研究报告

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BCI

BCI

50 -

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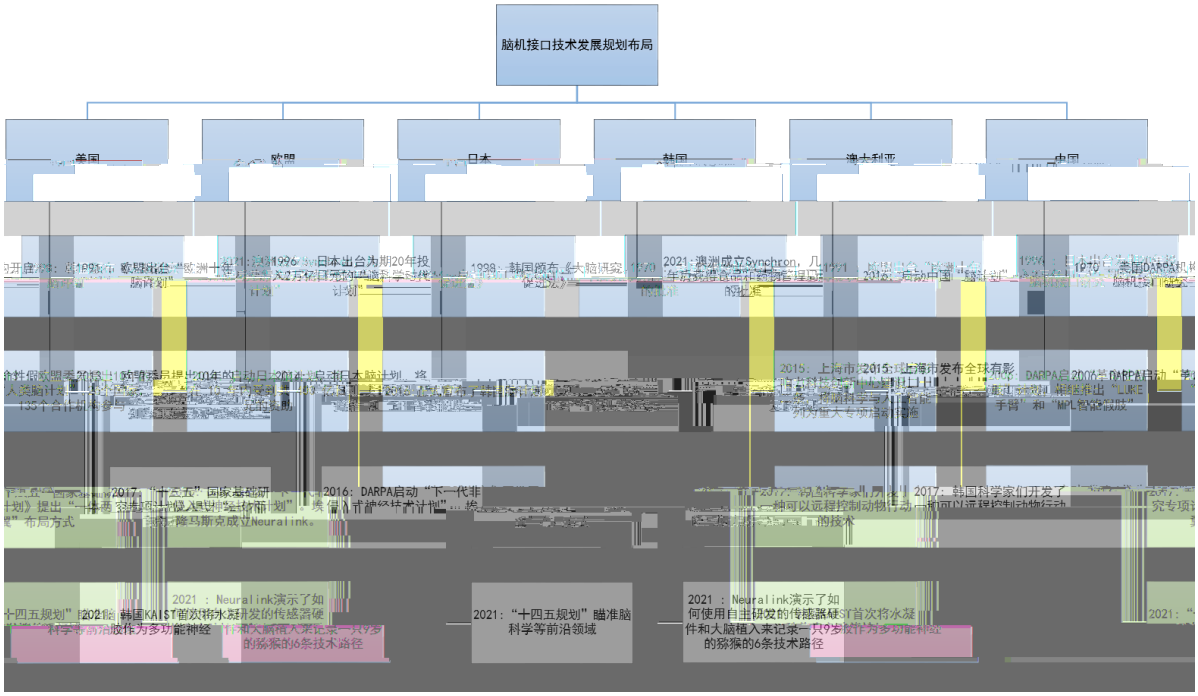
1

Brain-Computer Interface BCI



1-1

1989 20

10 10 2013 4 2

BRAIN Initiative

1 12 45

National Institutes of Health NIH

Defense Advanced Research Projects Agency

DARPA National Science Foundation NSF

2014 2

BRAIN 2015 2

6 5 NIH BRAIN BRAIN 2025

NIH

2014 6 20 Cal-BRAIN

2018 11 2 NIH

2.2 200

2019 10 21 BRAIN 2.0

BRAIN 2025

2016 NIH

DARPA

RE-NET

SUBNETS HAPTIX

N3 INI

Human Brain Project HBP 2013 10 1

26

135 [1] 10

13

HBP

/ Brain/MINDS 2014

10

400

Korean Brain Initiative, KBI

[2]

Alzheimer's disease,

AD PD

/

Australian Brain Alliance, ABA

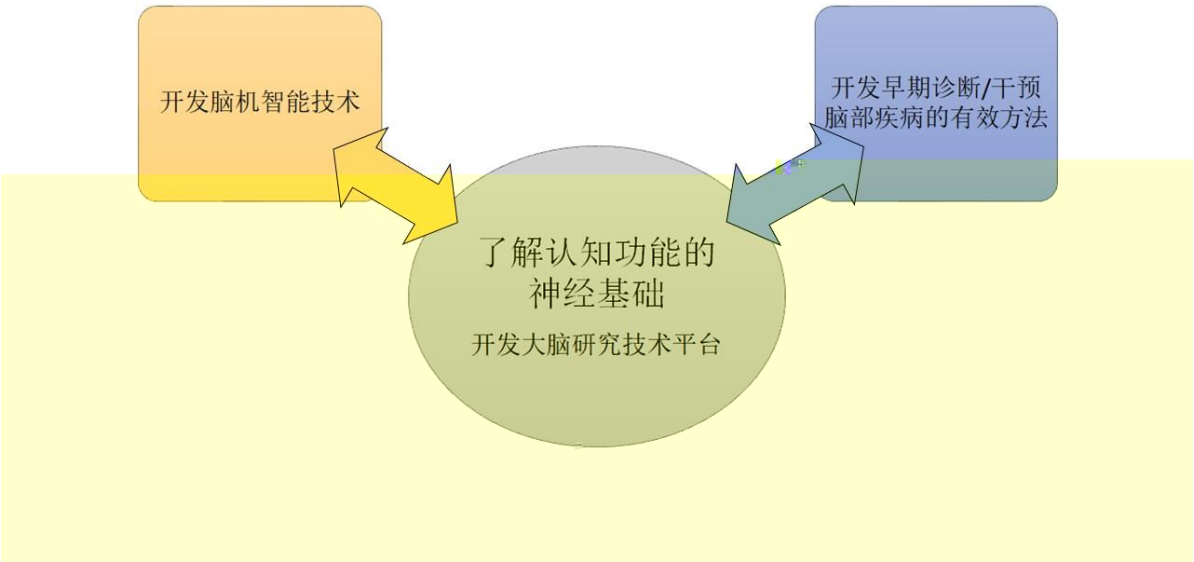
Australian Brain Initiative, ABI [3]

1-2

2016

2017

[4]



1-2

2035

2015

2018

2018 12

2015 5

2019

(2019 2022)

2021

BCI

[5]

BCI

[5]

[6]

1977 Jacques J. Vidal

4 1980

[6]

1980 1990

1988 L.A. Farwell E. Donchin

P300

Stevo Bozinovski

alpha

[6]

Gert Pfurtscheller

[6]

1992 Erich E. Sutter

10 / [6]

1999

[6]

21

xDAWN [7]

90

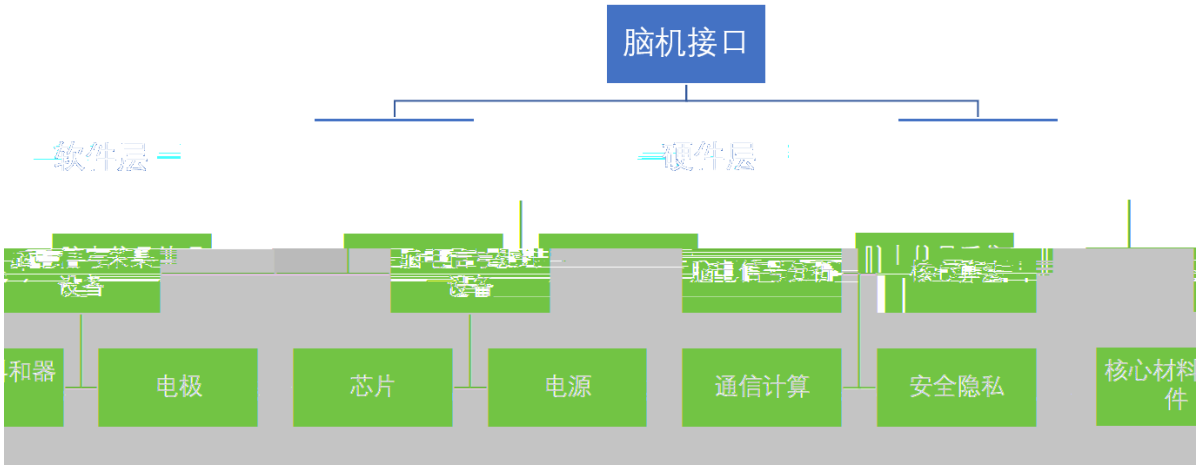
[4]

[8]

[9]

SmartCap

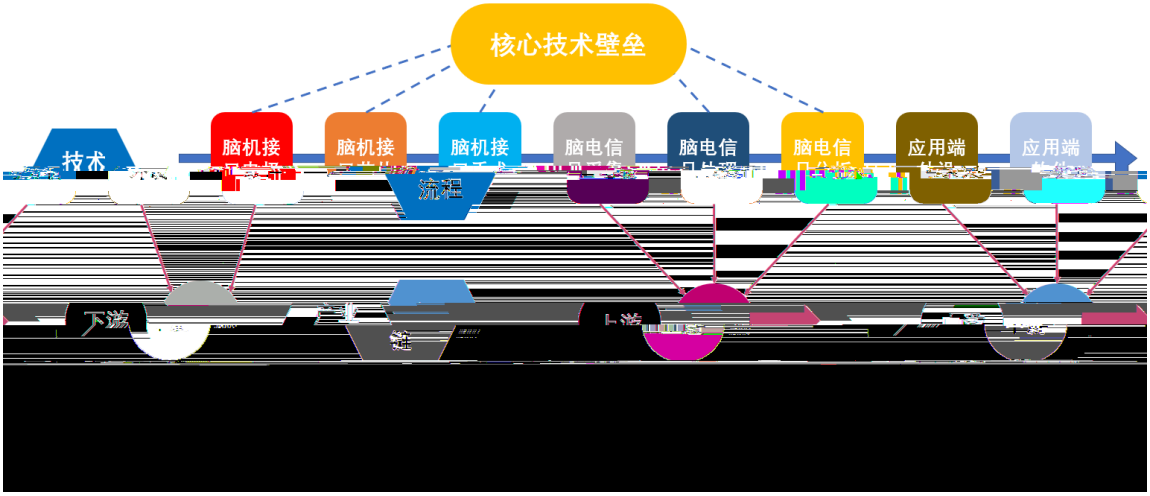
[9]



3-1

3-1

3-2

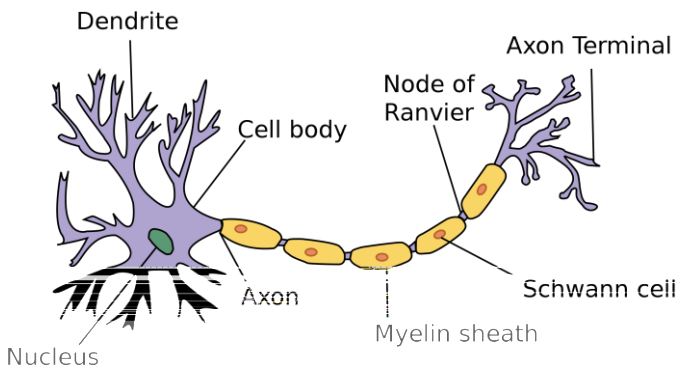


3-2

K^+

Na^+

3-3

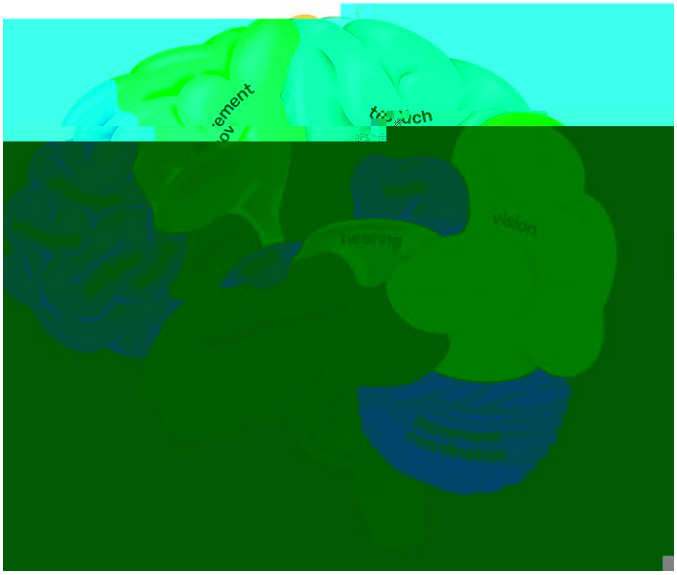

Dendrite
Axon Terminal
Node of
Ranvier
Cell body
Schwann cell
Axon
Myelin sheath
Nucleus

3-3 [17]

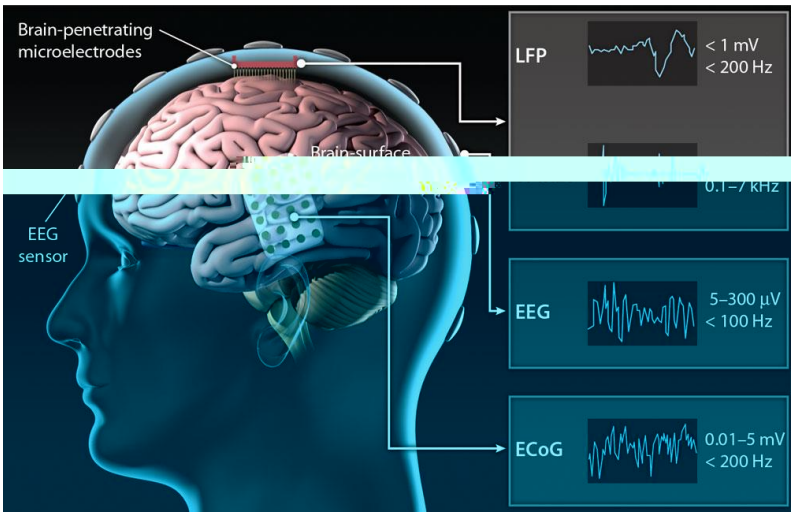
EPSP

IPSP

3-4



3-4 [18]



3-5 **[10]**

3-5

EEG

ECoG

Spike LFP

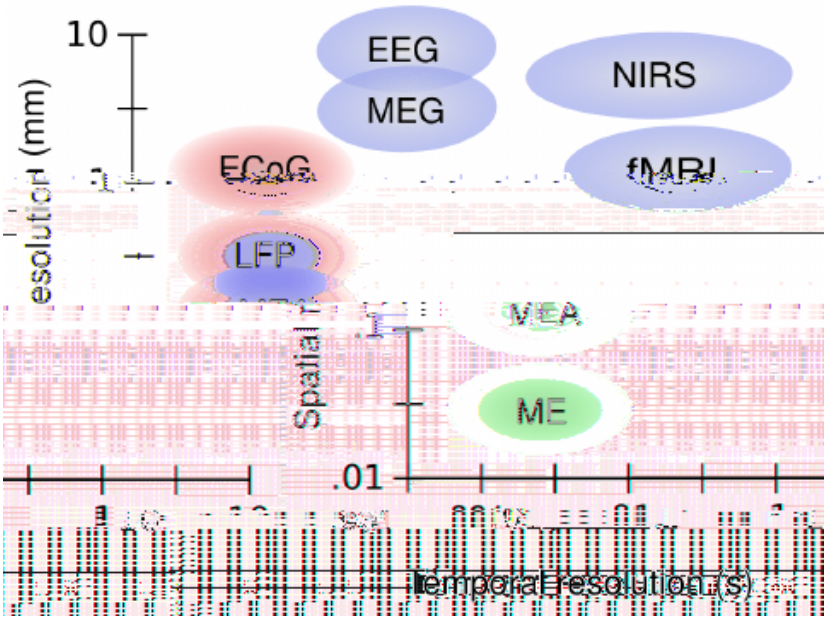
100-2000 Hz LFP

<200 Hz 0.1Hz <100 Hz

Neuropixel

3-6

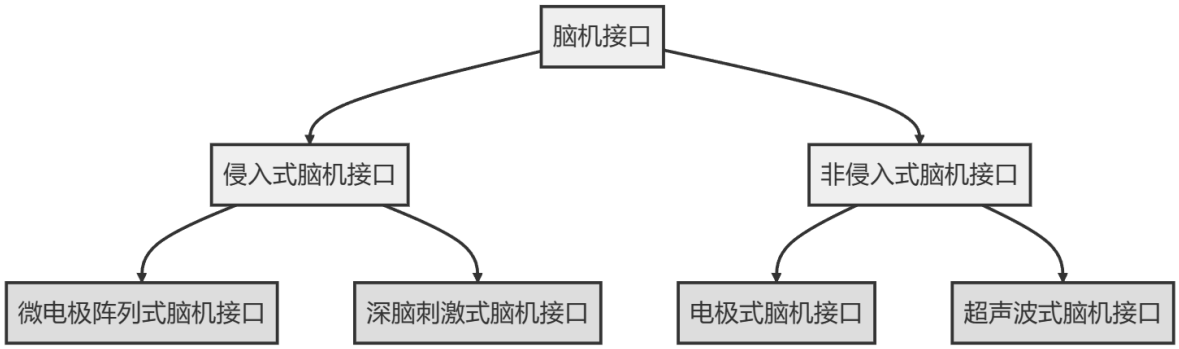
EEG



3-6 **[11]**

[8]

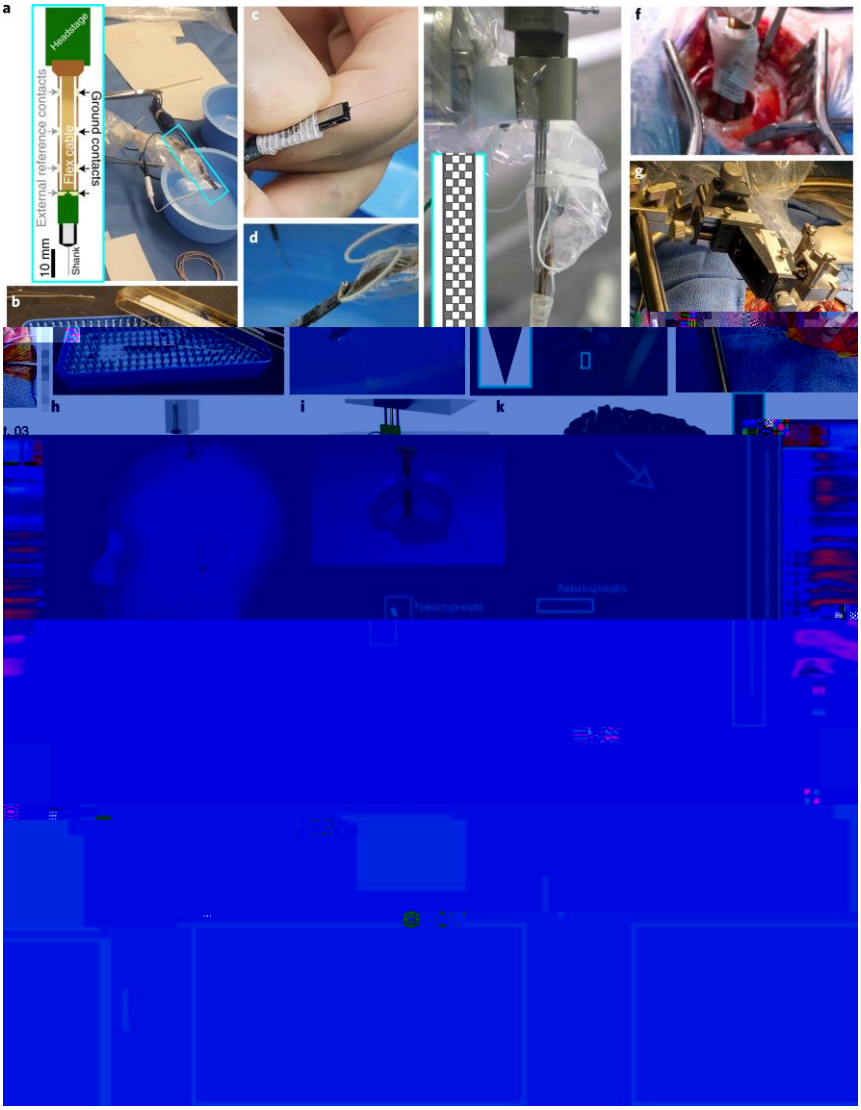
/ / 3-1


脑机接口
侵入式脑机接口
非侵入式脑机接口
微电极阵列式脑机接口
深脑刺激式脑机接口
电极式脑机接口
超声波式脑机接口

3-7

[8]

Deep Brain Stimulator, DBS 3-8 Neuropixel



3-8 Neuropixel **[12]**

St. Jude Medical 3-1

3-1

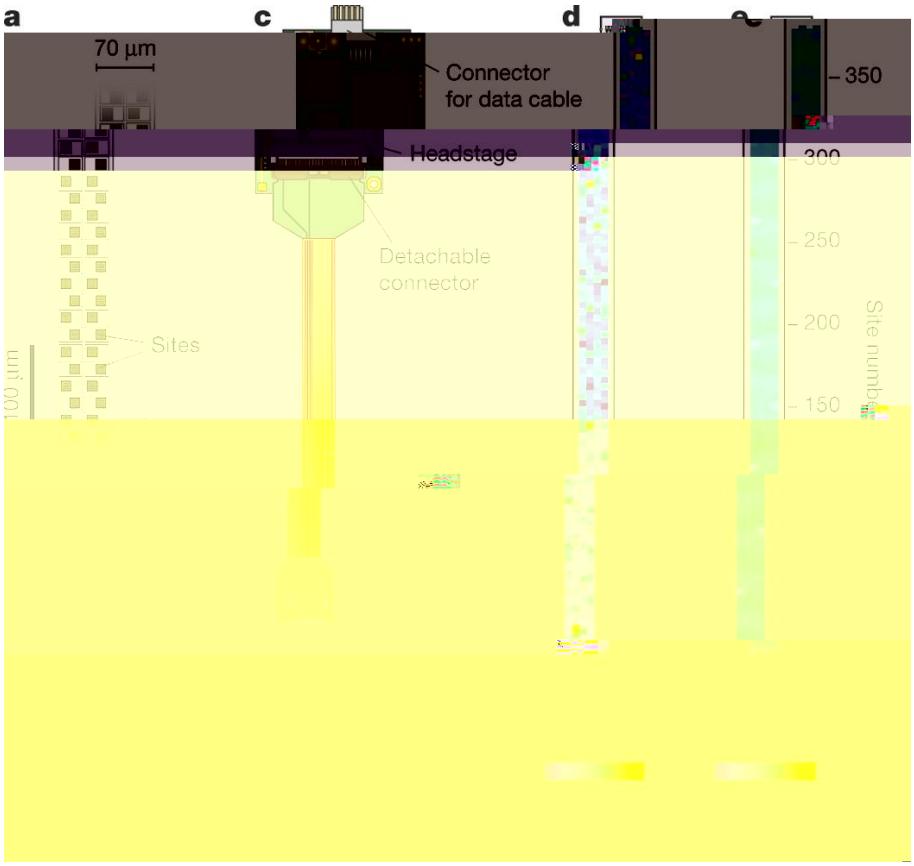
			G106R
Medtronic			Activa Soletra
St. Jude Medical			Infinity DBS System ILUMIEN OPTIS
Boston Scientific			Vercise DBS System Precision Montage MRI Spinal Cord Stimulator
Neuralink	. Elon Musk		N1 Implant
NeuroPace			RNS System
Ad-Tech Medical			Custom Stereotaxic Systems CT/MRI

[8]

Brain-Computer Interface, BCI

Neuropixel

MEMSCAP SCHOTT



3-9 Neuropixel [13]

/

NeuroSky Emotiv

/

Medtronic Sapiens

3-1

3-2

Imec			Neuropixel
NeuroNexus			NeuroNexus Probes
Blackrock Microsystems			Utah Array Cerebus System Wireless Neural Matrix
Neuralink	. Elon Musk		N1 Link
g.tec	-		g.HIamp g.BSImed g.GAMMAbox
Medtronic			Activa Soletra
Sapiens Neuro			Cereneo
Emotiv			Emotiv EPOC X
NeuroSky			MindWave Mobile 2

GlobalFoundries

TE Connectivity Furukawa Electric

3-2

3-3

Intan Technologies			RHD2216

	Intan		RHD2164 RHA2116 RHA2132
ADI			ADAS1000 ADSP-21489
TI			ADS1299 TMS320F28379D
NXP			Kinetis K24 LPC54114
Mindray			BeneVision N-Series M-series
NeuroSky			ThinkGear ASIC
			JDC1000 JDC1101
			S10 NT-3

BCI /

3-4

3-4

		Brain Products, NeuroScan, BrainCo
	BCI	TI, ST
	BLE IP	
		Rex Bionics, Oculus, Ekso
		Neuracle( ), Neuralink, BrainGate, NeuroSky( ), Synchron, g.tec, NeuraMatrix, NeuroXess( )
		, MindMaze, BrainCo, NeuroPace, CTRL-Labs
		( )

BCI

Texas Instruments TI

STMicroelectronics

BCI

BCI ASIC

Application-Specific Integrated Circuit

ASIC

ASIC Neuralink

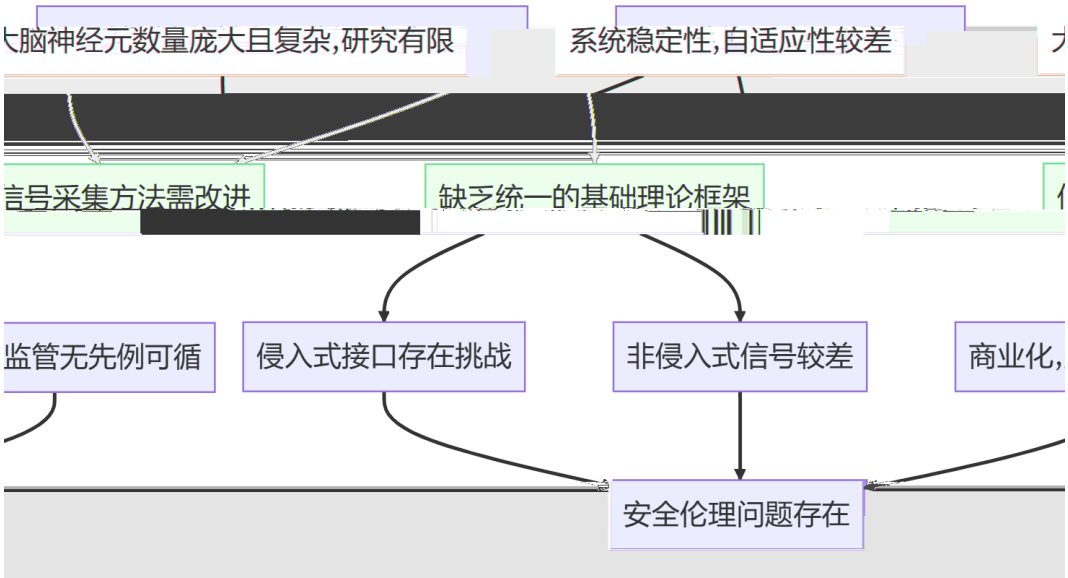
Neuralink Synchron BrainGate

[7]

[14]

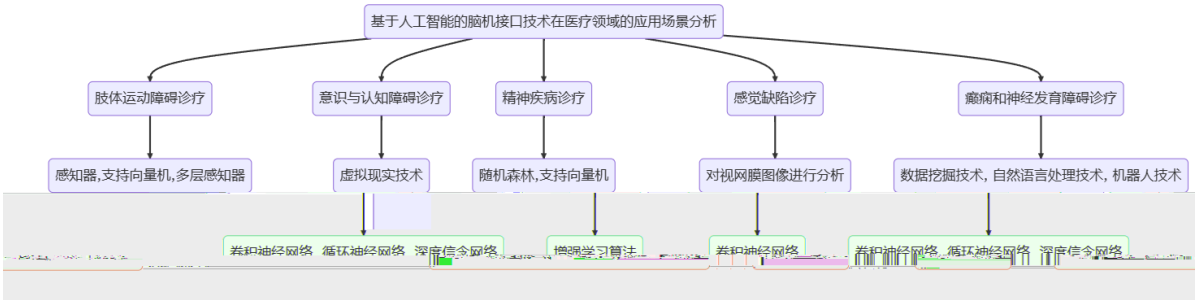
3-2

Neuralink 2020 8


大脑神经元数量庞大且复杂,研究有限
系统稳定性,自适应性较差
信号采集方法需改进
缺乏统一的基础理论框架
监管无先例可循
侵入式接口存在挑战
非侵入式信号较差
商业化,
安全伦理问题存在

3-10

4-1


基于人工智能的脑机接口技术在医疗领域的应用场景分析
肢体运动障碍诊疗
意识与认知障碍诊疗
精神疾病诊疗
感觉缺陷诊疗
癫痫和神经发育障碍诊疗
感知器,支持向量机,多层感知器
虚拟现实技术
随机森林,支持向量机
对视网膜图像进行分析
数据挖掘技术, 自然语言处理技术, 机器人技术
卷积神经网络, 循环神经网络, 深度信念网络
增强学习算法
卷积神经网络
卷积神经网络, 循环神经网络, 深度信念网络

4-1

[15]

Support Vector Machine SVM Multi-Layer Perceptron MLP

[15]

Convolutional Neural Network CNN Recurrent Neural Network RNN Deep Belief Network DBN

[15]

[15]

[16]

CNN

SVM

Random Forest RF

[16]

[16]

[16]

[16]

[16]

5-1

Neuropixel

5-1

/			
	Swartz		
	Wadsworth Wolpaw		
	Nicolelis Lab		
	Lab of Dr.Sydney Cash		

	BCI		

5-1

Neuralink

2016

2019 Facebook

10 CTRL-Labs 2020 8

Elon Musk Neuralink

B

2022

QYResearch

2019 12 2026

27 12.4

6

2020 14.6

5-2

5-3

5-4

5-2

Neuralink	2015 2016		Neuralink 2019 N1
NeuroSky	2004		NeuroSky ThinkGear A/D ASIC
	2018		2019
NeuraMatrix	2019		NeuraMatrix

5-3

/				
	Neuralink	2015 2016		2020 23mm Link V0.9

				2021
	BrainGate	BCI		2017 BCI
	Kernel	Bryan Johnson	2017 BCI	
	Paradromics	2015		
	Dreem	Rythm		
	MindMaze	2012		3D VR AR

	NeuroPace	1997		RNS Stimulator 2013 11 FDA
		2008		--
		2011		
	BrainCo	2015		EEG EMG

		2016		eCon eConHand
		2018		BrainUp
		2018		
		2019	-	

2014
12

			AI	

5-4 AI

Neuralink	2016	Neuralink 4 3.63 Neuralink 14 Raison Valor Equity Partners PrivCo 2021 6 30 Neuralink 5 10
BrainGate	2002	
Paradromics	2015	Paradromics 8 5830 2022 9 21 Venture - Series Unknown PrivCo 2021 7 23 Paradromics 5000 1
Dreem	2014	Dreem 3 5700 2018 6 26 Venture - Series Unknown
MindMaze	2012	MindMaze 10 3.407 2022 2 17 Venture - Series Unknown MindMaze 4 2018 11 13 Neuro Motor Innovations
NeuroPace	1997	NeuroPace 8 2.473 2021 6 30 Grant PrivCo 2020 8 31 NeuroPace 5 10
	2008	

	2011	2011 2015 12 2018 4 Pre-A 2019 8 A 6000 2021 3 B 2022 12 C
BrainCo	2015	BrainCo 2015 2021 9 BrainCo 2000 2016 1000 A 2018 BrainCo 1000 B
	2016	2016 12 2021 9 29 Pre-A 1000 2021 1 18 1000 2017 5 17
	2018	
	2018	2019 9 24 2022 5 17
	2019	
	2014	2014 12 2016 6 29 Pre-A 1000 2018 12 24 2016 1 30 100

Neuralink FDA Breakthrough Devices Program

Transcranial Direct/Alternating Current Stimulation tDCS/tACS

Transcranial Ultrasound Stimulation TUS

Magnetoencephalogram MEG

Positron Emission Tomography PET

Functional Magnetic Resonance Imaging fMRI

Functional Near Infrared Spectroscopy

fNIRS

Human Brain Project HBP

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0 1

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Neuralink

BrainGate Kernel Paradromics

zhuysh@pbcsf.tsinghua.edu.cn