——BrainLAB ClaroNav

Medtronic Stryker

3-3

BrainLAB	1989	BrainLAB	3D	2019 medineering 2017 1 10 medineering A 2016 1 25 Jan Medical 350 C 2013 8 30 Jan Medical B

			2011 6 17 Jan Medical 350 A
ClaroNav	2001	Navient Navient	2020 2 21 - ClaroNav 200 2019 3 4 - ClaroNav 4.456
Medtronic	1949	StealthStation S7 (EM)	2021 8 12 - 1.5 2021 4 26 A- Scivita 4 2020 12 6 : F- Brainsgate 1400 2020 9 23 - Triple Jump Medical 2000 * https://www.crunchbase.com/organization/medtronic/company_financials
Stryker	1941	Stryker	2019 OrthoSpace 2006 8 11 A - Histogenics 1310

Stryker

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Stryker

1 BrainLAB

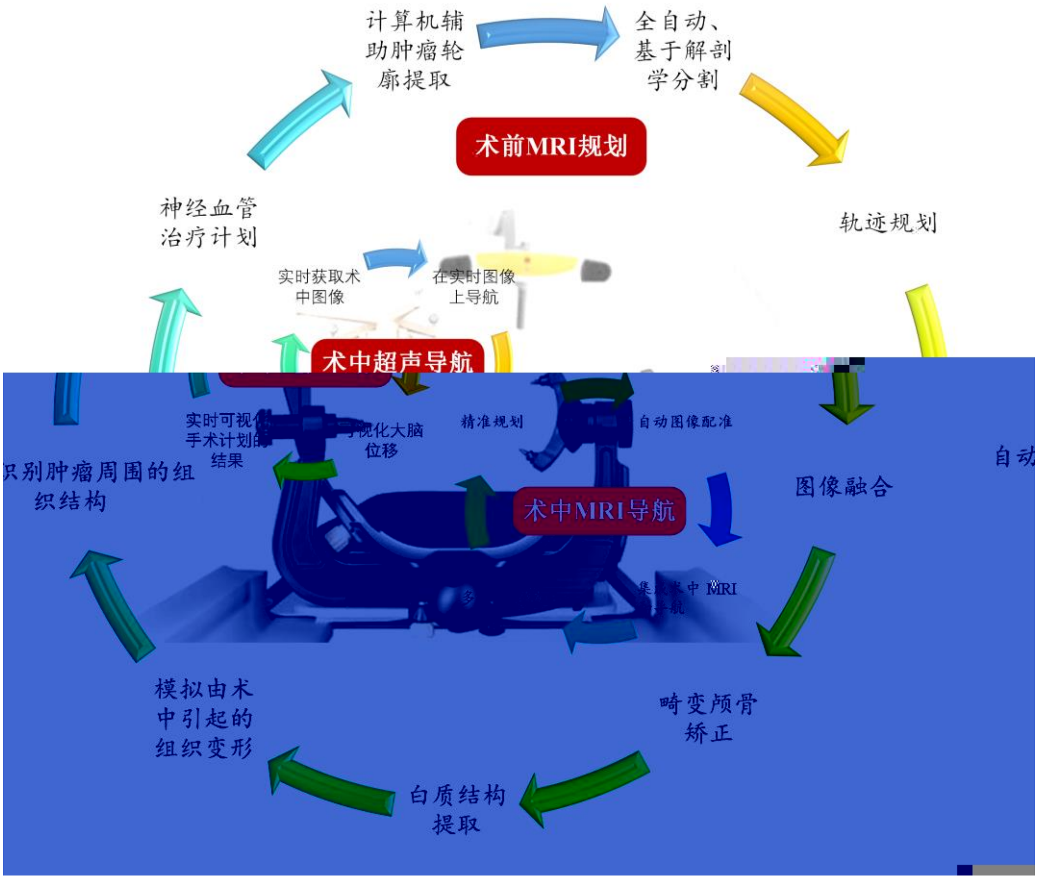
BrainLAB

3D

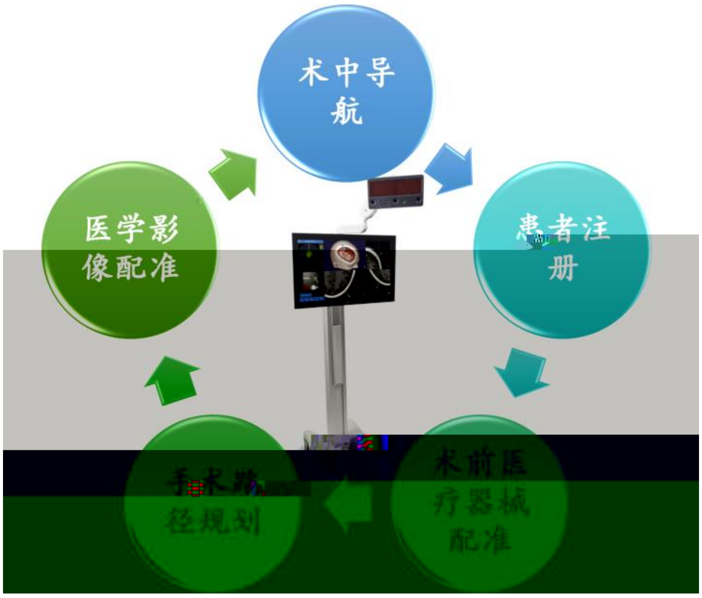
3-3

2 ClaroNav

Navient



计算机辅
助肿瘤轮
廓提取
全自动、
基于解剖
学分割
术前MRI规划
轨迹规划
神经血管
治疗计划
实时获取术
中图像
在实时图像
上导航
术中超声导航
精准规划
自动图像配准
图像融合
术中MRI导航
织结构
模拟由术
中引起的
组织变形
畸变颅骨
矫正
白质结构
提取



术中导
航
患者注
册
医学影
像配准

3 Medtronic

Medtronic StealthStation S7

CT MR

StealthStation S7

StealthStation S7

Stealth ——

3-5

4 Stryker

Stryker

3-6

X CT

MRI

GPU

Artificial Intelligence AI

Computer-aided Diagnosis CAD

Convolutional Neural Network CNN

Deep Belief Network DBN

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Deep Learning DL

Image Guided Surgery IGS

Machine Learning ML

Multilayer Perceptron MLP

Reinforcement Learning RL

Recurrent Neural Network RNN

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[1]Kooi T, Litjens G, Ginneken B, *et al*. Large Scale Deep Learning for Computer Aided Detection of Mammographic Lesions[J]. Medical Image Analysis, 2017, 35:303-312.

[2] Ghafoorian M , Karssemeijer N , Heskes T , *et al*. Non-uniform patch sampling with deep convolutional neural networks for white matter hyperintensity segmentation. IEEE, 2016:1414-1417.

[3] Charbonnier J P, Rikxoort E, Setio A, *et al*. Improving airway segmentation in computed tomography using leak detection with convolutional networks.[J]. Medical image analysis, 2017, 36:52-60.

[4] Grinsven M V , Ginneken B V , Hoyng C , *et al*. Fast Convolutional Neural Network Training Using Selective Data Sampling: Application to Hemorrhage Detection in Color Fundus Images[J]. IEEE Transactions on Medical Imaging, 2016:1273-1284.

[5] Andre E , Brett K , Novoa R A , *et al*. Dermatologist-level classification of skin cancer with deep neural networks[J]. Nature, 2019, 2017 542 7639 :115-118 .

[6] Yang, Wei, Chen, *et al*. Cascade of multi-scale convolutional neural networks for bone suppression of chest radiographs in gradient domain.[J]. Medical Image Analysis, 2017, 35:421-433.

[7] Zhang L , Zhang Y . Big data analysis by infinite deep neural networks[J]. Journal of Computer Research and Development, 2016, 53: 68 79.

[8] Zhou T , Canu S , Su R . Fusion based on attention mechanism and context constrain for multi-modal brain tumor segmentation[J]. Computerized Medical Imaging and Graphics, 2020, 86(13):101811.

[9] Ali M B , Gu Y H , Berger M S , *et al*. Domain Mapping and Deep Learning from Multiple MRI Clinical Datasets for Prediction of Molecular Subtypes in Low Grade Gliomas[J]. Brain Sciences, 10(7).
[10] Weickenmeier J , Butler C , Young P G , *et al*. The mechanics of decompressive craniectomy: Personalized simulations[J]. Computer Methods in Applied Mechanics and Engineering, 2016, 314: 180 – 195.
[11] Mohammadi A , Ahmadian A , Rabbani S , *et al*. A combined registration and finite element analysis method for fast estimation of intraoperative brain shift; phantom and animal model study[J]. The International Journal of Medical Robotics and Computer Assisted Surgery, 2017, 13(4).
[12]Mohammadi A , Ahmadian A , Azar A D , *et al*. Estimation of intraoperative brain shift by combination of stereovision and doppler ultrasound: phantom and animal model study[J]. International Journal of Computer Assisted Radiology and Surgery, 2015, 10(11): 1753 1764.
[13] Miga M I , Sun K , Chen I , *et al*. Clinical evaluation of a model-updated image-guidance approach to brain shift compensation: experience in 16 cases[J]. International Journal of Computer Assisted Radiology & Surgery, 2015, 11(8):1467-1474.
[14] Hamze N, Bilger A , Duriez C , *et al*. Anticipation of Brain Shift in Deep Brain Stimulation Automatic Planning.[J]. Annual International Conference of the IEEE Engineering in Medicine and Biology Society, United States: 2015: 3635 3638.
[15] Simpson A L, Sun K, Pheiffer T S, *et al*. Evaluation of Conoscopic Holography for Estimating Tumor Resection Cavities in Model-Based Image-Guided Neurosurgery[J]. IEEE Trans Biomed Eng, 2014, 61(6):1833-1843.

[16] Sun K , Pheiffer T S , Simpson A I , *et al.* Near Real-Time Computer Assisted Surgery for Brain Shift Correction Using Biomechanical Models[J]. IEEE Journal of Translational Engineering in Health & Medicine, 2014, 2(1):1-13.
[17] Serej N D , Ahmadian A , Mohagheghi S , *et al.* A projected landmark method for reduction of registration error in image-guided surgery systems[J]. International Journal of Computer Assisted Radiology & Surgery, 2015, 10(5):541-554.
[18] Joldes G R , Wittek A , Miller K . Real-Time Nonlinear Finite Element Computations on GPU - Application to Neurosurgical Simulation[J]. Computer Methods in Applied Mechanics & Engineering, 2010, 199(49-52): 3305 3314.
[19] Zhang C , Wang M , Song Z . A Brain-Deformation Framework Based on a Linear Elastic Model and Evaluation Using Clinical Data[J]. IEEE Transactions on Biomedical Engineering, 2011, 58(1):191-199.
[20] Bucki M , Palombi O , Bailet M , *et al.* Doppler Ultrasound Driven Biomechanical Model of the Brain for Intraoperative Brain-Shift Compensation: A Proof of Concept in Clinical Conditions[J]. Springer Berlin Heidelberg, 2012.
[21] Zhuang D X , Liu Y X , Wu J S , *et al.* A Sparse Intraoperative Data-Driven Biomechanical Model to Compensate for Brain Shift during Neuronavigation[J]. Ajnr American Journal of Neuroradiology, 2011, 32(2):395-402.
[22] Fa Ria C , Erlhagen W , Momi E D , *et al.* Review of Robotic Technology for Stereotactic Neurosurgery[J]. IEEE Reviews in Biomedical Engineering, 2015, 8: 125 – 137.
[23] Sutherland G R , Latour I , Greer A D . Integrating an Image-Guided Robot with Intraoperative MRI[J]. Engineering in Medicine & Biology Magazine IEEE, 2008, 27(3):59-65.
[24]MD Comparetti, Momi E D , Vaccarella A , *et al.* Optically tracked multi-robot system for keyhole neurosurgery[C]// 2011 IEEE International Conference on Robotics and Automation. 2011: 661 – 666.

[25] Devito D P , Kaplan L , Dietl R , *et al.* Clinical acceptance and accuracy assessment of spinal implants guided with SpineAssist surgical robot: retrospective study.[J]. Spine, 2010, 35(24): 2109 – 2115.

[26]Amin D V , Lunsford L D . Volumetric resection using the SurgiScope: a quantitative accuracy analysis of robot-assisted resection.[J]. Stereotactic & Functional Neurosurgery, 2004, 82(5-6):250-253.

[27] Li Q H , Ph. D , Zamorano L , *et al.* The Application Accuracy of the NeuroMate Robot A Quantitative Comparison with Frameless and Frame-Based Surgical Localization Systems. [J]. Computer Aided Surgery: Official Journal Of The International Society For Computer Aided Surgery, England: 2002, 7(2): 90 98.

[28] Gonzalez-Martinez J , Vadera S , Mullin J , *et al.* Robot-Assisted Stereotactic Laser Ablation in Medically Intractable Epilepsy[J]. Neurosurgery, 2014, United States: 2014, 10 Suppl 2: 163 – 167.

[29] ArneRadetzky, MichaelRudolph, WernerStefanon, *et al.* Simulating Minimally Invasive Neurosurgical Interventions Using an Active Manipulator[C]// International Conference on Medical Image Computing and Computer-Assisted Intervention. Springer, Berlin, Heidelberg, 2000.

[30] Deacon G , Harwood A , Holdback J , *et al.* The Pathfinder image-guided surgical robot[J]. Proc Inst Mech Eng H, 2010, 224(5):691-713.

[31] Said A , Aboulfotouh M , Sobhi M , *et al.* Adaptation of a hexapod-based robotic system for extended endoscope-assisted transsphenoidal skull base surgery.[J]. Minim Invasive Neurosurg, 2004, 47(01):41-46.

[32] Ma C , Chen G , Zhang X , *et al.* Moving-tolerant Augmented Reality Surgical Navigation System using Autostereoscopic 3D Image Overlay[J]. IEEE Journal of Biomedical and Health Informatics, 2019, 23(6): 2483 – 2493.

[33] A A W , A G J , C M C A , *et al.* Patient-specific non-linear finite element modelling for predicting soft organ deformation in real-time; Application to non-rigid neuroimage registration[J]. Progress in Biophysics and Molecular Biology, 2010, 103(2 3):292-303.

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BrainLAB ClaroNav

Medtronic Stryker

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