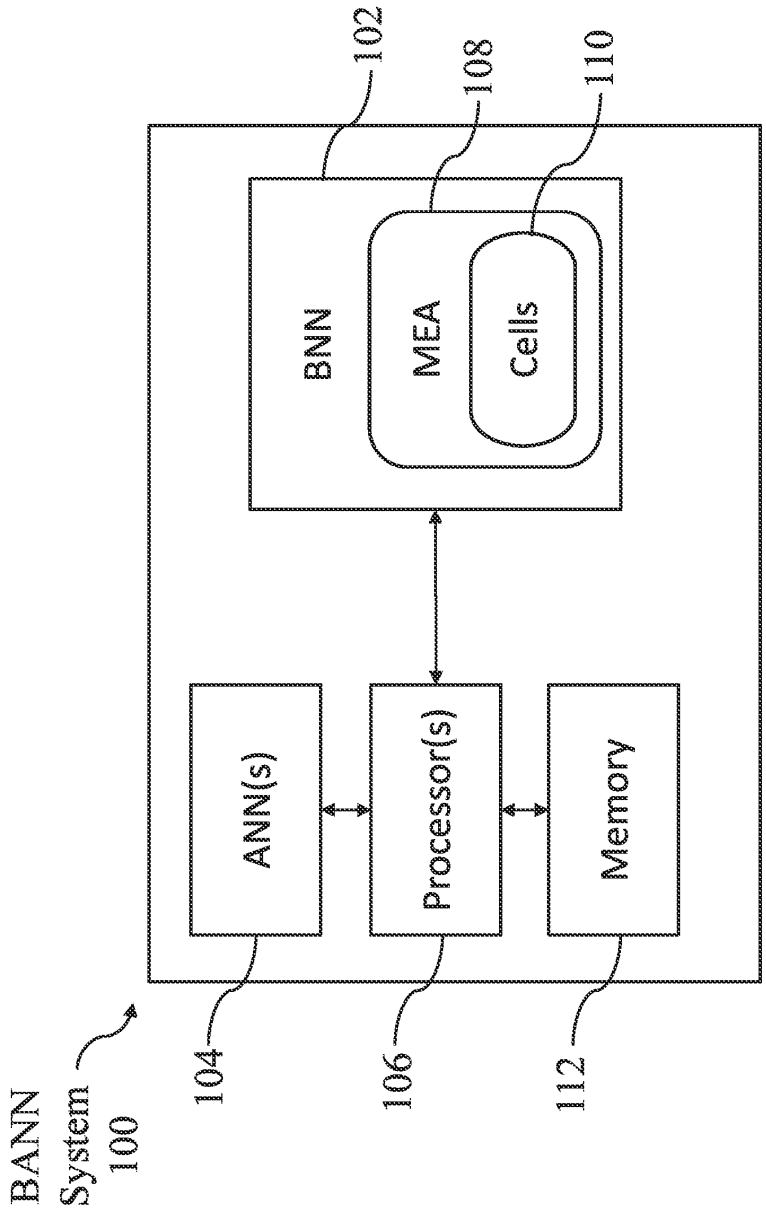

BANN System 100
102
108
110
BNN
MEA
Cells
ANN(s)
Processor(s)
Memory
104
106
112

FIG. 1

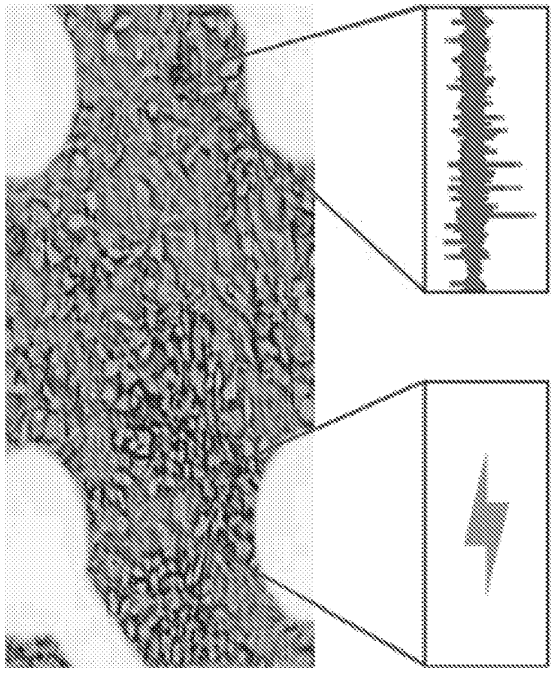


FIG. 2

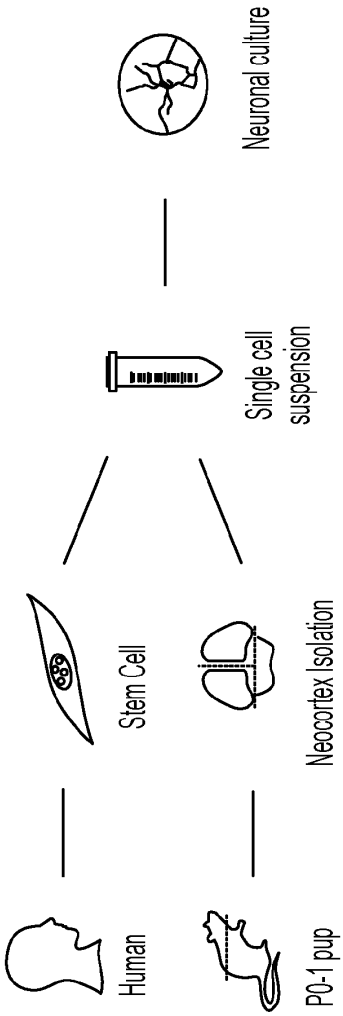

Neuronal culture
Single cell suspension
Stem Cell
Neocortex Isolation
Human
P0-1 pup

FIG. 3

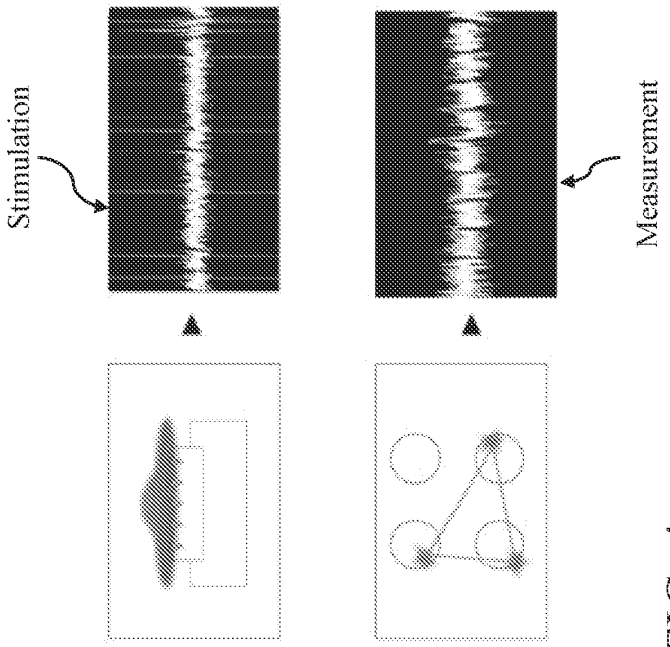
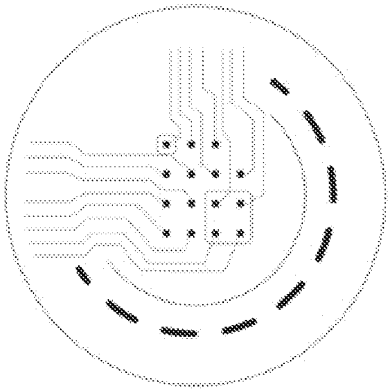


FIG. 4



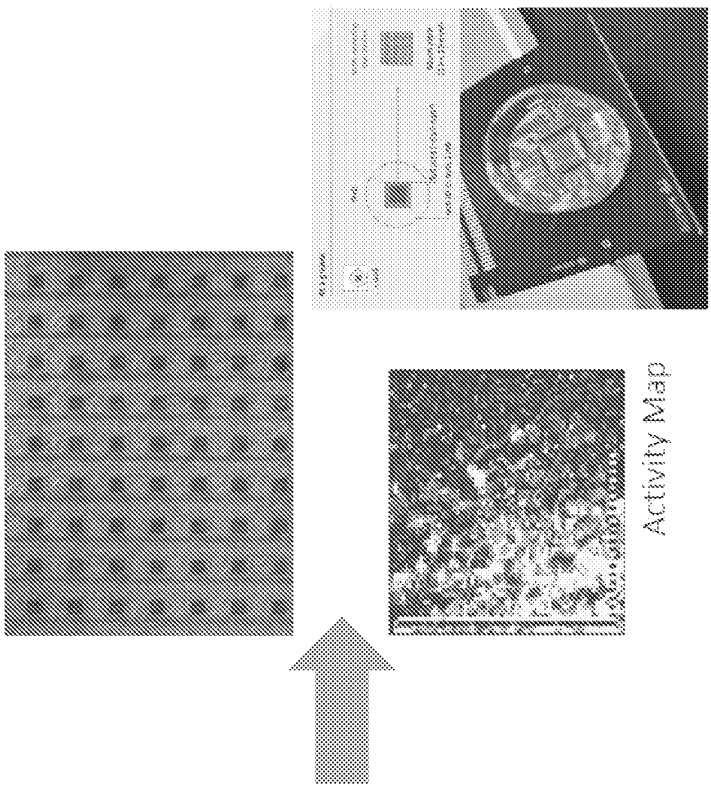


FIG. 5A

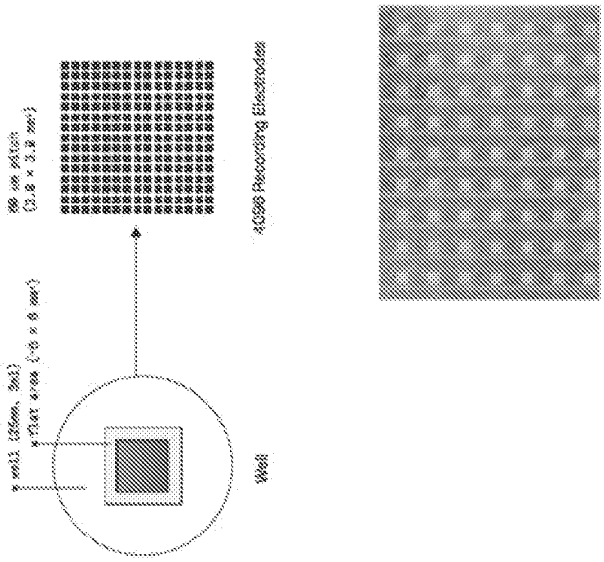


FIG. 5B

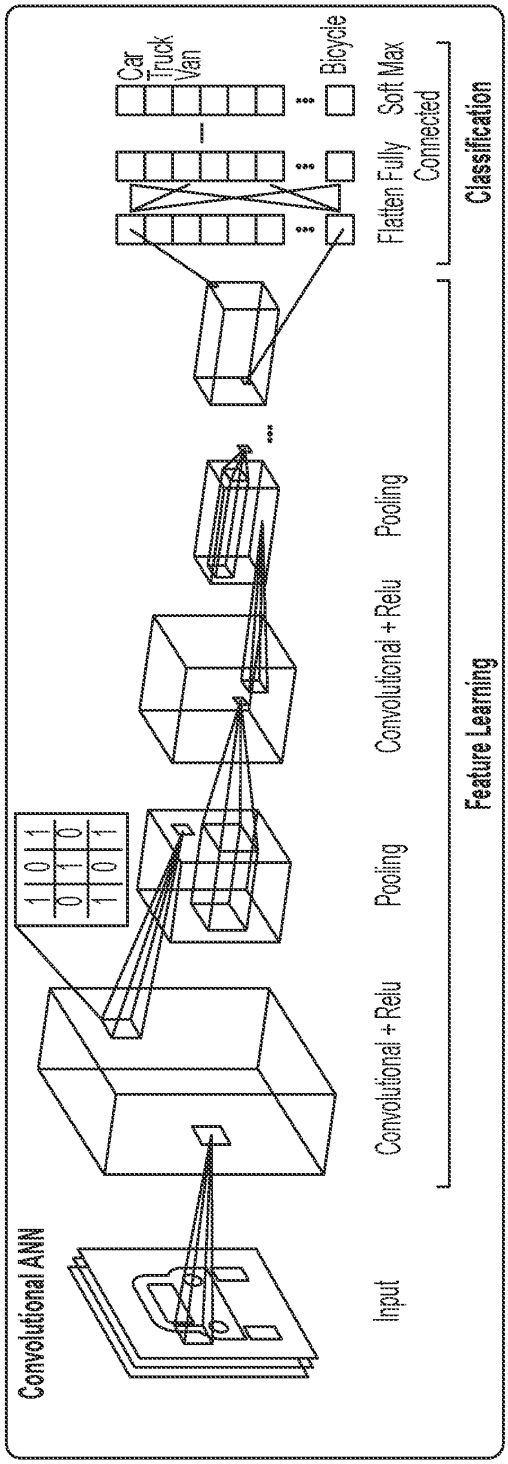

Convolutional ANN
Input
Convolutional + Relu
Pooling
Convolutional + Relu
Pooling
Flatten Fully Connected
Soft Max
Car
Truck
Van
Bicycle
Feature Learning
Classification

FIG. 6A

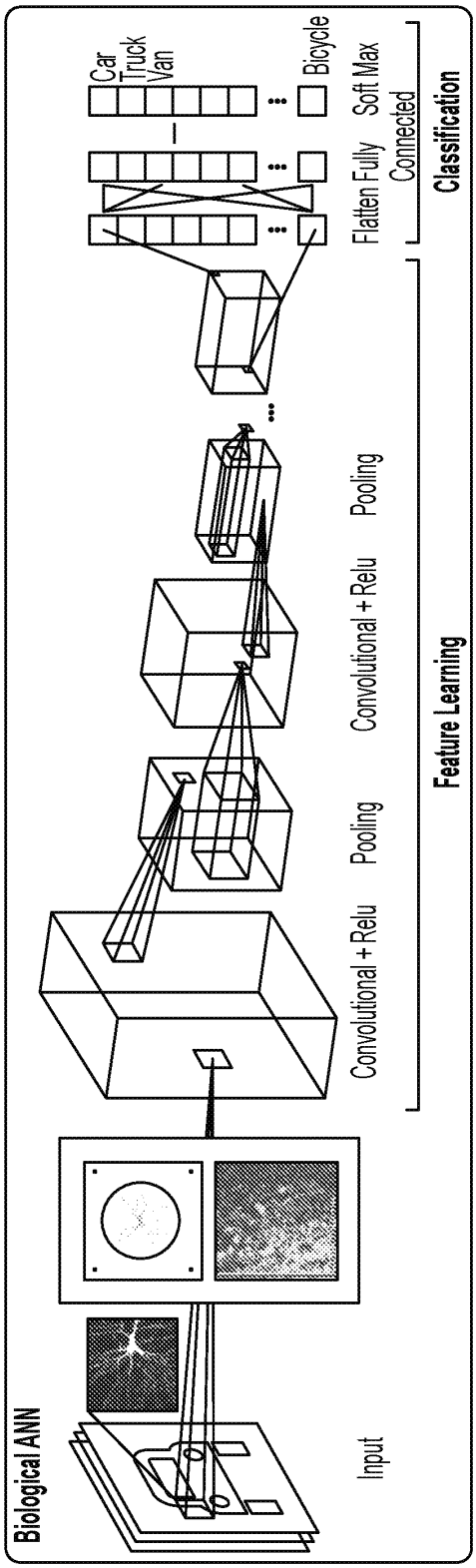

Biological ANN
Input
Convolutional + Relu
Pooling
Convolutional + Relu
Pooling
Feature Learning
Flatten Fully Connected
Soft Max
Classification
Car
Truck
Van
Bicycle

FIG. 6B

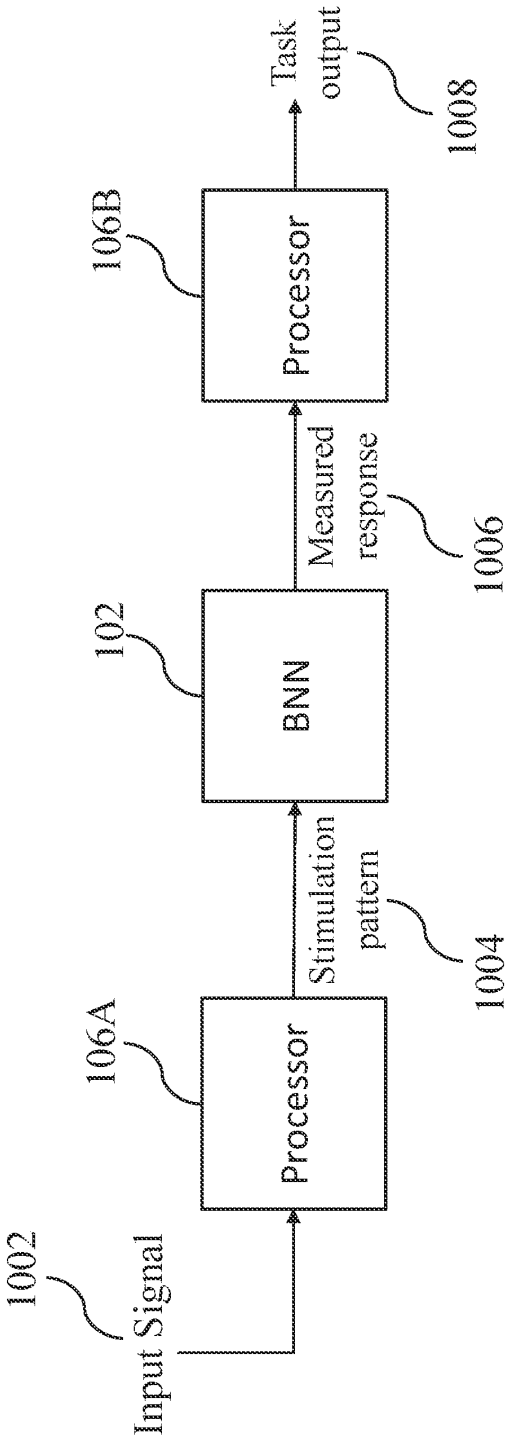

1002
Input Signal
106A
Processor
Stimulation pattern
1004
102
BNN
Measured response
1006
106B
Processor
Task output
1008

FIG. 7A

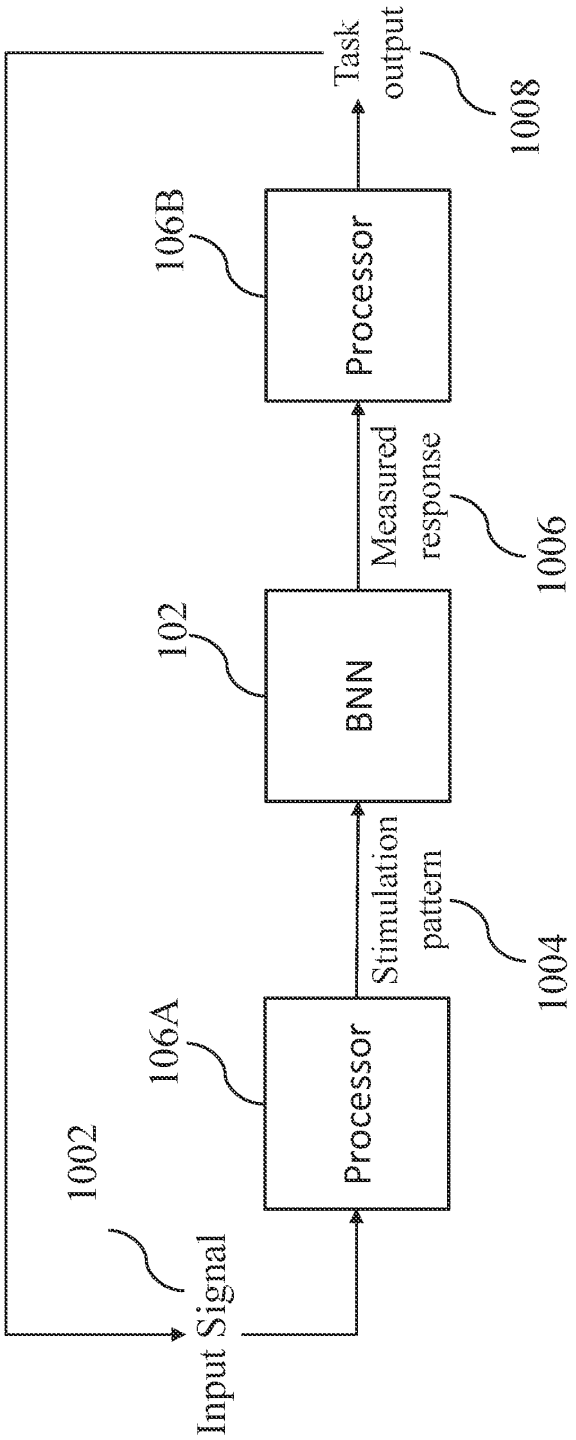

Input Signal
1002
Processor
106A
Stimulation pattern
1004
BNN
102
Measured response
1006
Processor
106B
Task output
1008

FIG. 7B

Encode %
change from
previous day:
(n+1/n) - 1
Biphasic Pelvic Stimulation / 1
1 min
5
10
15
20
60

FIG. 8

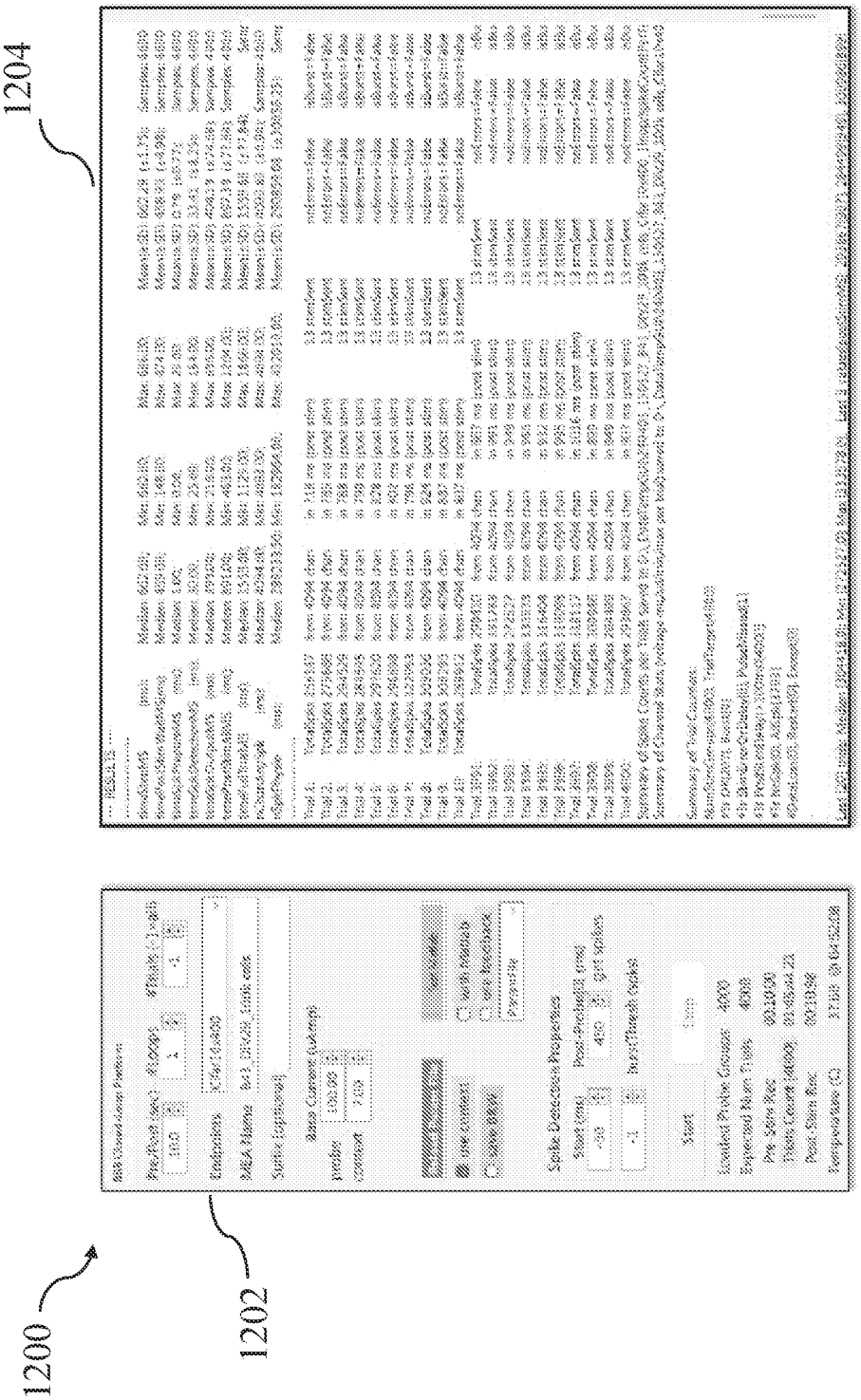


FIG. 9

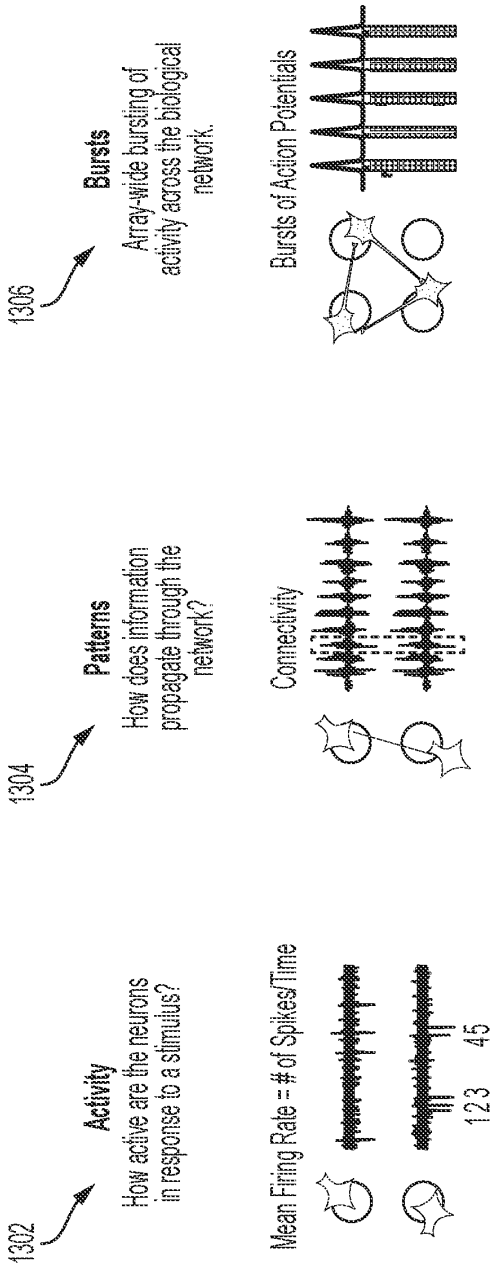

1302
Activity
How active are the neurons in response to a stimulus?
Mean Firing Rate = # of Spikes/Time
1 2 3 4 5
1304
Patterns
How does information propagate through the network?
Connectivity
1306
Bursts
Array-wide bursting of activity across the biological network.
Bursts of Action Potentials

FIG. 10

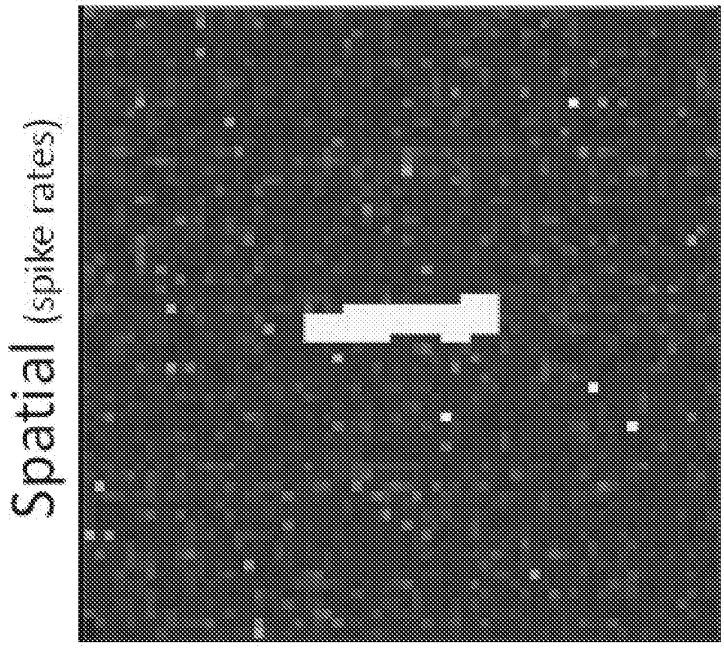


FIG. 11

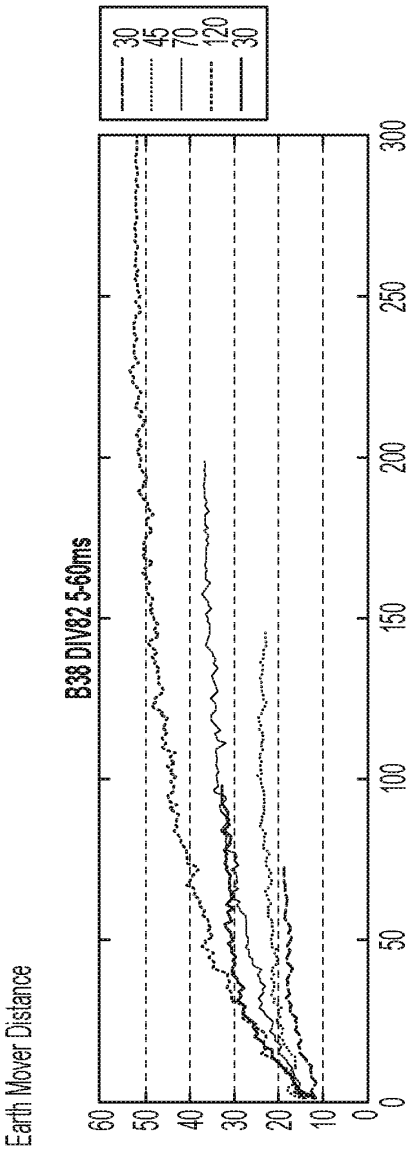

B38 DIV82 5-60ms
Earth Mover Distance
0
10
20
30
40
50
60
0
50
100
150
200
250
300
30
45
70
120
30

FIG. 12

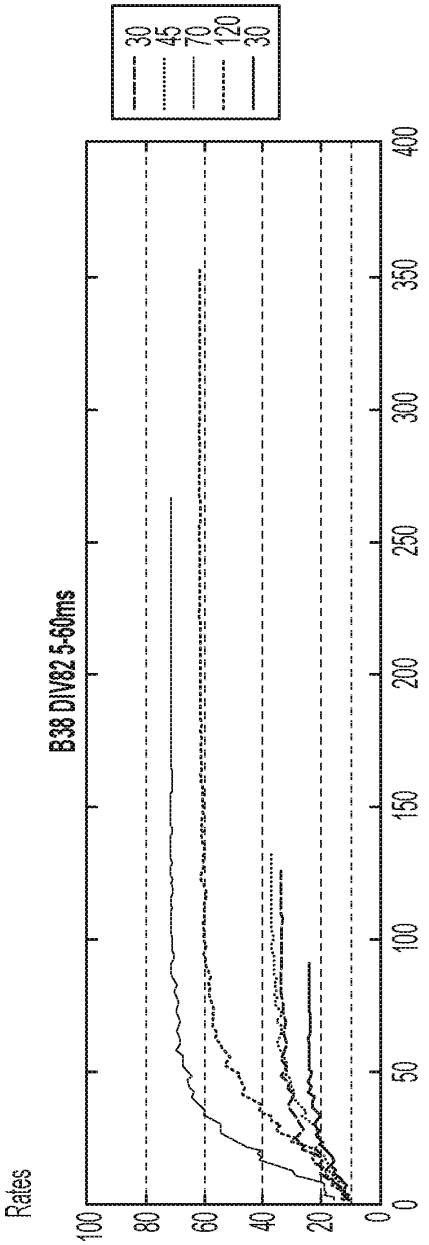

B38 DIV82 5-60ms
Rates
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
30
45
70
120
30

FIG. 13

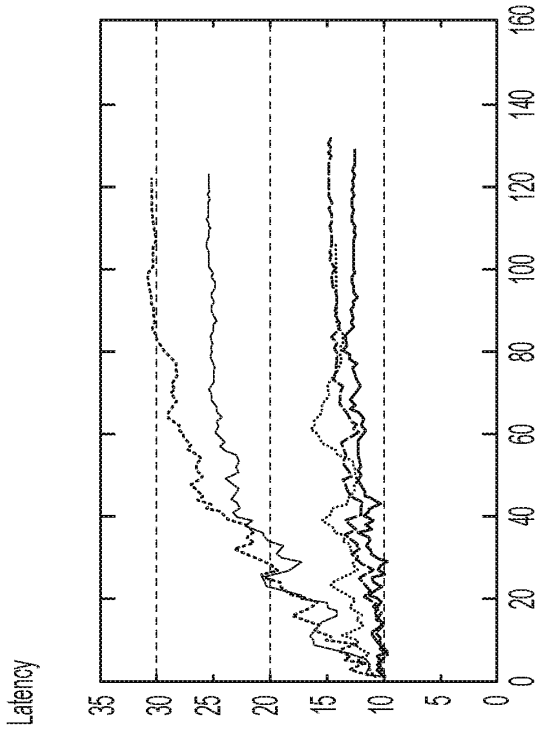


FIG. 14

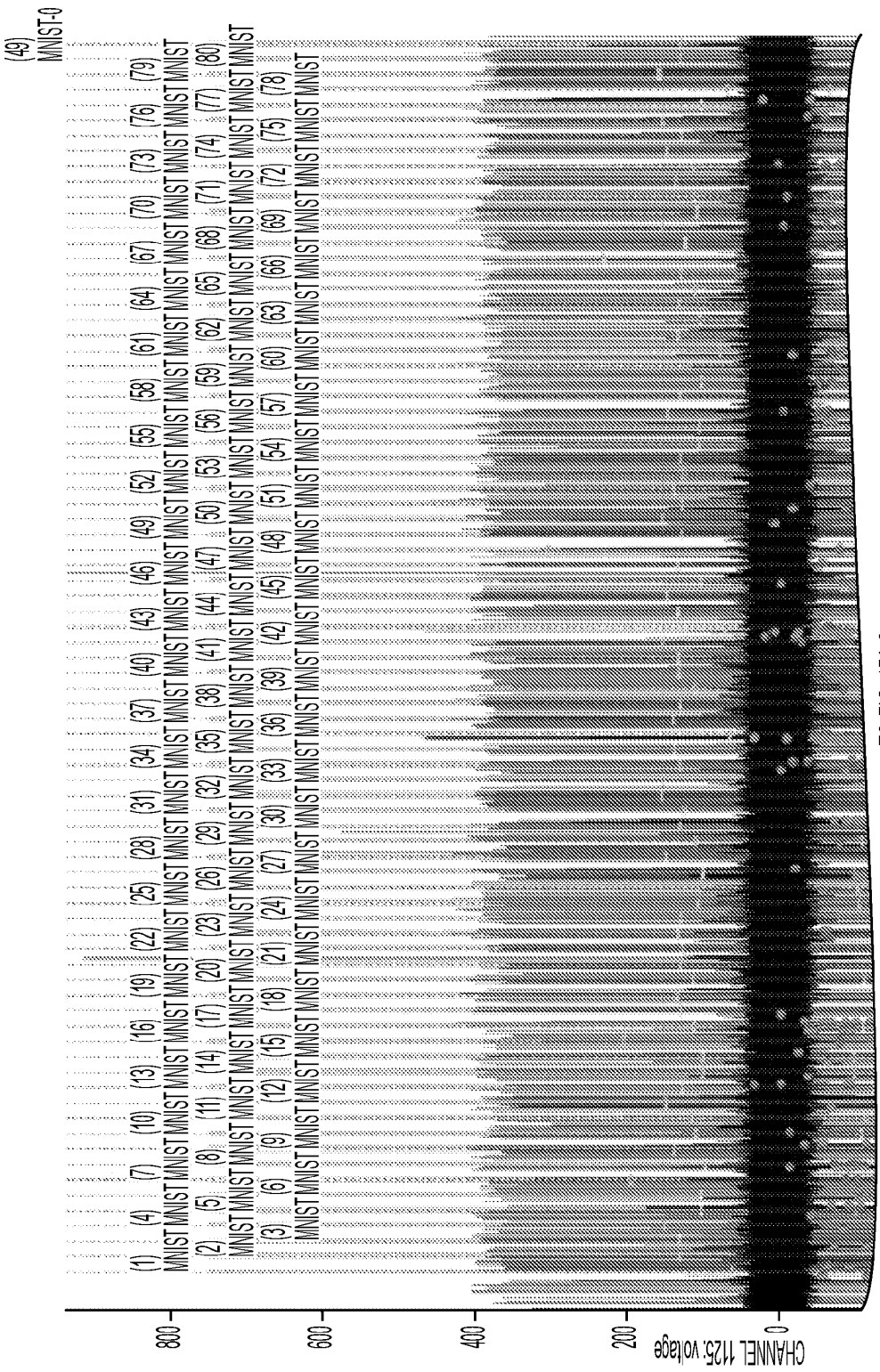

CHANNEL 1125: voltage
800
600
400
200
0
(49) MNIST-0
(1) MNIST (2) MNIST (3) MNIST (4) MNIST (5) MNIST (6) MNIST (7) MNIST (8) MNIST (9) MNIST (10) MNIST (11) MNIST (12) MNIST (13) MNIST (14) MNIST (15) MNIST (16) MNIST (17) MNIST (18) MNIST (19) MNIST (20) MNIST (21) MNIST (22) MNIST (23) MNIST (24) MNIST (25) MNIST (26) MNIST (27) MNIST (28) MNIST (29) MNIST (30) MNIST (31) MNIST (32) MNIST (33) MNIST (34) MNIST (35) MNIST (36) MNIST (37) MNIST (38) MNIST (39) MNIST (40) MNIST (41) MNIST (42) MNIST (43) MNIST (44) MNIST (45) MNIST (46) MNIST (47) MNIST (48) MNIST (49) MNIST (50) MNIST (51) MNIST (52) MNIST (53) MNIST (54) MNIST (55) MNIST (56) MNIST (57) MNIST (58) MNIST (59) MNIST (60) MNIST (61) MNIST (62) MNIST (63) MNIST (64) MNIST (65) MNIST (66) MNIST (67) MNIST (68) MNIST (69) MNIST (70) MNIST (71) MNIST (72) MNIST (73) MNIST (74) MNIST (75) MNIST (76) MNIST (77) MNIST (78) MNIST (79) MNIST (80) MNIST
TO FIG. 15A-2

FIG. 15A-1

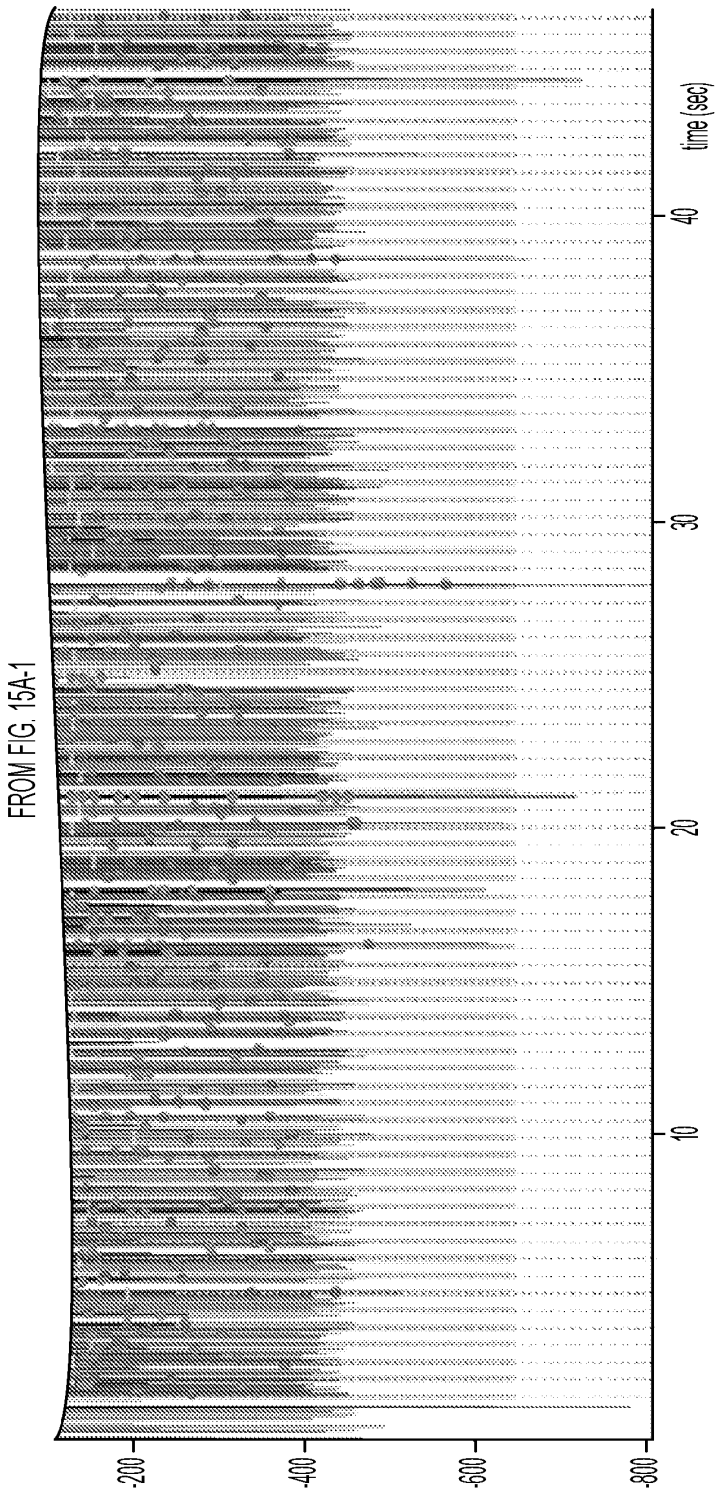


FIG. 15A-2

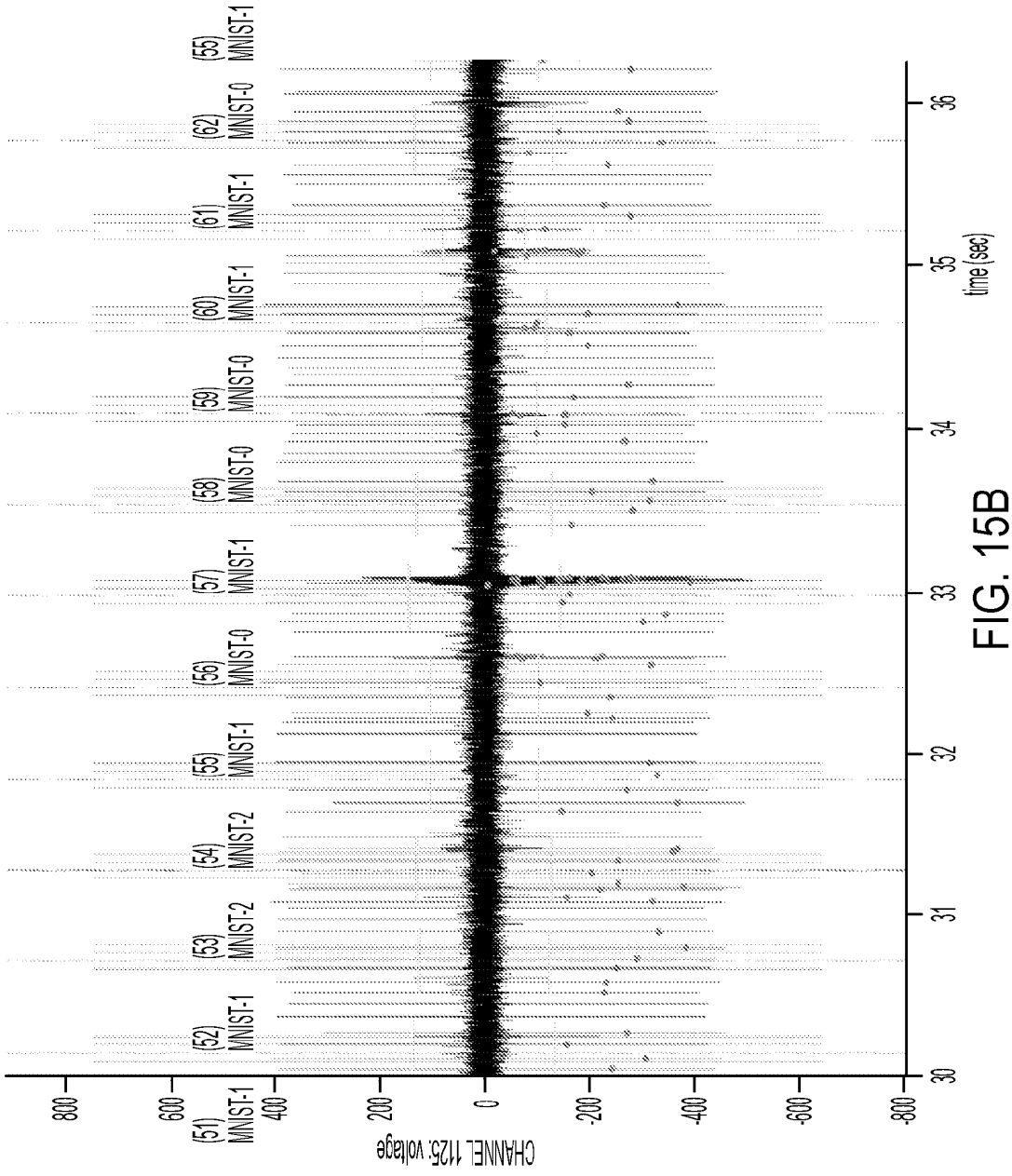

CHANNEL 1125: voltage
800
600
400
200
0
-200
-400
-600
-800
30
31
32
33
34
35
36
time (sec)
(51) MNIST-1
(52) MNIST-1
(53) MNIST-2
(54) MNIST-2
(55) MNIST-1
(56) MNIST-0
(57) MNIST-1
(58) MNIST-0
(59) MNIST-0
(60) MNIST-1
(61) MNIST-1
(62) MNIST-0
(55) MNIST-1

FIG. 15B

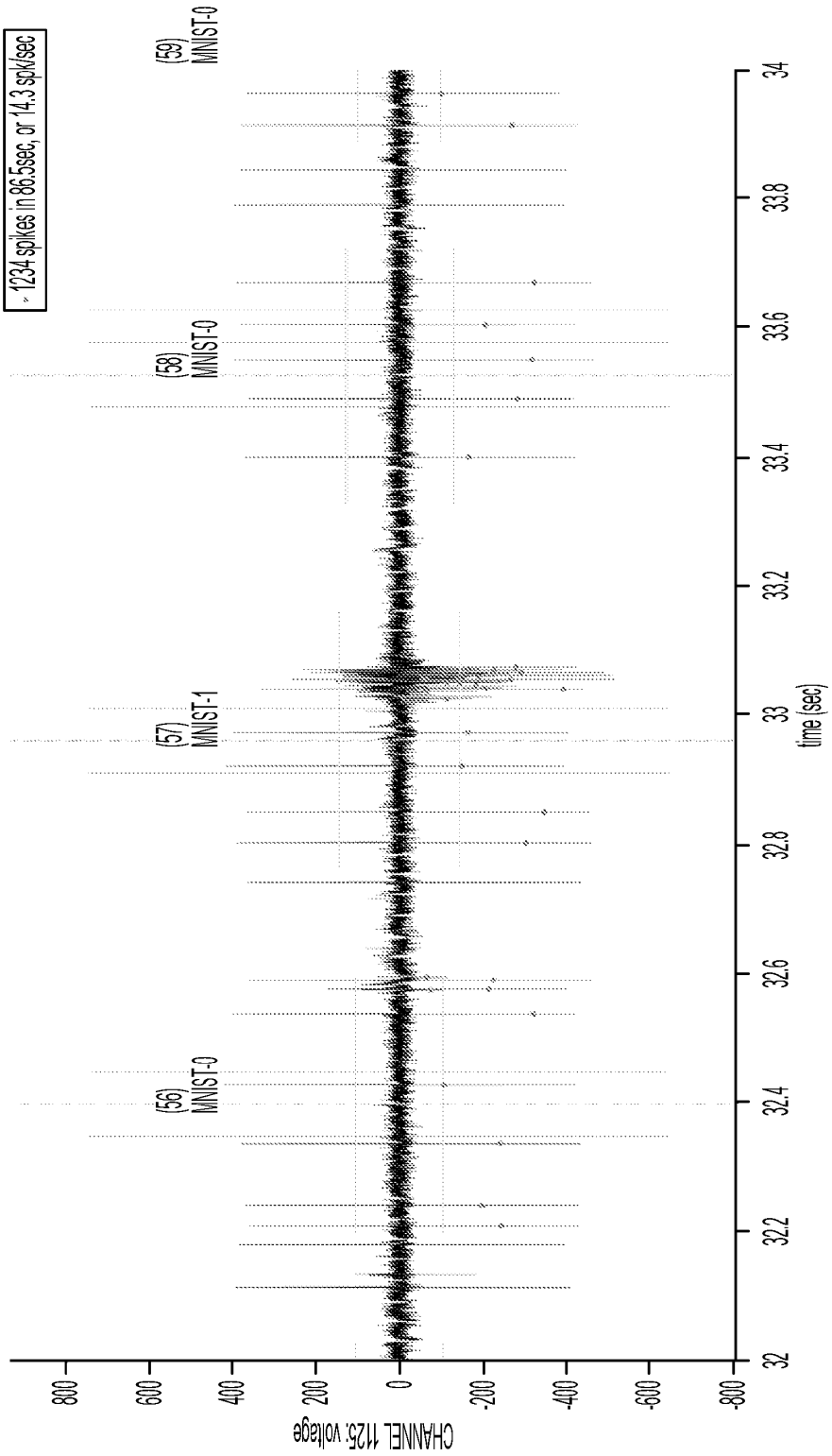

1234 spikes in 86.5sec, or 14.3 spk/sec
(56) MNIST-0
(57) MNIST-1
(58) MNIST-0
(59) MNIST-0
CHANNEL 1125: voltage
800
600
400
200
0
-200
-400
-600
-800
32
32.2
32.4
32.6
32.8
33
33.2
33.4
33.6
33.8
34
time (sec)

FIG. 15C

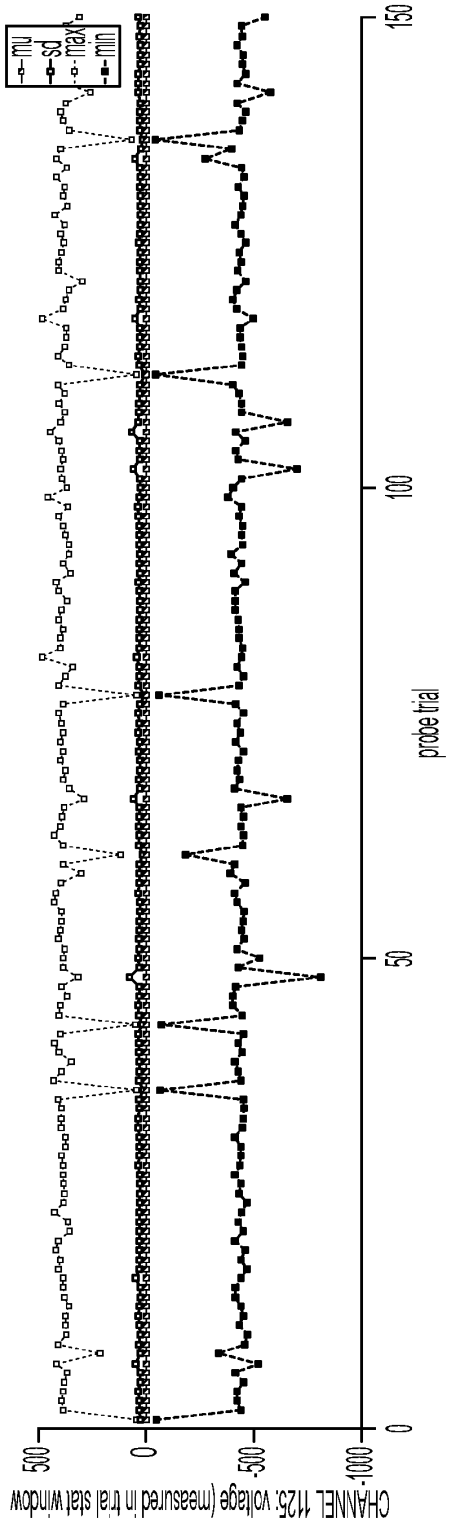


FIG. 16

RECTIFIED SHEET (RULE 91)

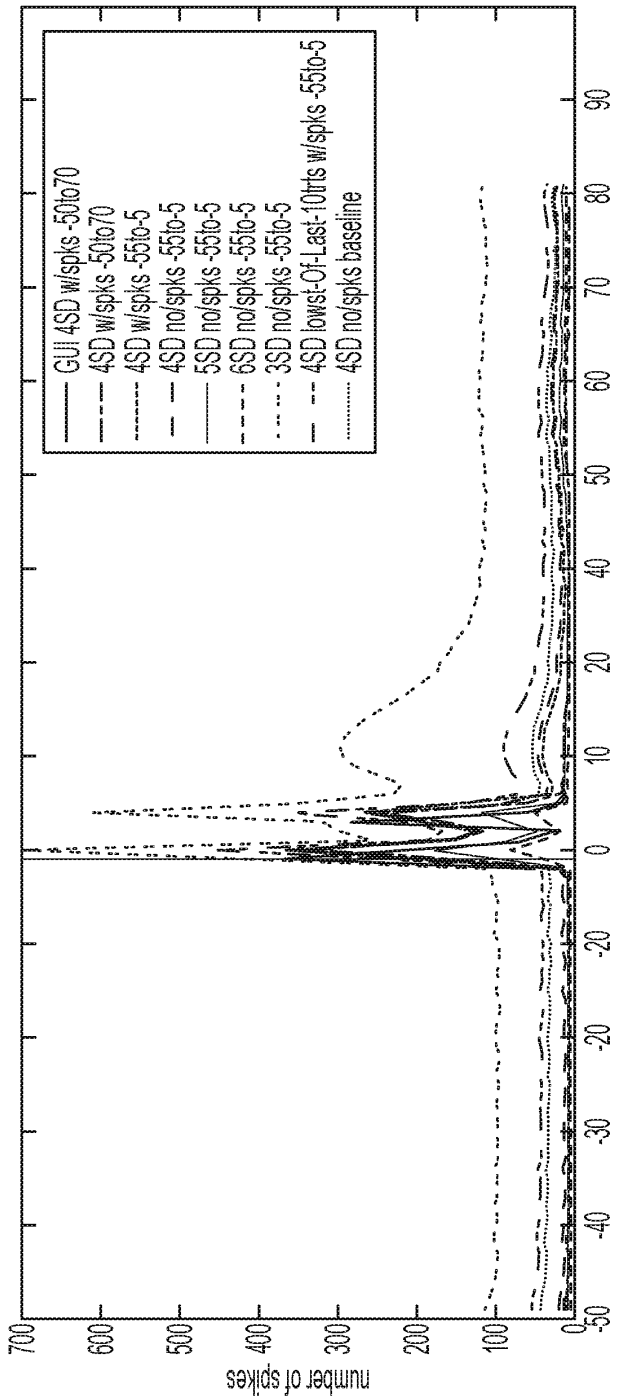

GUI 4SD w/spks -50to70
4SD w/spks -50to70
4SD w/spks -55to-5
4SD no/spks -55to-5
5SD no/spks -55to-5
6SD no/spks -55to-5
3SD no/spks -55to-5
4SD lowst-Of-Last-10trls w/spks -55to-5
4SD no/spks baseline
number of spikes
time (ms)
700
600
500
400
300
200
100
0
-50
-40
-30
-20
-20
0
10
20
40
50
60
70
80
90

FIG. 17

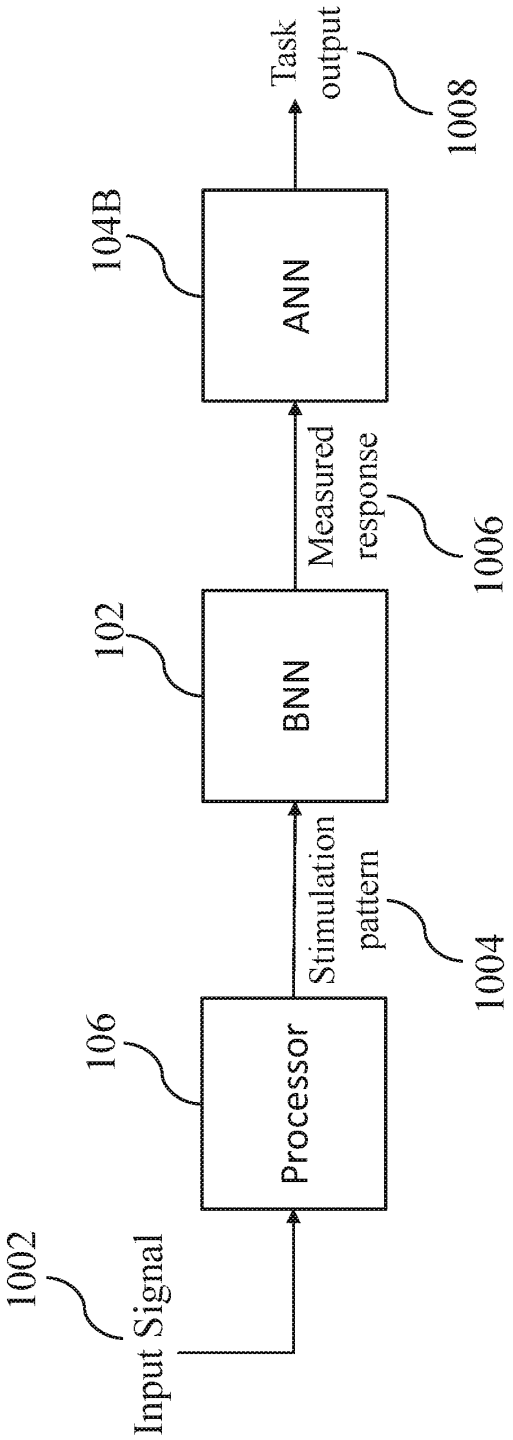

1002
Input Signal
106
Processor
Stimulation pattern
1004
102
BNN
Measured response
1006
104B
ANN
Task output
1008

FIG. 18A

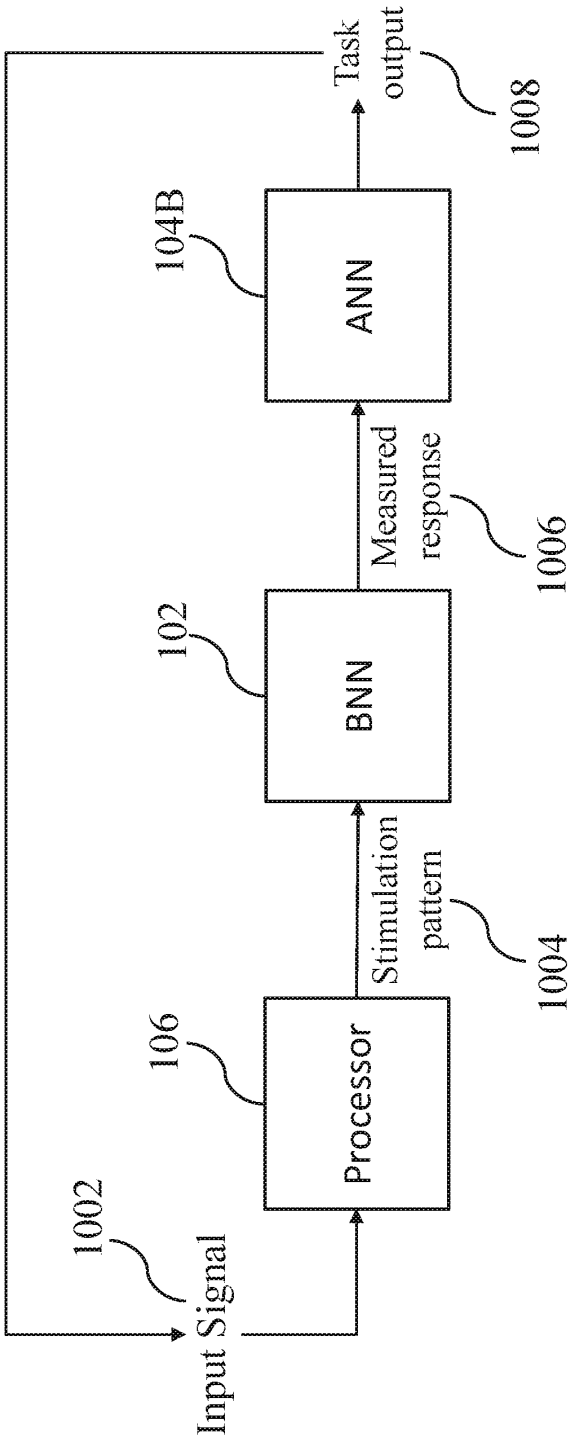

Input Signal
1002
Processor
106
Stimulation pattern
1004
BNN
102
Measured response
1006
ANN
104B
Task output
1008

FIG. 18B

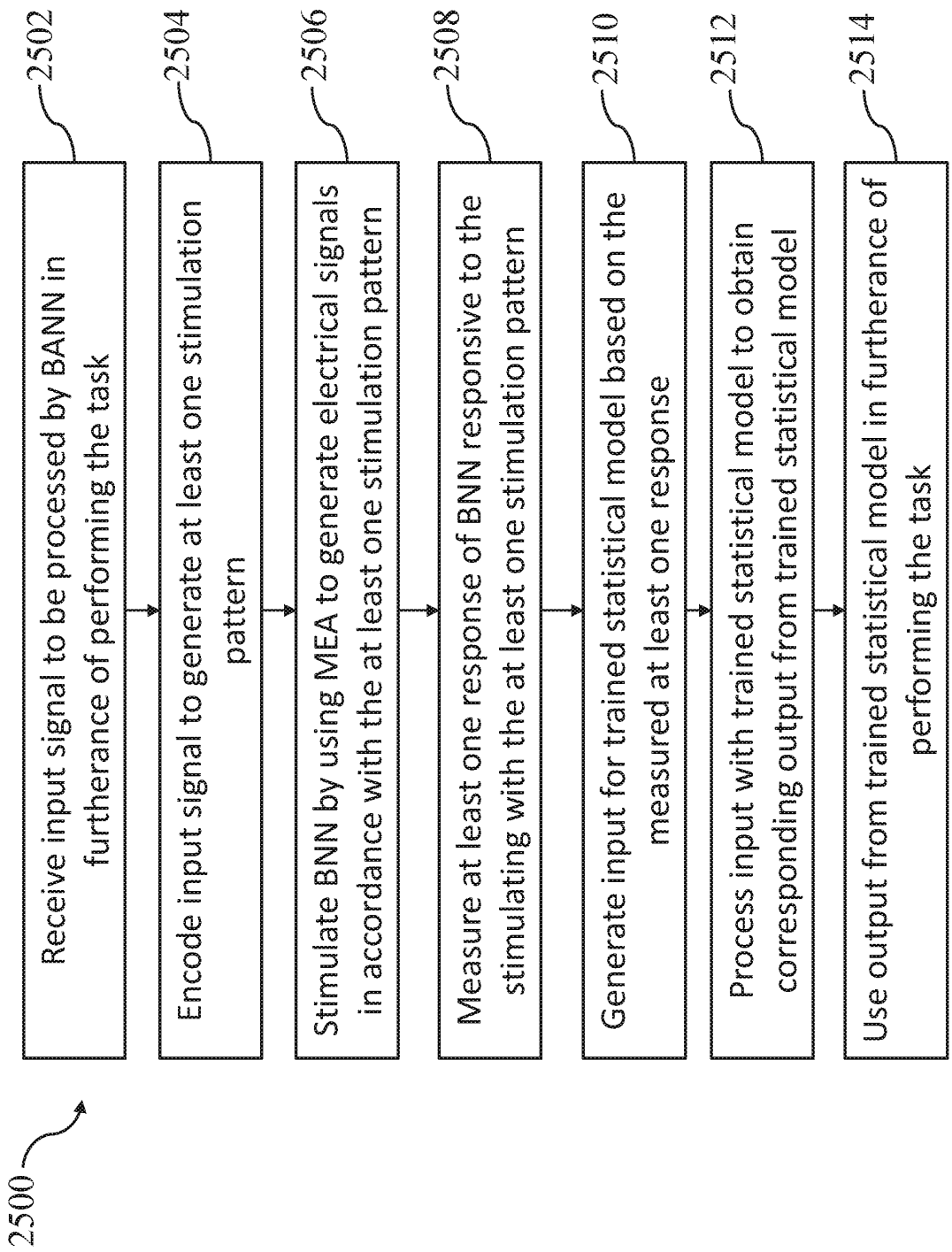

2500
2502
Receive input signal to be processed by BANN in furtherance of performing the task
2504
Encode input signal to generate at least one stimulation pattern
2506
Stimulate BNN by using MEA to generate electrical signals in accordance with the at least one stimulation pattern
2508
Measure at least one response of BNN responsive to the stimulating with the at least one stimulation pattern
2510
Generate input for trained statistical model based on the measured at least one response
2512
Process input with trained statistical model to obtain corresponding output from trained statistical model
2514
Use output from trained statistical model in furtherance of performing the task

FIG. 19

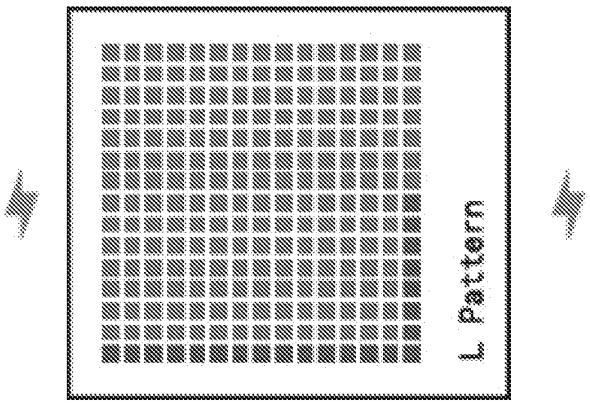


FIG. 20

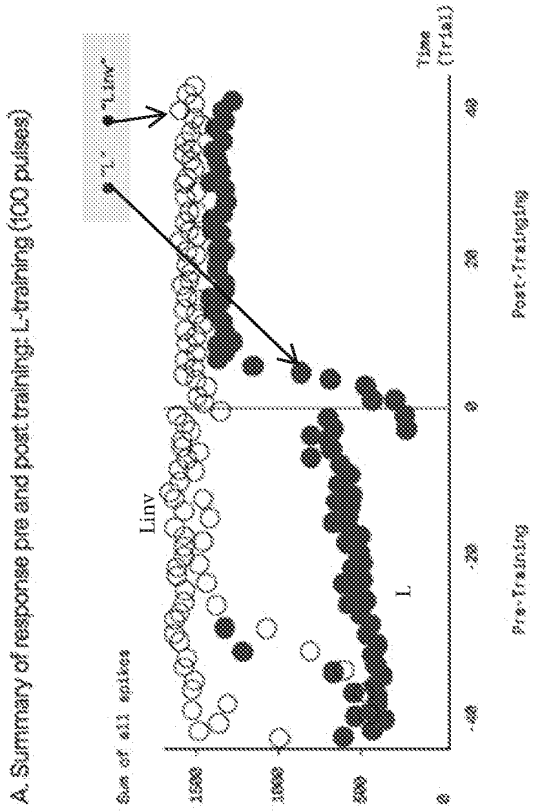

A. Summary of response pre and post training: L-training (100 pulses)
Sum of all spikes
1500
1000
500
0
Linv
L
-400
-200
0
200
400
Time (Trial)
Pre-Training
Post-Training

FIG. 21A

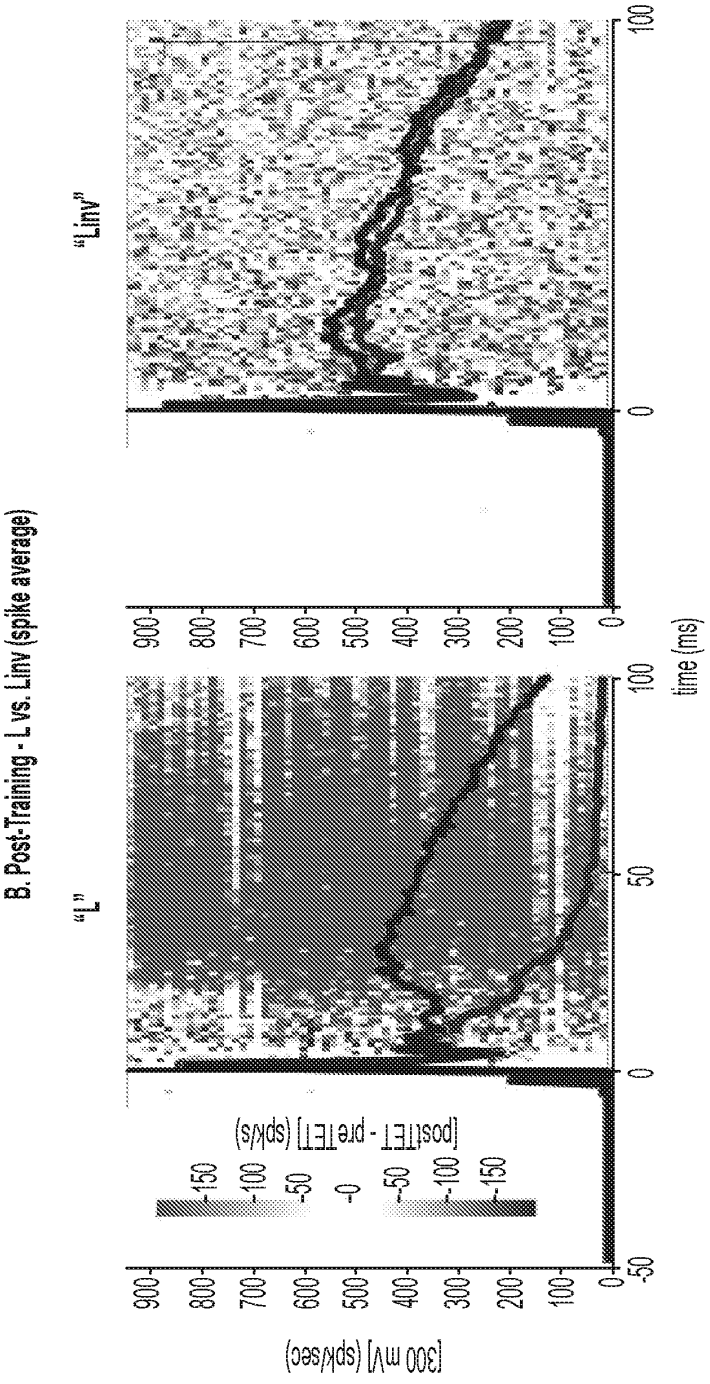

B. Post-Training - L vs. Linv (spike average)
"L"
"Linv"
[300 mV] (spk/sec)
[postTET - preTET] (spk/s)
time (ms)

FIG. 21B

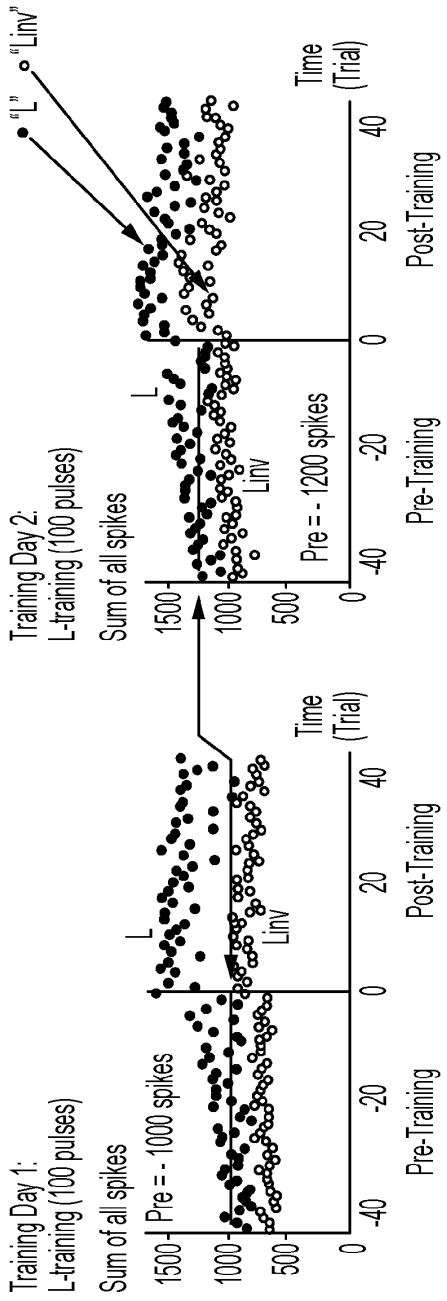

"L"
"Linv"
Training Day 1:
L-training (100 pulses)
Sum of all spikes
Pre = - 1000 spikes
L
Linv
Pre-Training
Post-Training
Time
(Trial)
Training Day 2:
L-training (100 pulses)
Sum of all spikes
Pre = - 1200 spikes
L
Linv
Pre-Training
Post-Training
Time
(Trial)

FIG. 22

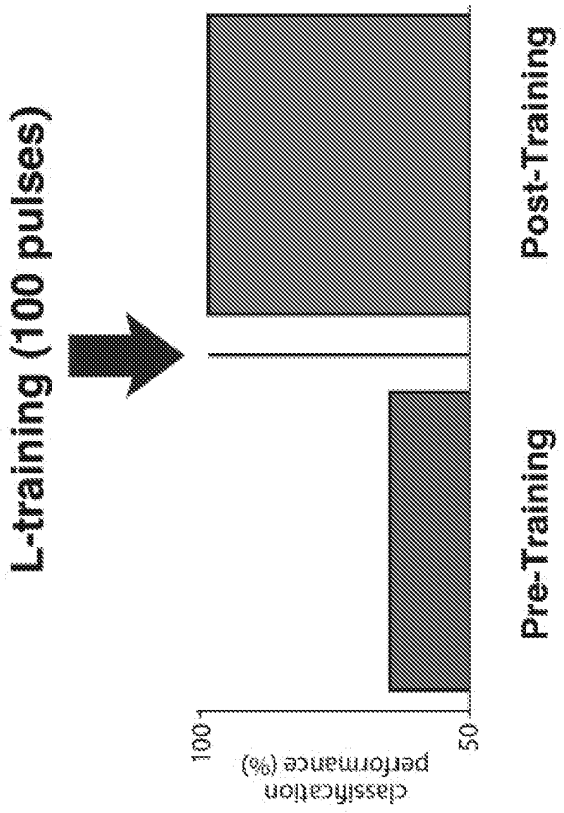

L-training (100 pulses)
Pre-Training
Post-Training
100
50
classification performance (%)

FIG. 23

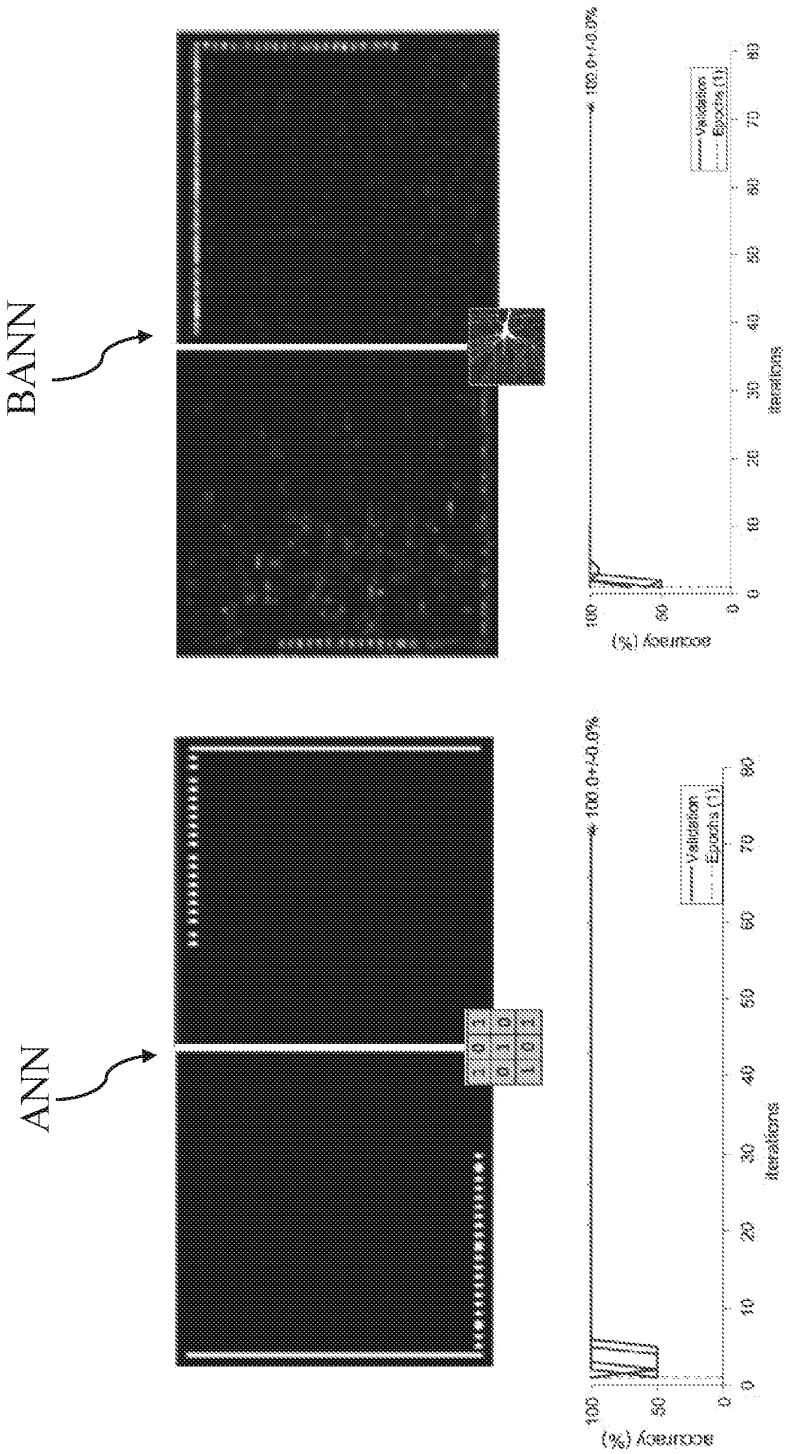

BANN
ANN
100.0+/-0.0%
100.0+/-0.0%
Validation
Epochs (1)
accuracy (%)
iterations

FIG. 24

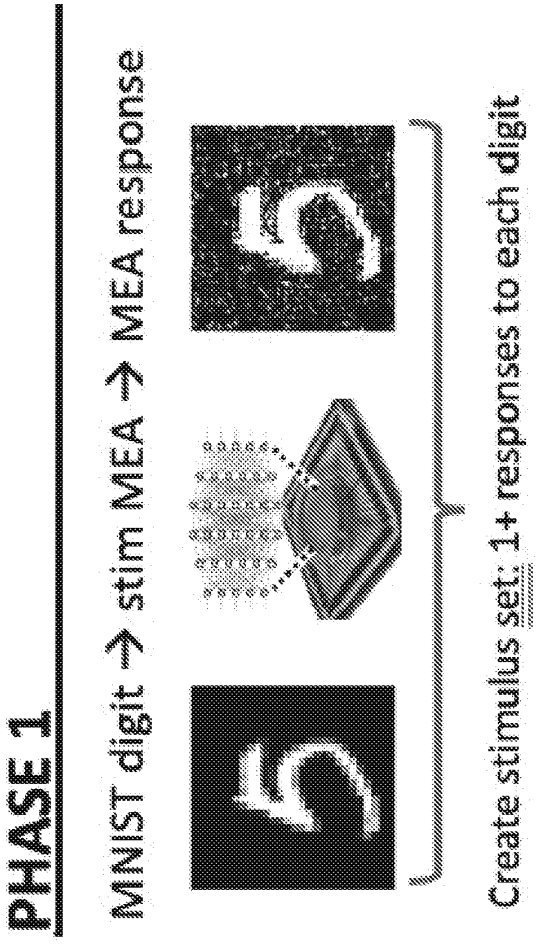

PHASE 1
MNIST digit → stim MEA → MEA response
Create stimulus set: 1+ responses to each digit

FIG. 25

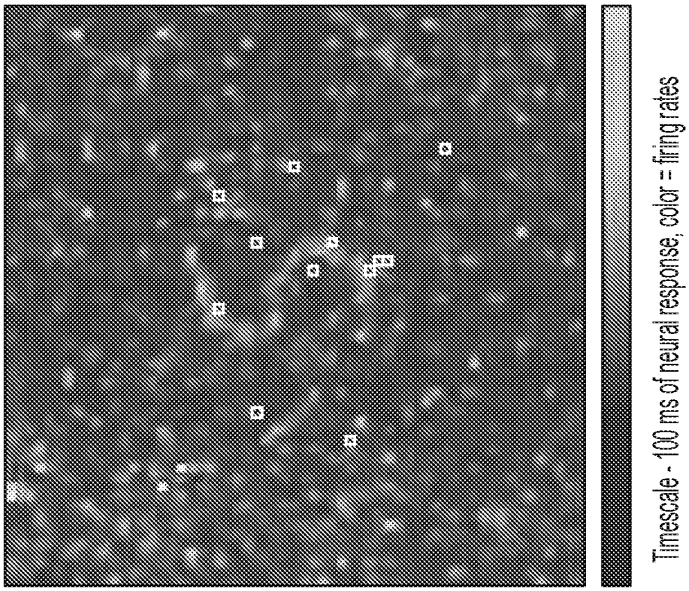


FIG. 26

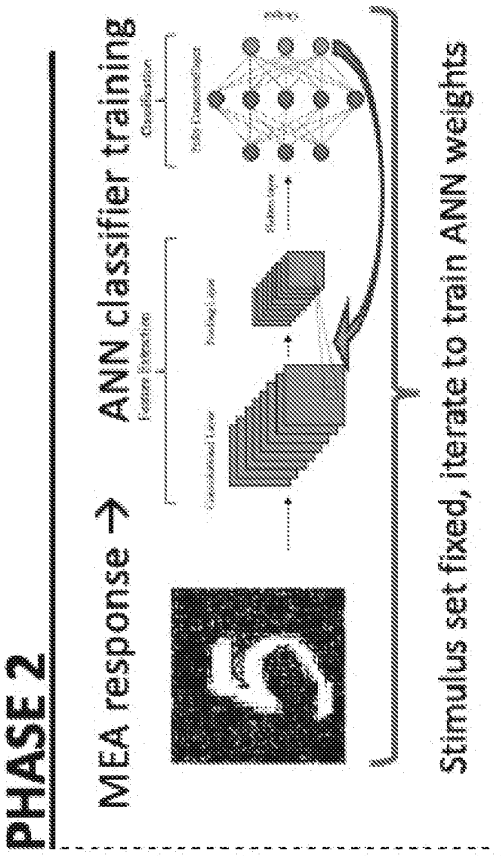

PHASE 2
MEA response →
ANN classifier training
Stimulus set fixed, iterate to train ANN weights

FIG. 27

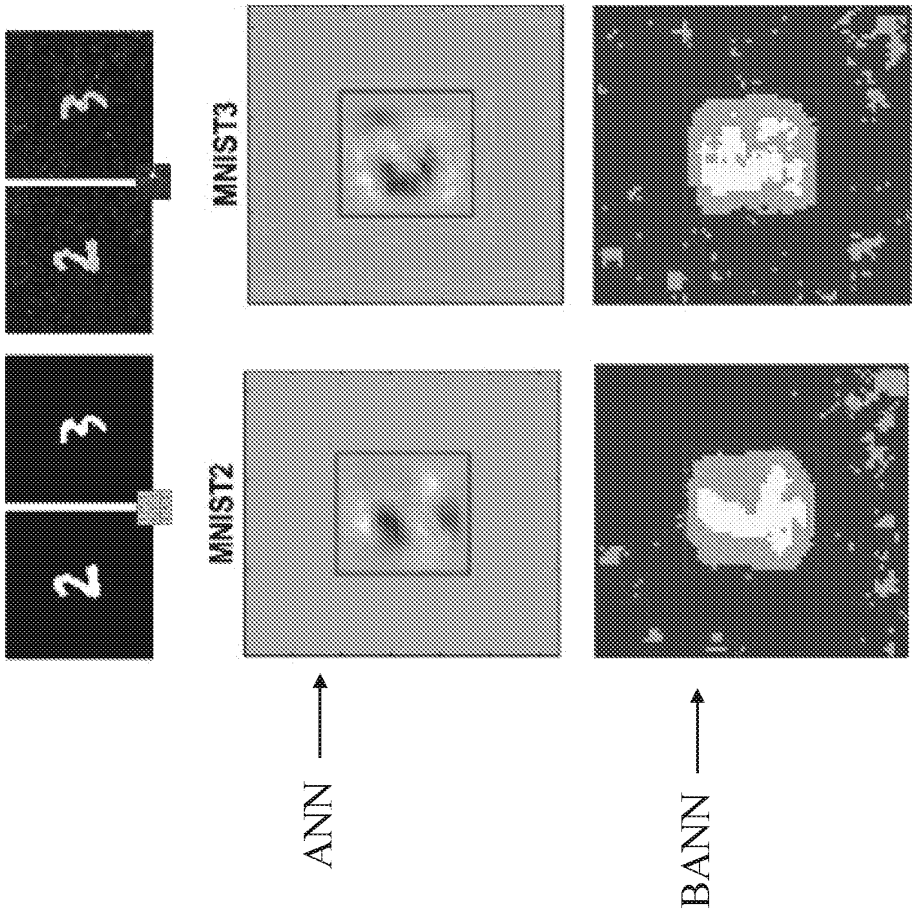


FIG. 28

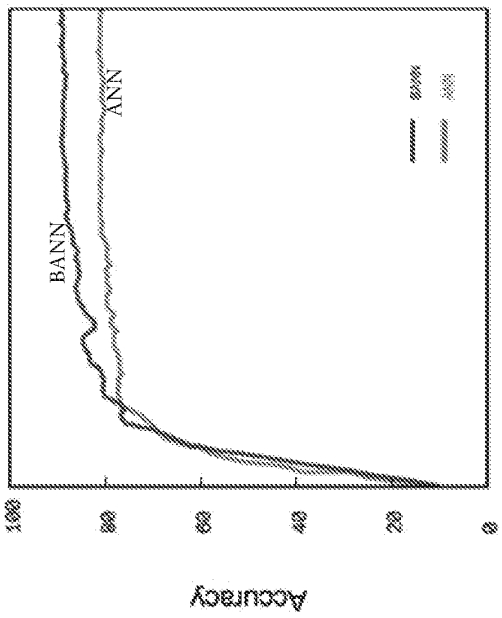


FIG. 29A

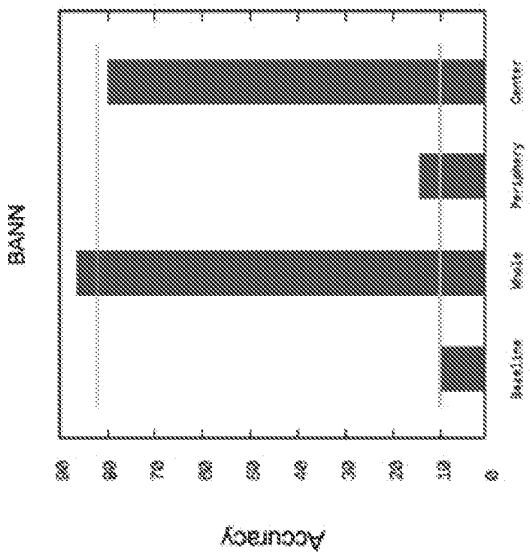


FIG. 29B

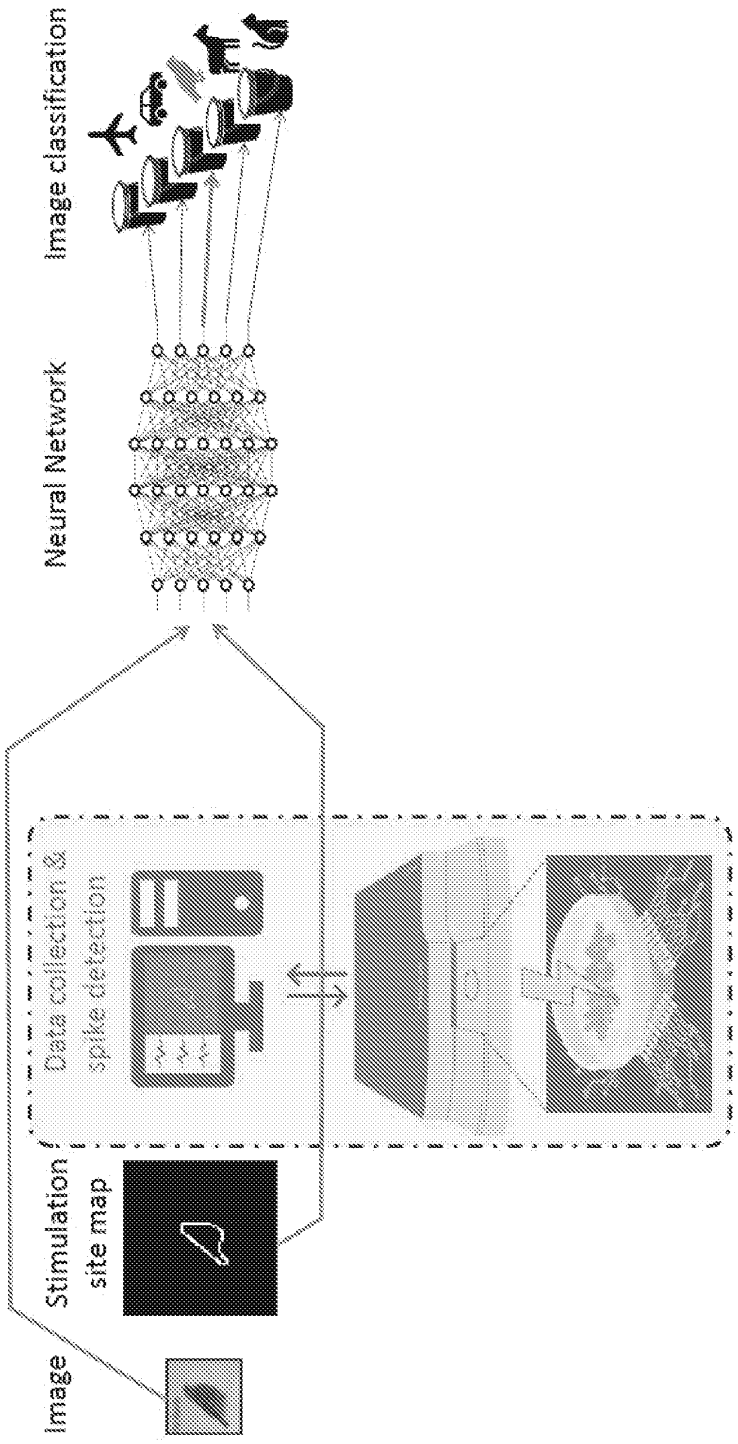
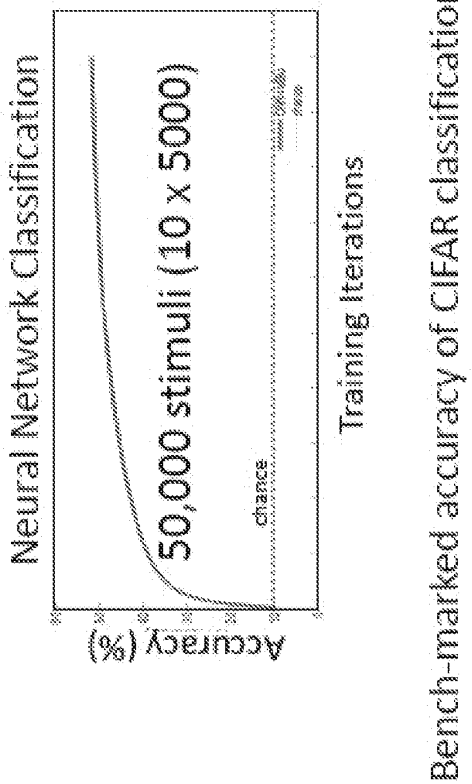

Image classification
Neural Network
Data collection & spike detection
Stimulation site map
Image

FIG. 30



Bench-marked accuracy of CIFAR classification (CNN)

FIG. 31

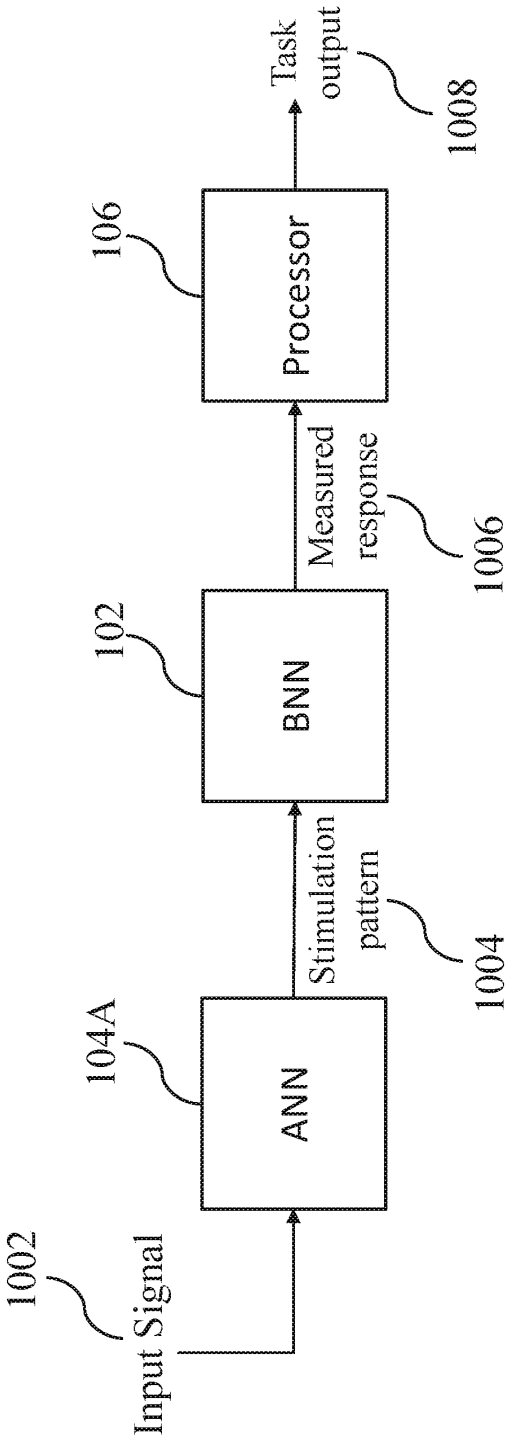

1002
Input Signal
104A
ANN
Stimulation pattern
1004
102
BNN
Measured response
1006
106
Processor
Task output
1008

FIG. 32A

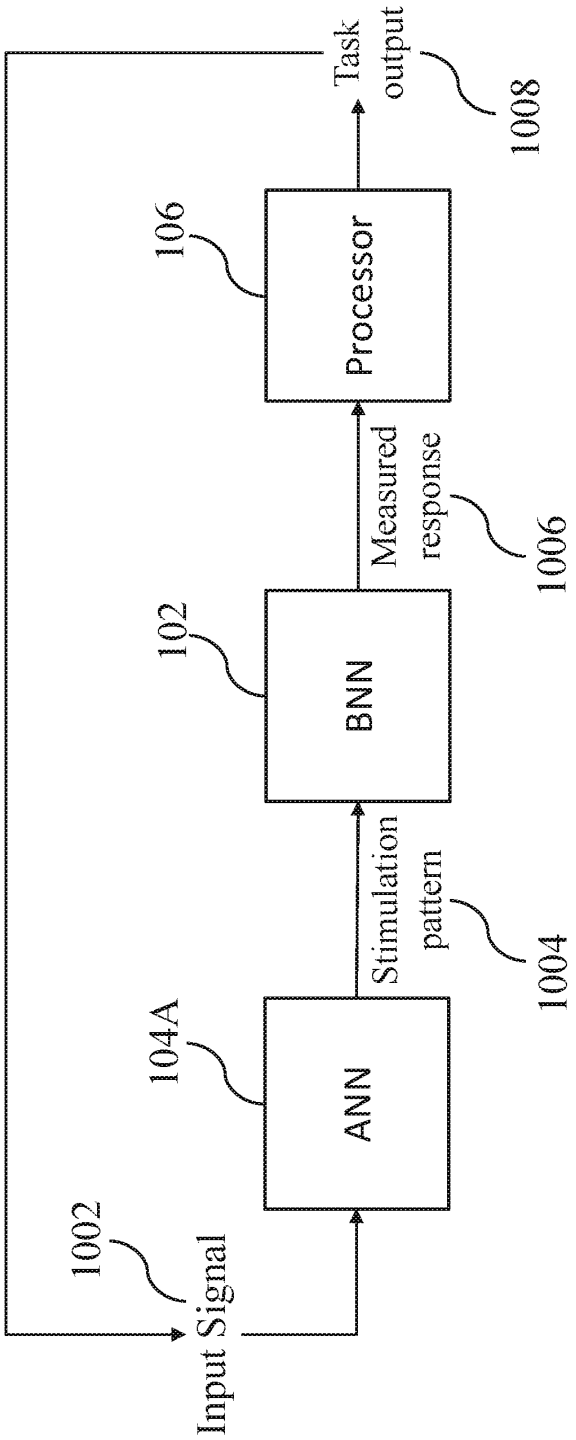

1002
Input Signal
104A
ANN
Stimulation pattern
1004
102
BNN
Measured response
1006
106
Processor
Task output
1008

FIG. 32B

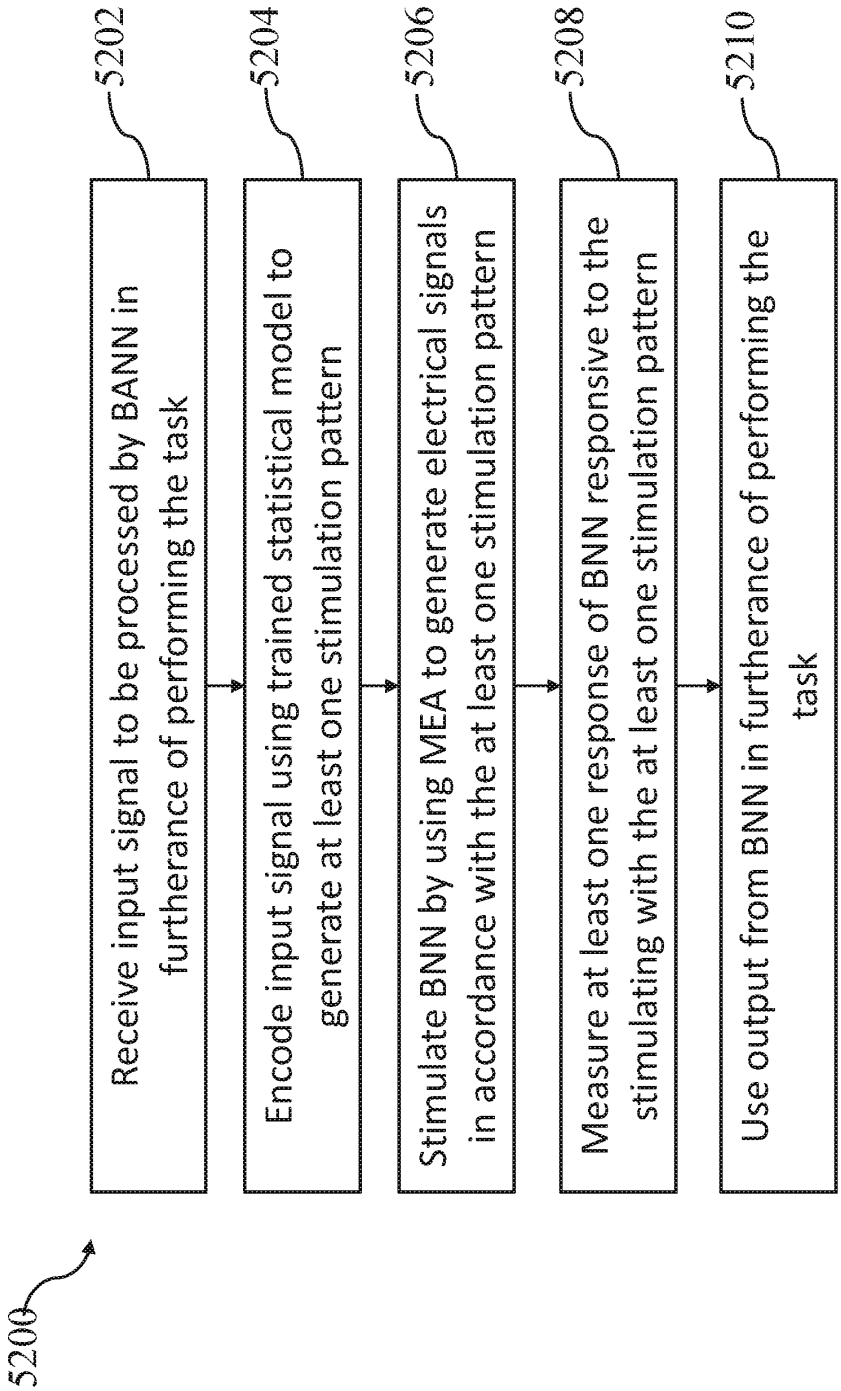

5200
5202
Receive input signal to be processed by BANN in furtherance of performing the task
5204
Encode input signal using trained statistical model to generate at least one stimulation pattern
5206
Stimulate BNN by using MEA to generate electrical signals in accordance with the at least one stimulation pattern
5208
Measure at least one response of BNN responsive to the stimulating with the at least one stimulation pattern
5210
Use output from BNN in furtherance of performing the task

FIG. 33

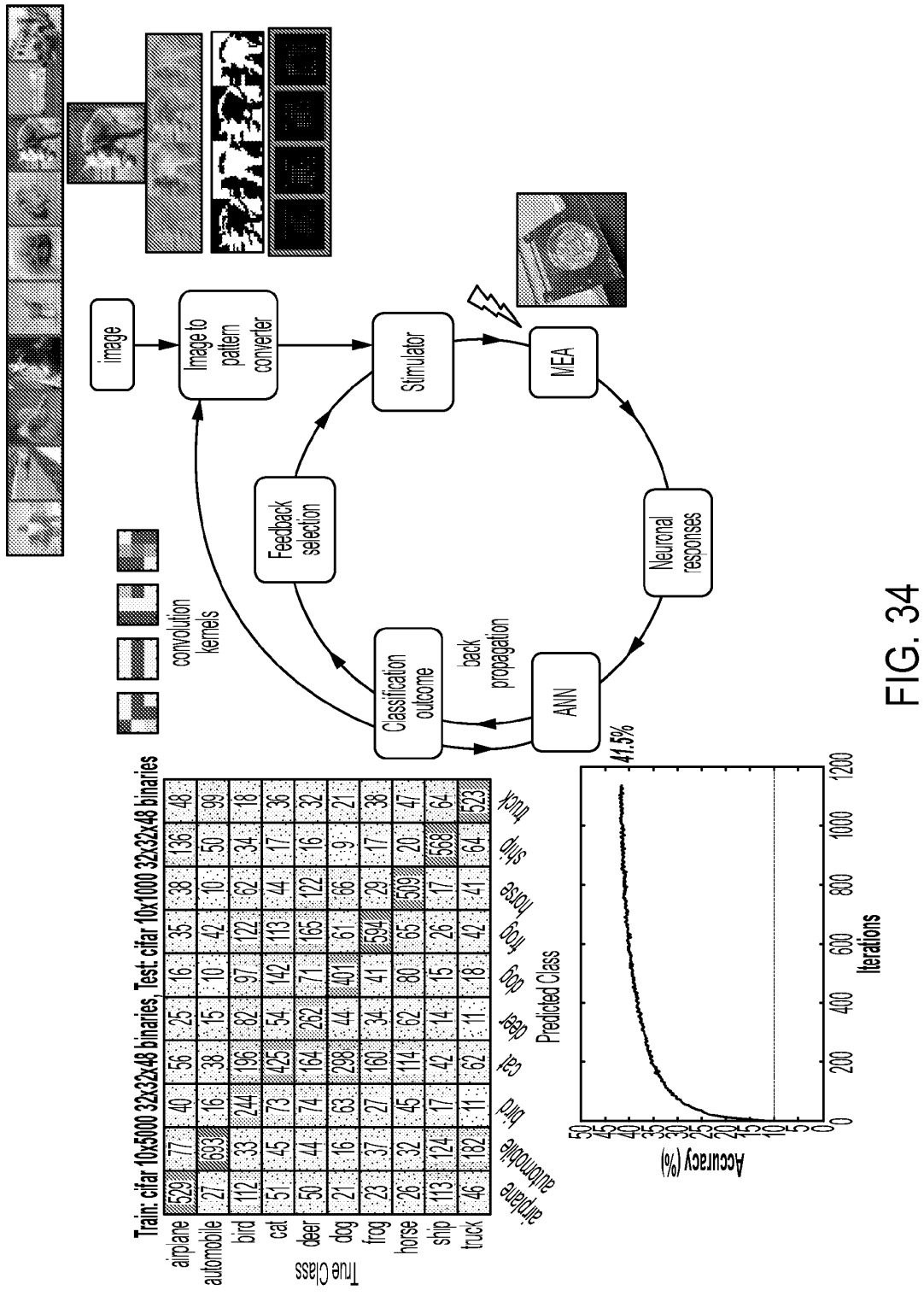


FIG. 34

RECTIFIED SHEET (RULE 91)

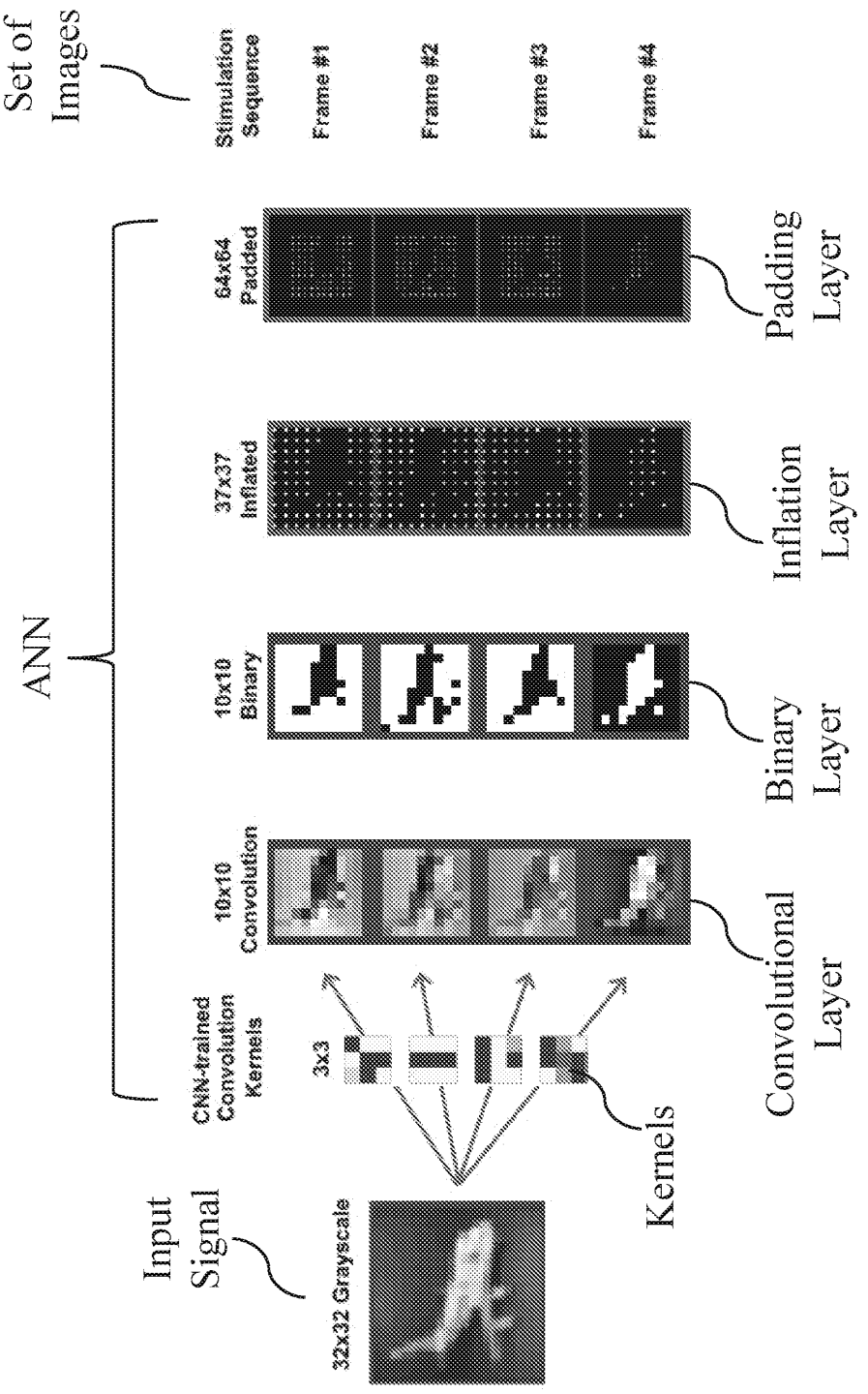

Set of Images
Stimulation Sequence
Frame #1
Frame #2
Frame #3
Frame #4
ANN
64x64 Padded
Padding Layer
37x37 Inflated
Inflation Layer
10x10 Binary
Binary Layer
10x10 Convolution
Convolutional Layer
CNN-trained Convolution Kernels
3x3
Kernels
Input Signal
32x32 Grayscale

FIG. 35

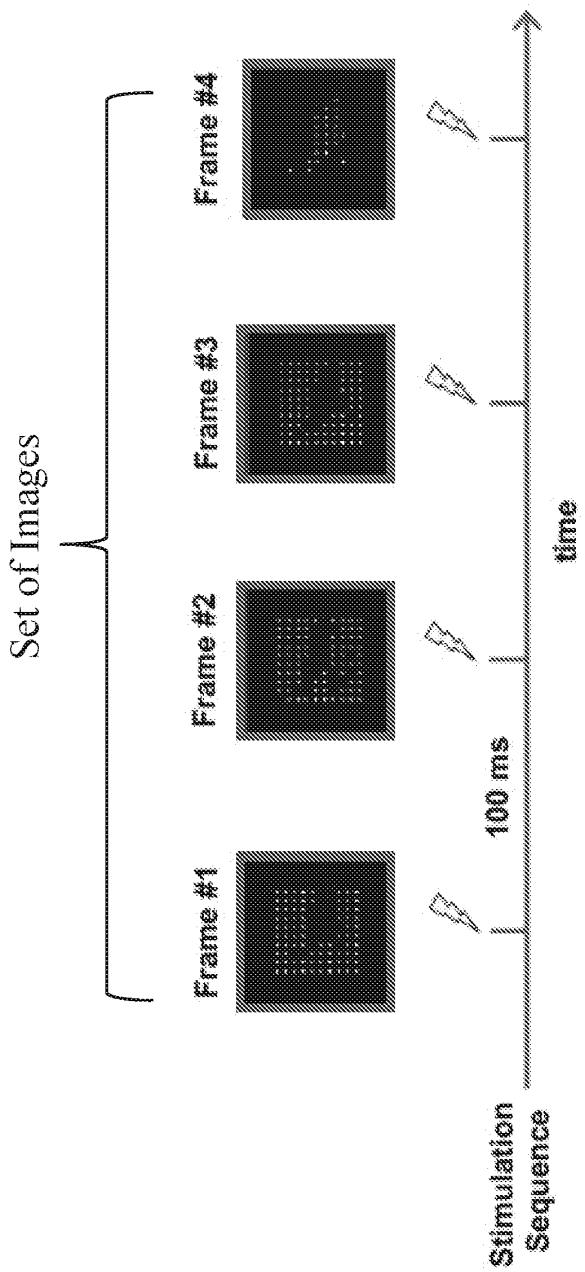

Set of Images
Frame #1
Frame #2
Frame #3
Frame #4
100 ms
time
Stimulation Sequence

FIG. 36

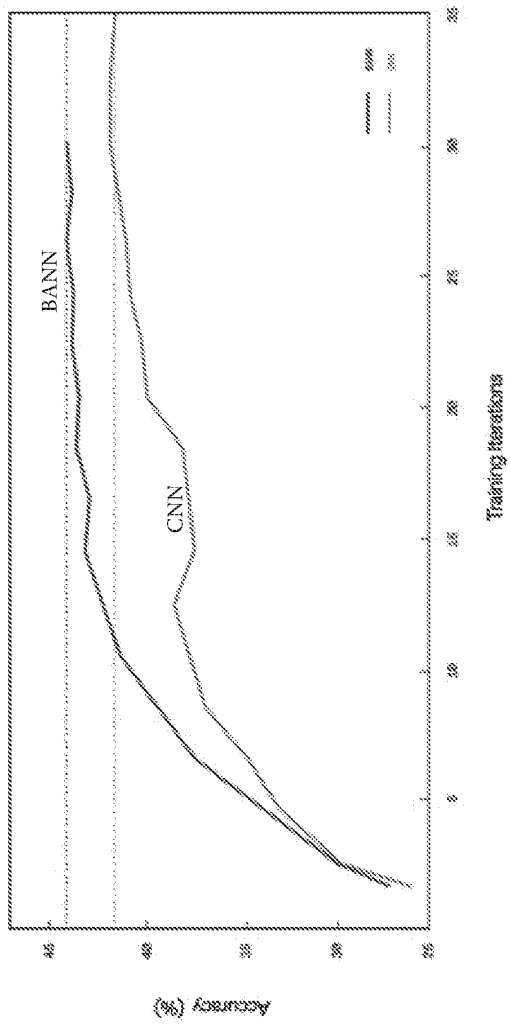


FIG. 37

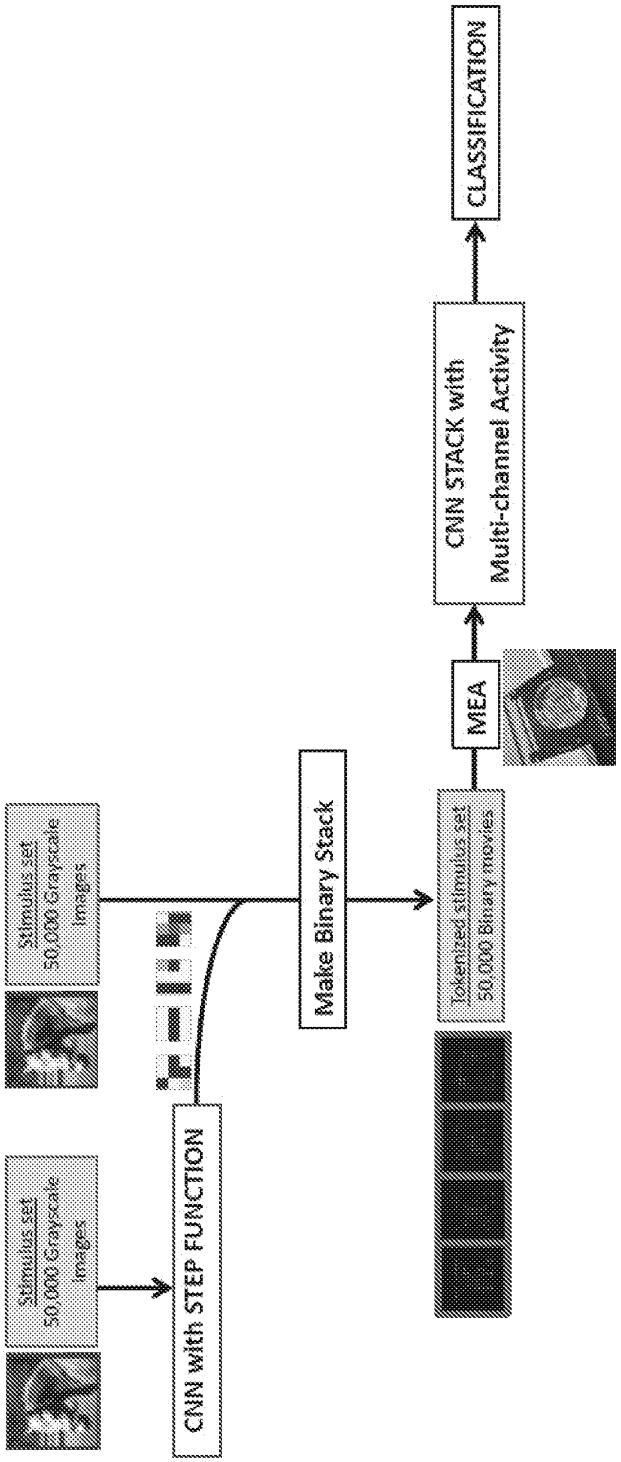

Stimulus set
50,000 Grayscale
Images
Stimulus set
50,000 Grayscale
Images
CNN with STEP FUNCTION
Make Binary Stack
Tokenized stimulus set
50,000 Binary movies
MEA
CNN STACK with
Multi-channel Activity
CLASSIFICATION

FIG. 38

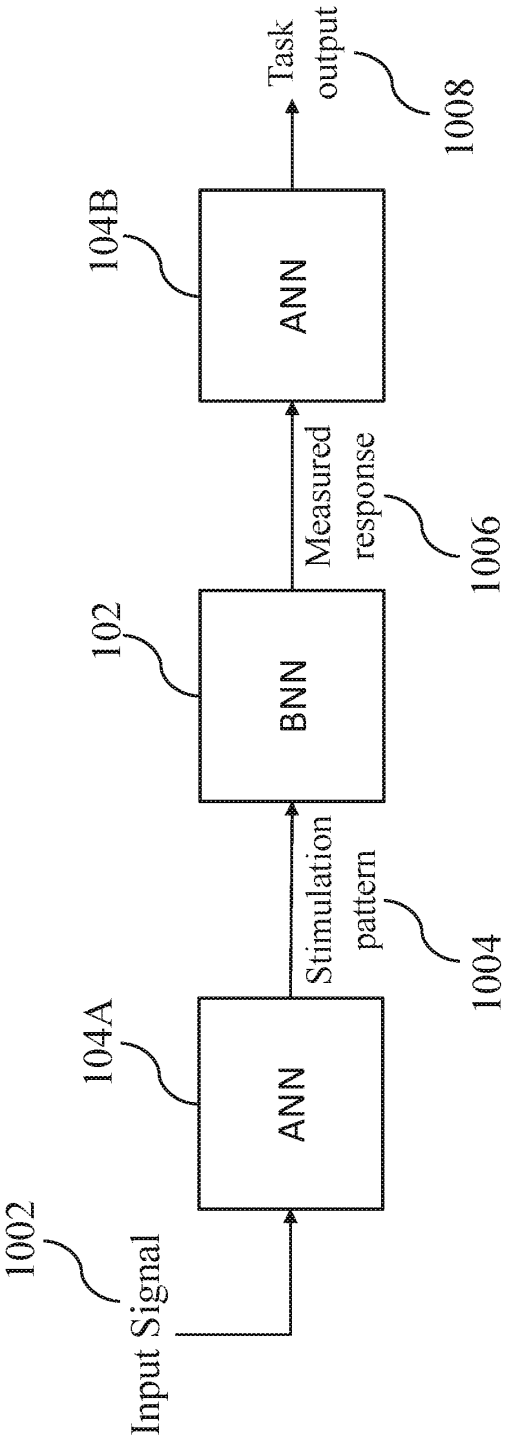

1002
Input Signal
104A
ANN
Stimulation pattern
1004
102
BNN
Measured response
1006
104B
ANN
Task output
1008

FIG. 39A

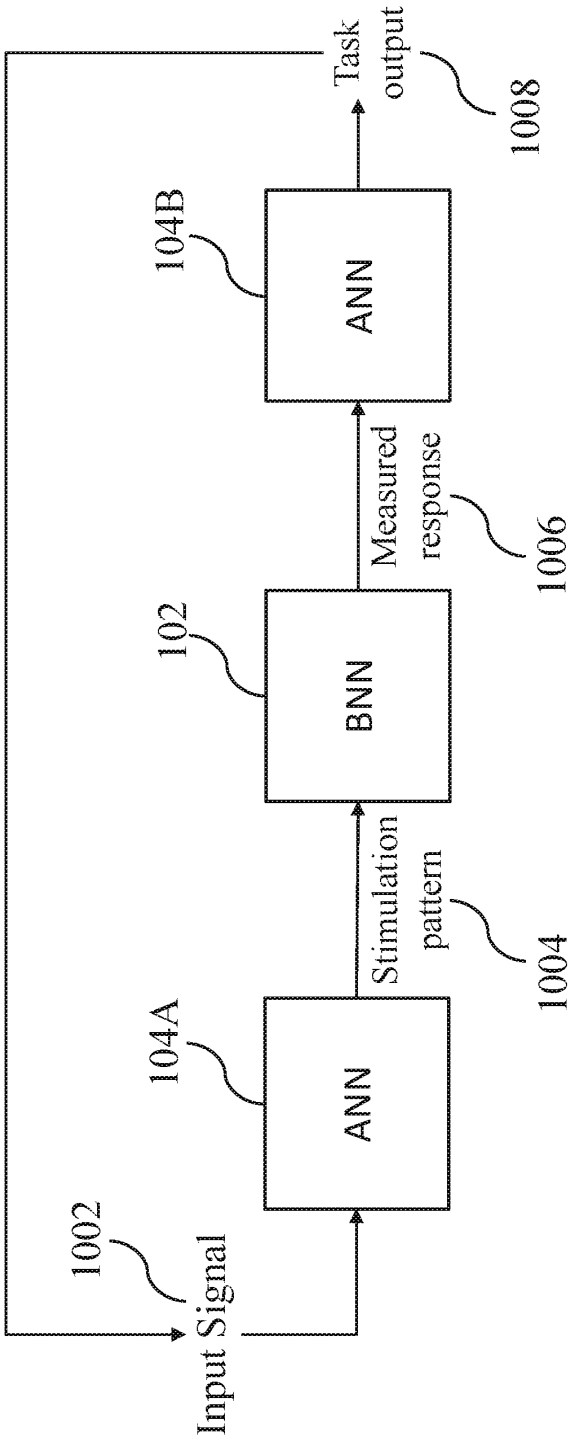

1002
Input Signal
104A
ANN
Stimulation pattern
1004
102
BNN
Measured response
1006
104B
ANN
Task output
1008

FIG. 39B

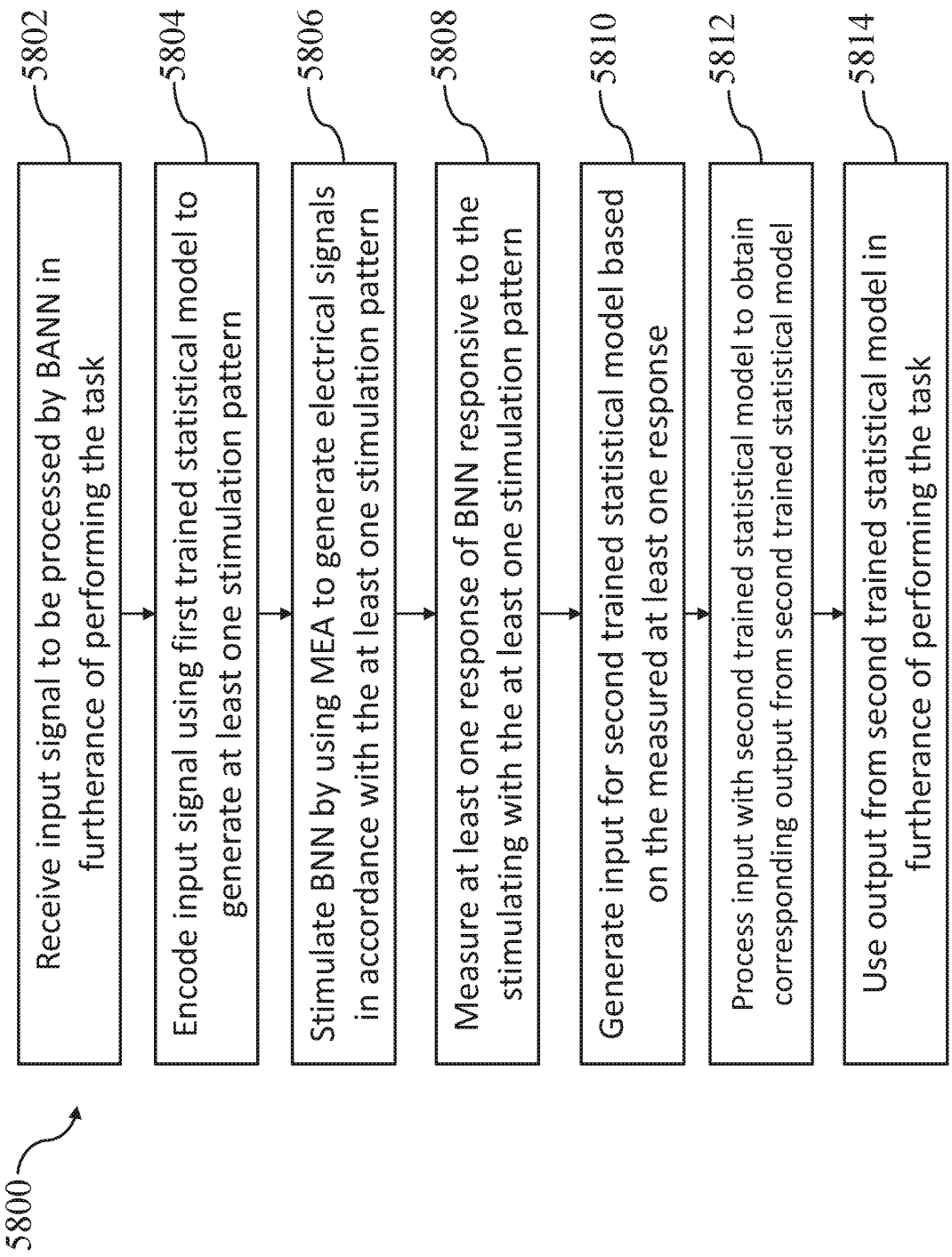

5800
5802
Receive input signal to be processed by BANN in furtherance of performing the task
5804
Encode input signal using first trained statistical model to generate at least one stimulation pattern
5806
Stimulate BNN by using MEA to generate electrical signals in accordance with the at least one stimulation pattern
5808
Measure at least one response of BNN responsive to the stimulating with the at least one stimulation pattern
5810
Generate input for second trained statistical model based on the measured at least one response
5812
Process input with second trained statistical model to obtain corresponding output from second trained statistical model
5814
Use output from second trained statistical model in furtherance of performing the task

FIG. 40

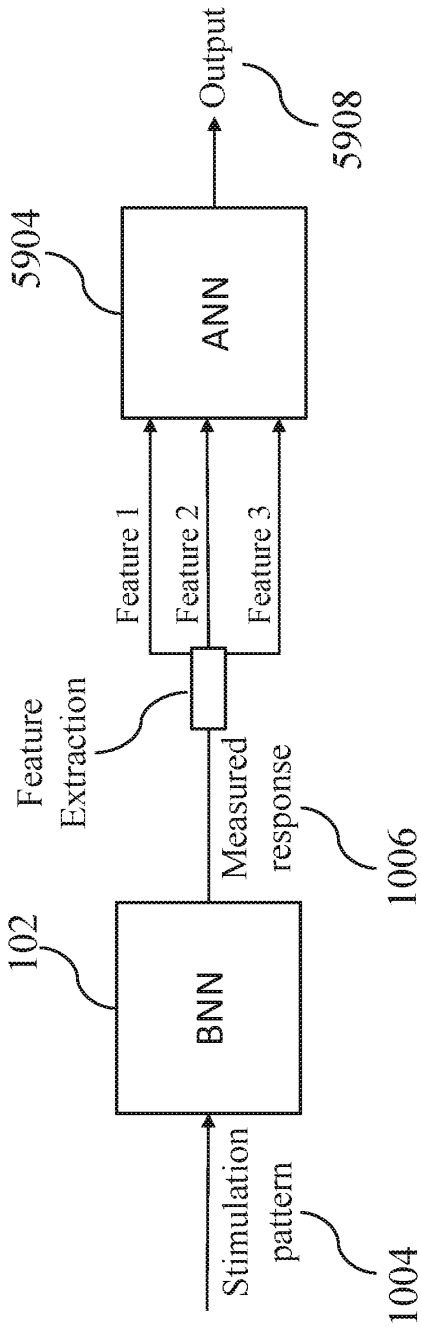

Stimulation pattern
1004
BNN
102
Measured response
1006
Feature Extraction
Feature 1
Feature 2
Feature 3
ANN
5904
Output
5908

FIG. 41

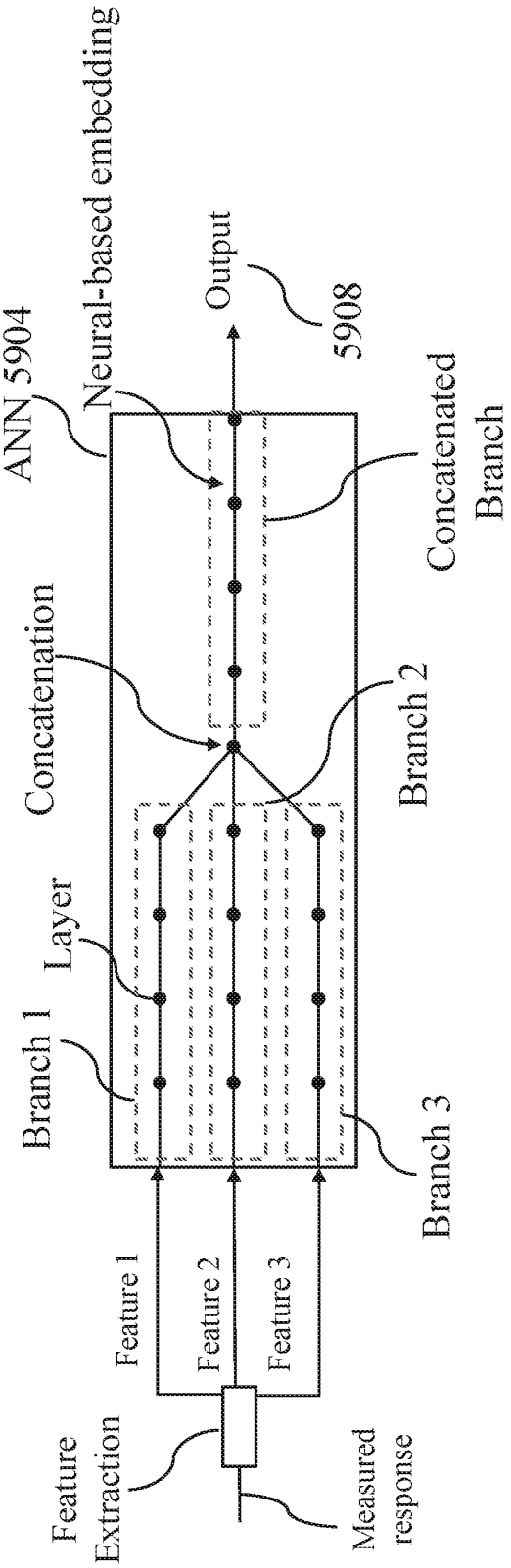

ANN 5904
Neural-based embedding
Output
5908
Concatenated Branch
Concatenation
Branch 2
Layer
Branch 1
Branch 3
Feature 1
Feature 2
Feature 3
Feature Extraction
Measured response

FIG. 42

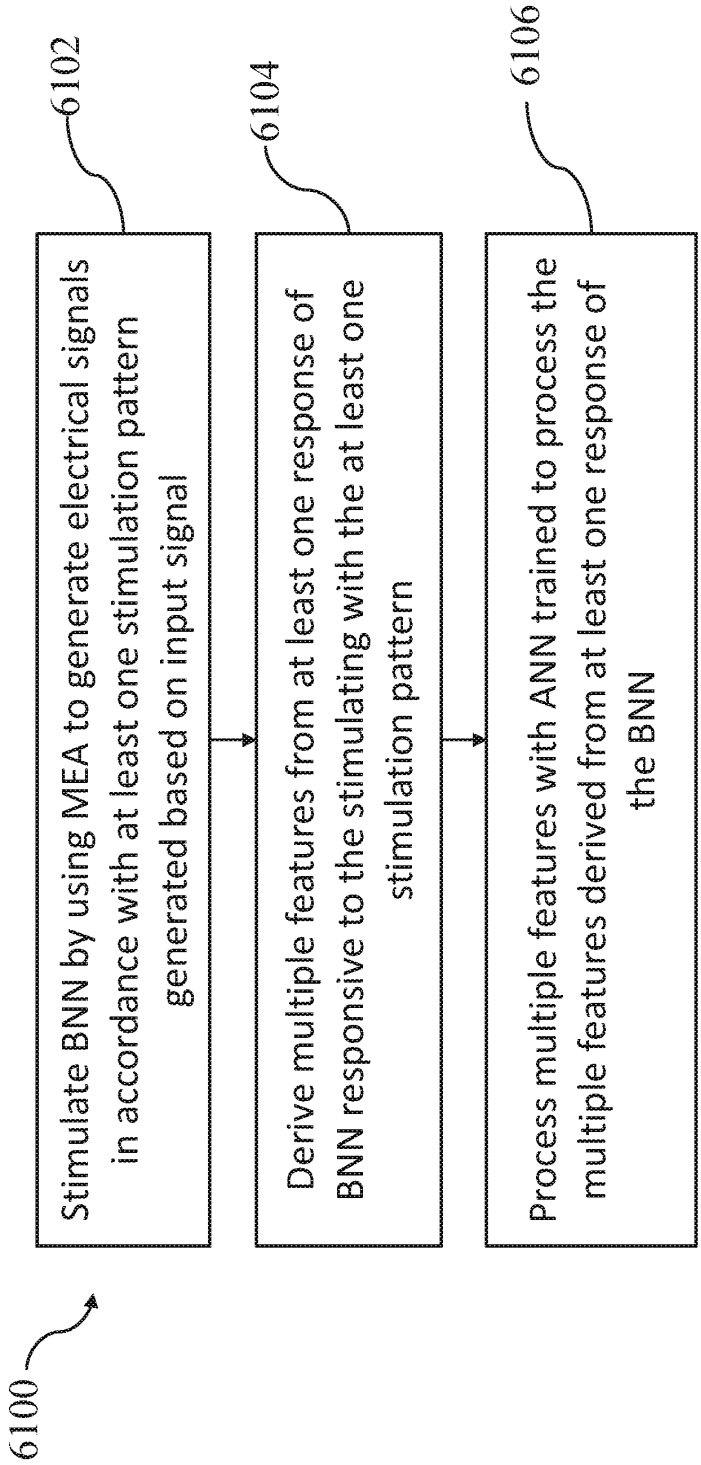

6100
6102
Stimulate BNN by using MEA to generate electrical signals in accordance with at least one stimulation pattern generated based on input signal
6104
Derive multiple features from at least one response of BNN responsive to the stimulating with the at least one stimulation pattern
6106
Process multiple features with ANN trained to process the multiple features derived from at least one response of the BNN

FIG. 43

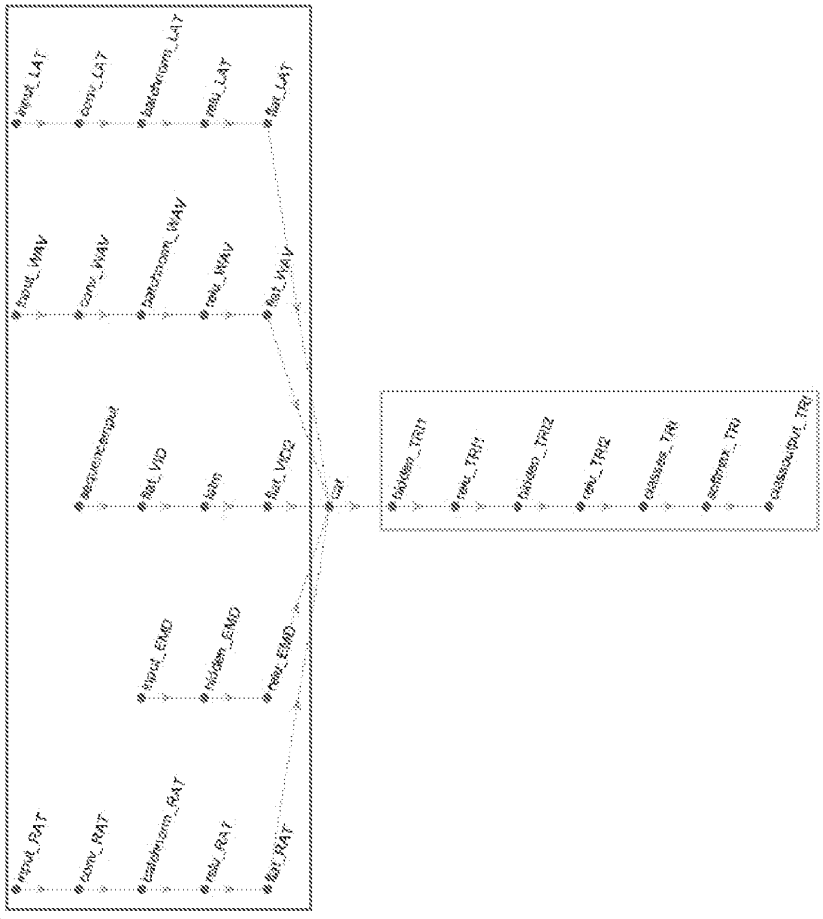

input_LAT
conv_LAT
batchnorm_LAT
relu_LAT
flat_LAT
input_VAV
conv_VAV
batchnorm_VAV
relu_VAV
flat_VAV
sequenceInput
flat_VID
lstm
flat_VID2
cat
hidden_TRI1
relu_TRI1
hidden_TRI2
relu_TRI2
classifc_TRI
softmax_TRI
classoutput_TRI
input_EMD
hidden_EMD
relu_EMD
input_RAT
conv_RAT
batchnorm_RAT
relu_RAT
flat_RAT

FIG. 44

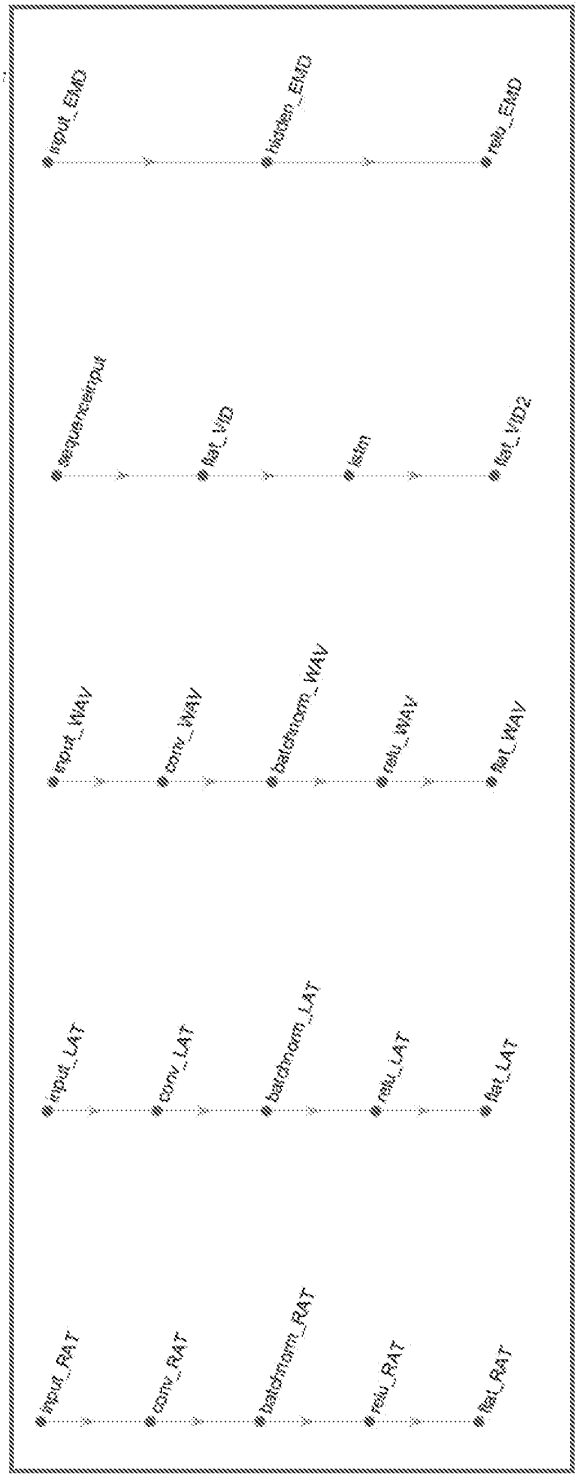

input_RAT
conv_RAT
batchnorm_RAT
relu_RAT
flat_RAT
input_LAT
conv_LAT
batchnorm_LAT
relu_LAT
flat_LAT
input_WAV
conv_WAV
batchnorm_WAV
relu_WAV
flat_WAV
sequenceinput
flat_VID
lstm
flat_VID2
input_EMO
hidden_EMO
relu_EMO

FIG. 45

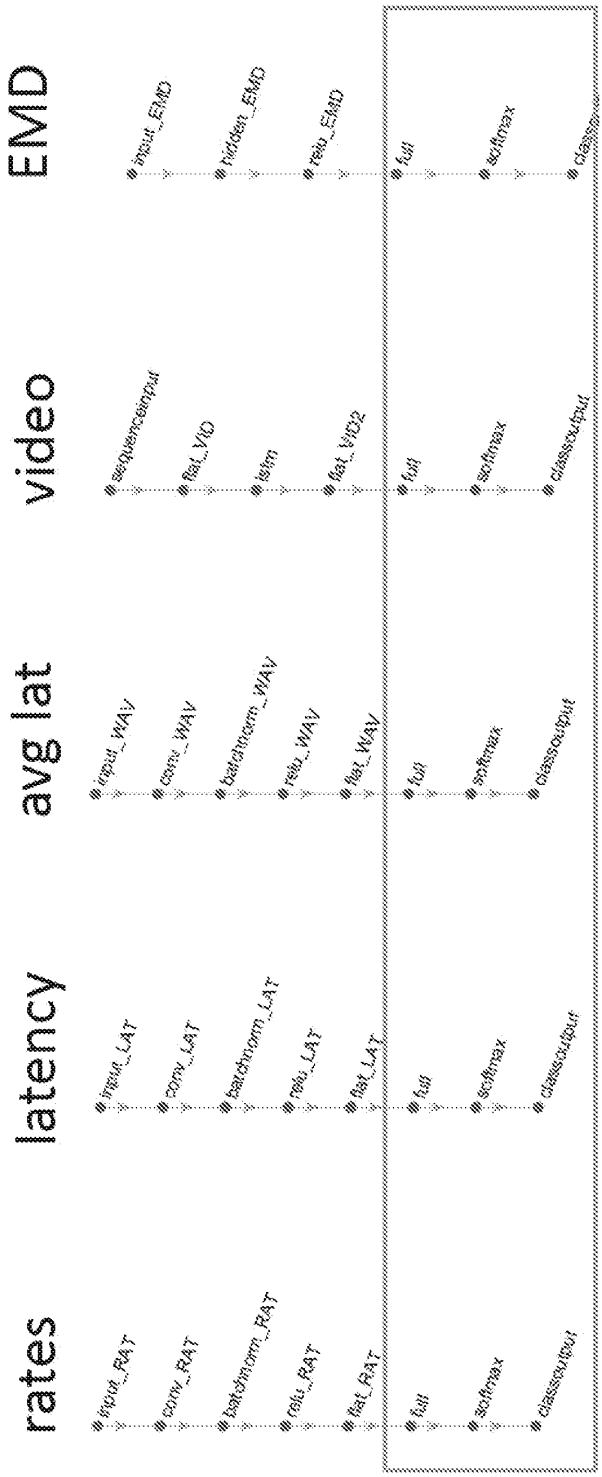

rates
input_RAT
conv_RAT
batchnorm_RAT
relu_RAT
flat_RAT
full
softmax
classoutput
latency
input_LAT
conv_LAT
batchnorm_LAT
relu_LAT
flat_LAT
full
softmax
classoutput
avg lat
input_WAV
conv_WAV
batchnorm_WAV
relu_WAV
flat_WAV
full
softmax
classoutput
video
sequenceinput
flat_VID
lstm
flat_VID2
full
softmax
classoutput
EMD
input_EMD
hidden_EMD
relu_EMD
full
softmax
classo

FIG. 46

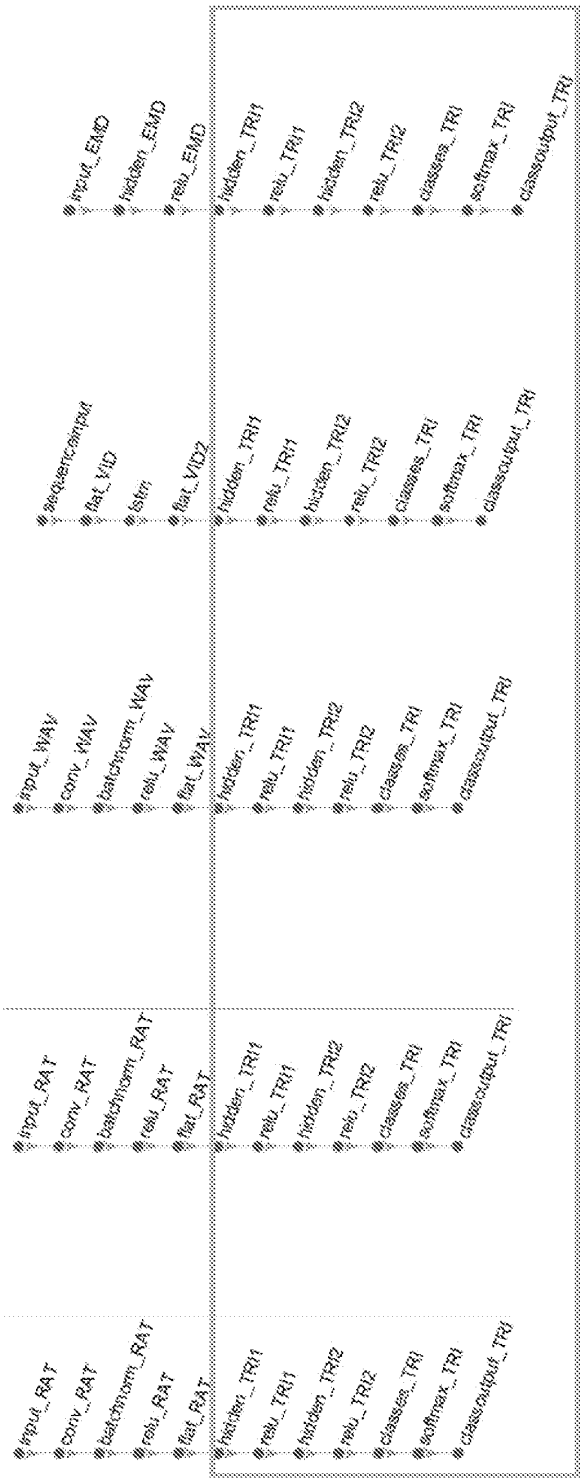

input_EMD
hidden_EMD
relu_EMD
hidden_TRI1
relu_TRI1
hidden_TRI2
relu_TRI2
classes_TRI
softmax_TRI
classoutput_TRI
sequenceinput
flat_VID
lstm
flat_VID2
hidden_TRI1
relu_TRI1
hidden_TRI2
relu_TRI2
classes_TRI
softmax_TRI
classoutput_TRI
input_WAV
conv_WAV
batchnorm_WAV
relu_WAV
flat_WAV
hidden_TRI1
relu_TRI1
hidden_TRI2
relu_TRI2
classes_TRI
softmax_TRI
classoutput_TRI
input_RAT
conv_RAT
batchnorm_RAT
relu_RAT
flat_RAT
hidden_TRI1
relu_TRI1
hidden_TRI2
relu_TRI2
classes_TRI
softmax_TRI
classoutput_TRI
input_RAT
conv_RAT
batchnorm_RAT
relu_RAT
flat_RAT
hidden_TRI1
relu_TRI1
hidden_TRI2
relu_TRI2
classes_TRI
softmax_TRI
classoutput_TRI

FIG. 47

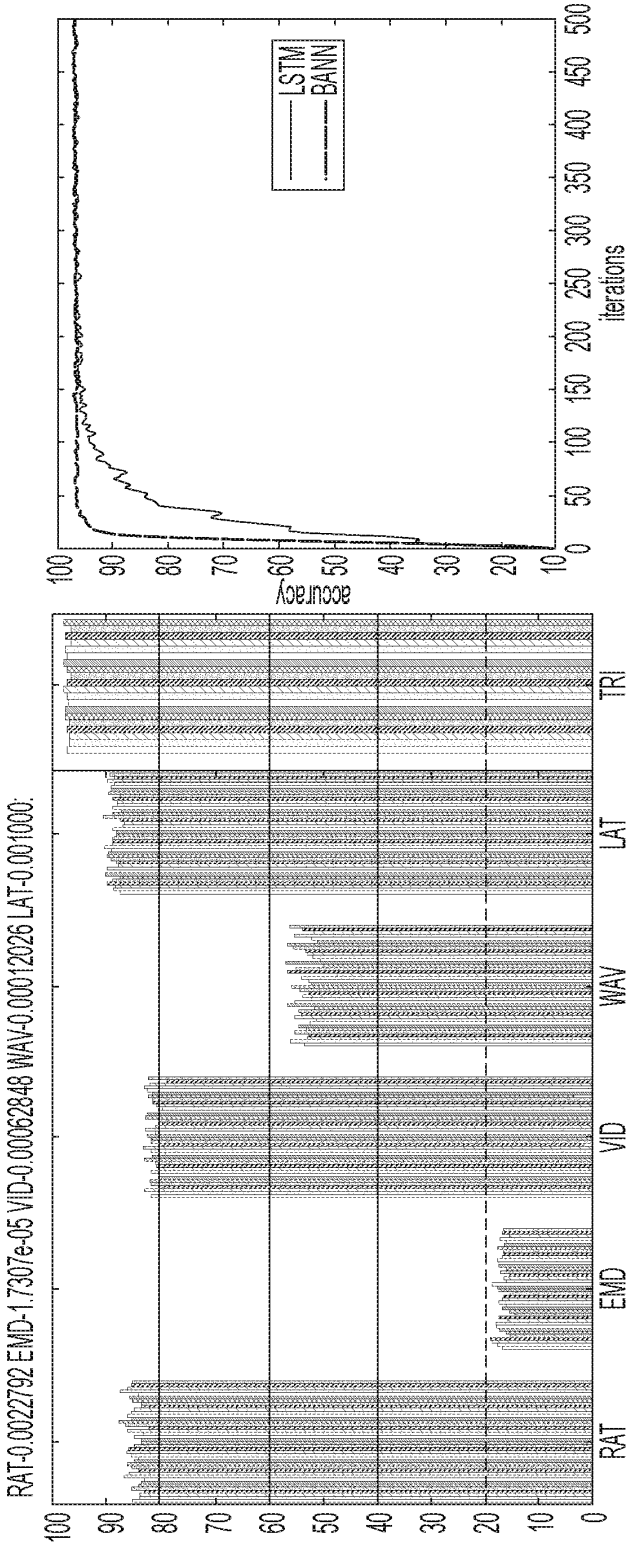

RAT-0.0022792 EMD-1.7307e-05 VID-0.00062848 WAV-0.00012026 LAT-0.001000:
RAT
EMD
VID
WAV
LAT
TRI
accuracy
iterations
LSTM
BANN

FIG. 48

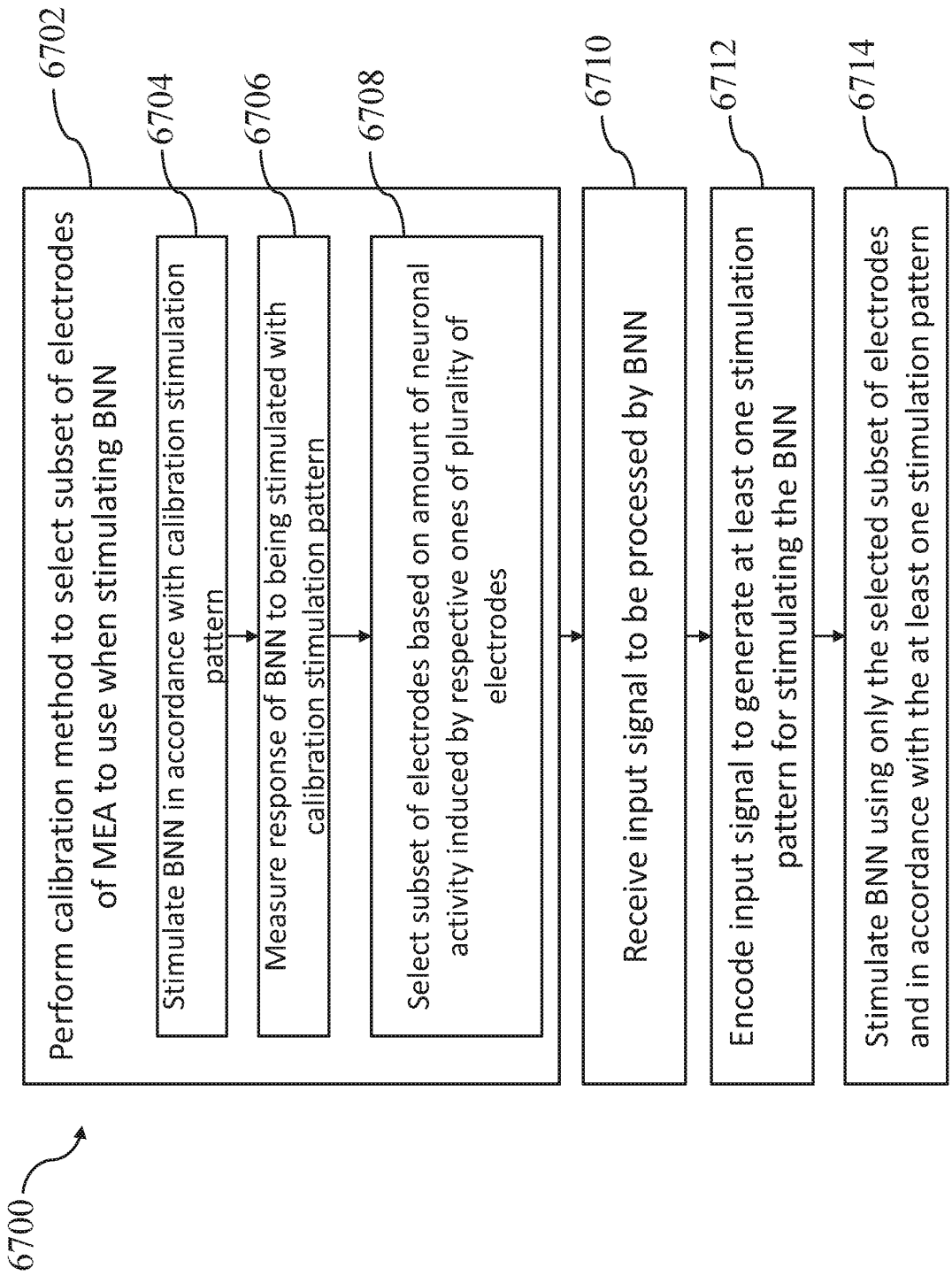

6700
6702
Perform calibration method to select subset of electrodes of MEA to use when stimulating BNN
6704
Stimulate BNN in accordance with calibration stimulation pattern
6706
Measure response of BNN to being stimulated with calibration stimulation pattern
6708
Select subset of electrodes based on amount of neuronal activity induced by respective ones of plurality of electrodes
6710
Receive input signal to be processed by BNN
6712
Encode input signal to generate at least one stimulation pattern for stimulating the BNN
6714
Stimulate BNN using only the selected subset of electrodes and in accordance with the at least one stimulation pattern

FIG. 49

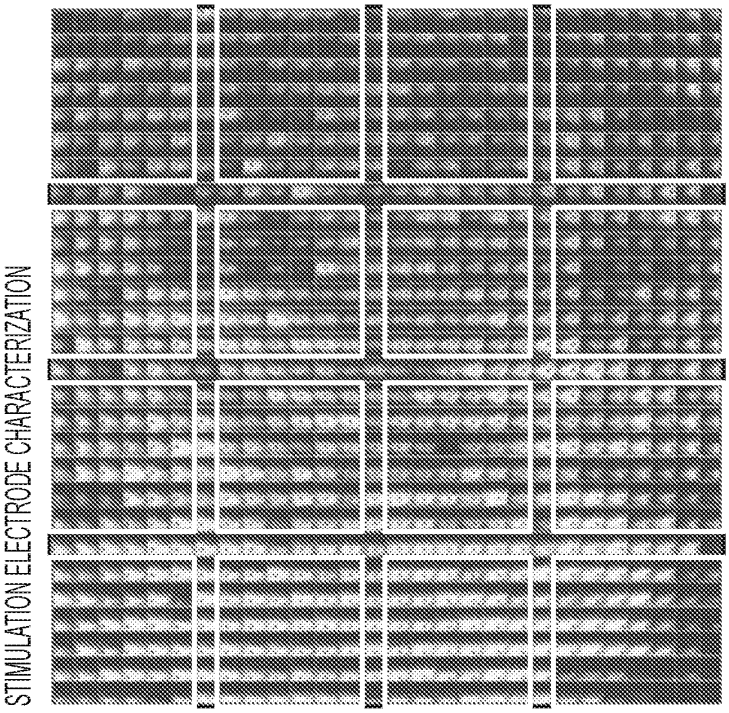


FIG. 50

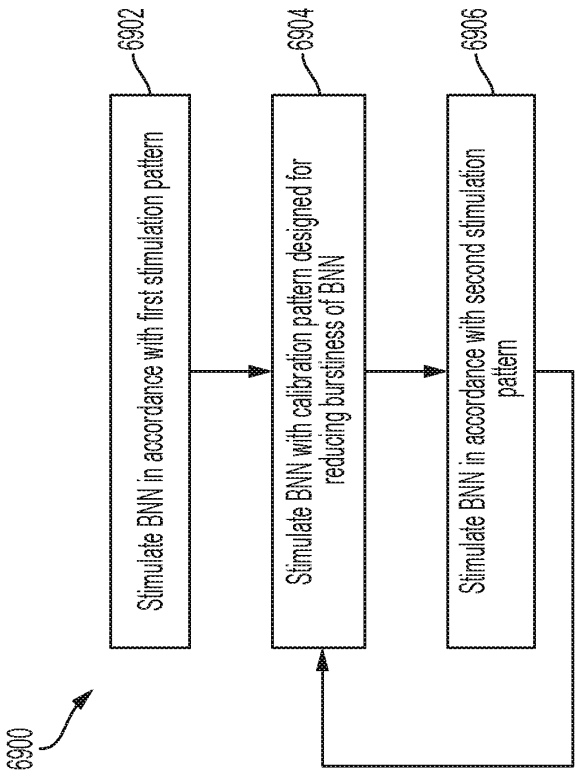

6900
6902
Stimulate BNN in accordance with first stimulation pattern
6904
Stimulate BNN with calibration pattern designed for reducing burstiness of BNN
6906
Stimulate BNN in accordance with second stimulation pattern

FIG. 51

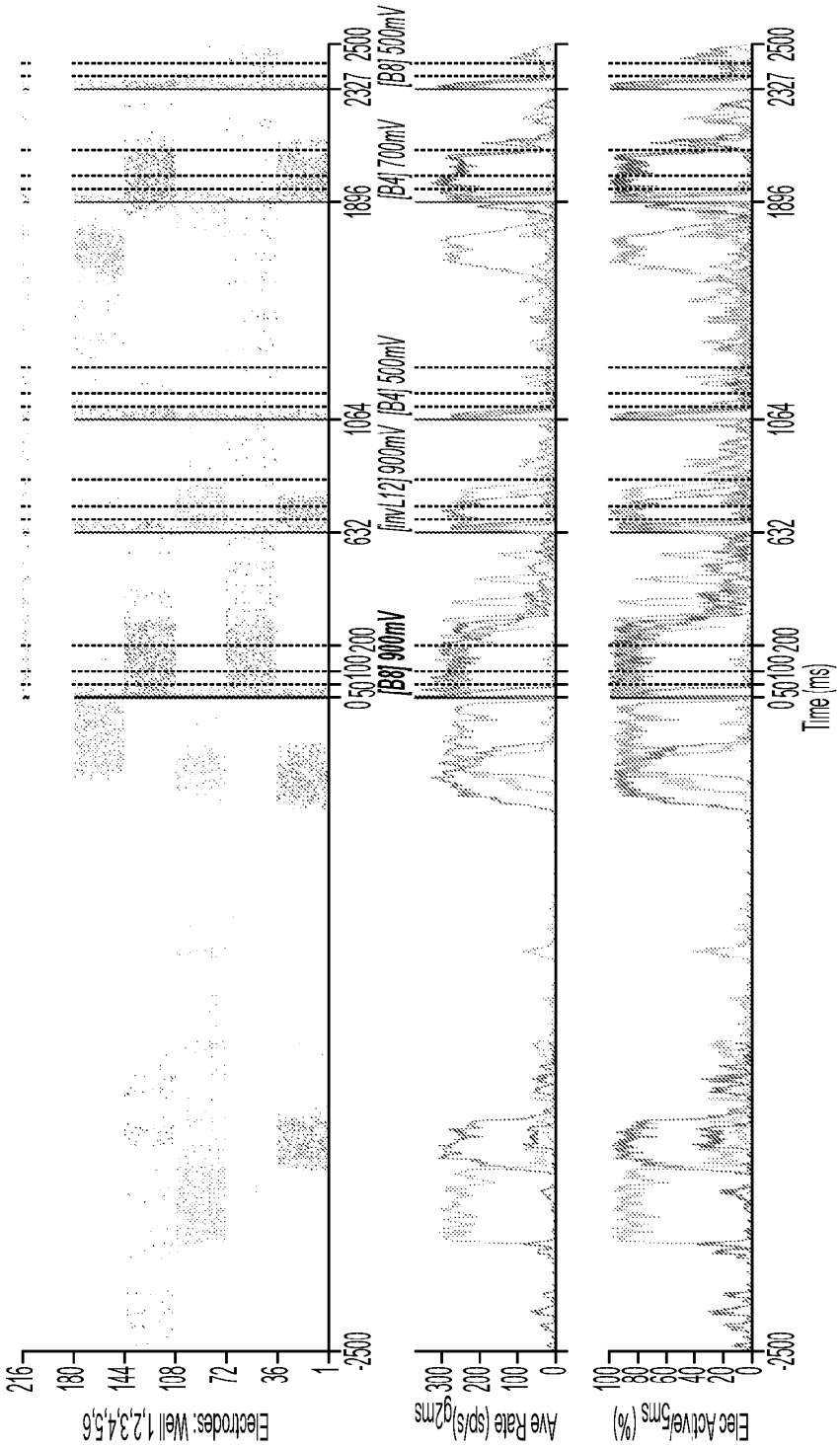

Electrodes: Well 1,2,3,4,5,6
216
180
144
108
72
36
1
-2500
0
632
1064
1896
2327
2500
[B8] 900mV
[Inv L12] 900mV
[B4] 500mV
[B4] 700mV
[B8] 500mV
Ave Rate (sp/s)g2ms
300
200
100
0
Elec Activel5ms (%)
100
80
60
40
20
0
50
100
200
Time (ms)

FIG. 52

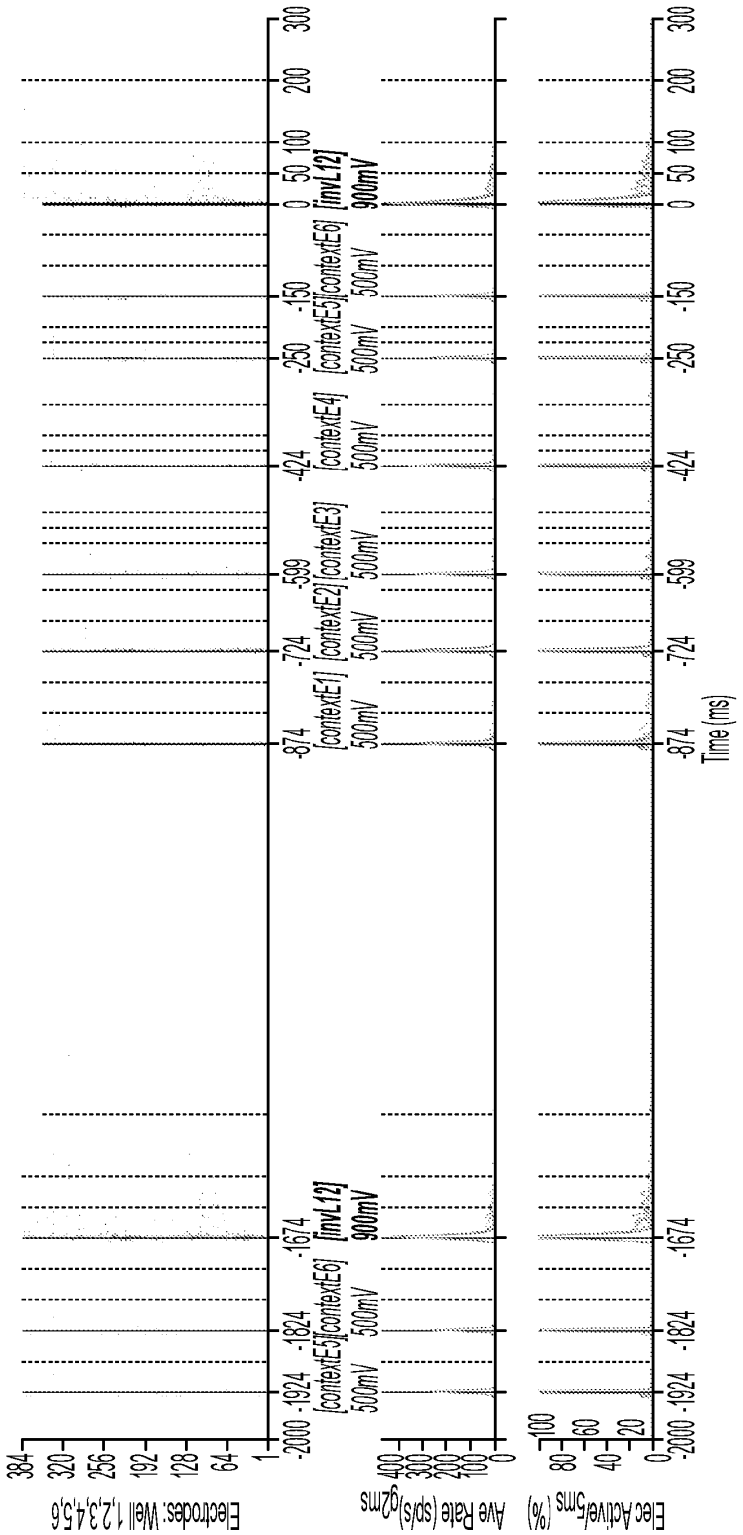

Electrodes: Well 1,2,3,4,5,6
Ave Rate (sp/s)g2ms
Elec Activeg5ms (%)
Time (ms)
[contextE5][contextE6] [invL12]
500mV 500mV 900mV
[contextE1] [contextE2] [contextE3] [contextE4] [contextE5][contextE6] [invL12]
500mV 500mV 500mV 500mV 500mV 500mV 900mV

FIG. 53

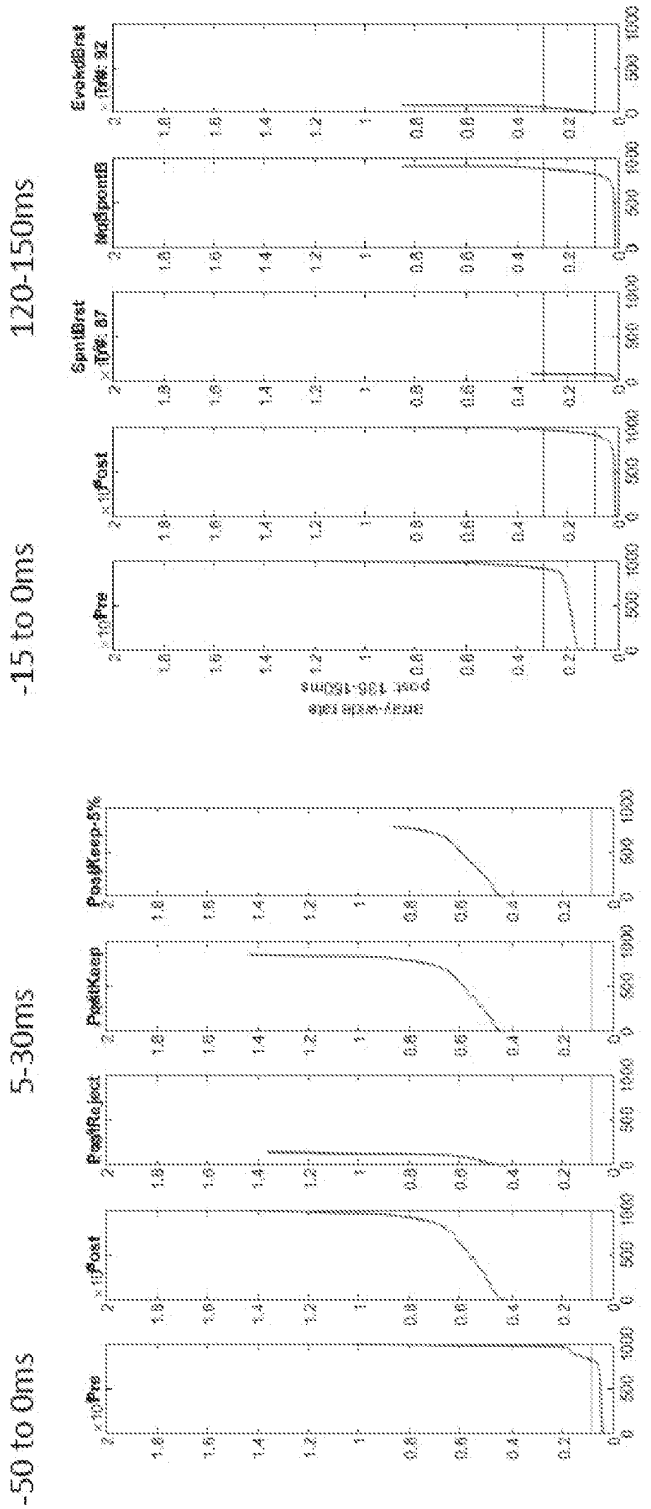

-50 to 0ms
5-30ms
-15 to 0ms
120-150ms
Pre
Post
PostReject
PostKeep
PostKeep-5%
SpntBrst
Type: 87
MxSpnt8
EvokedBrst
Type: 92

FIG. 54

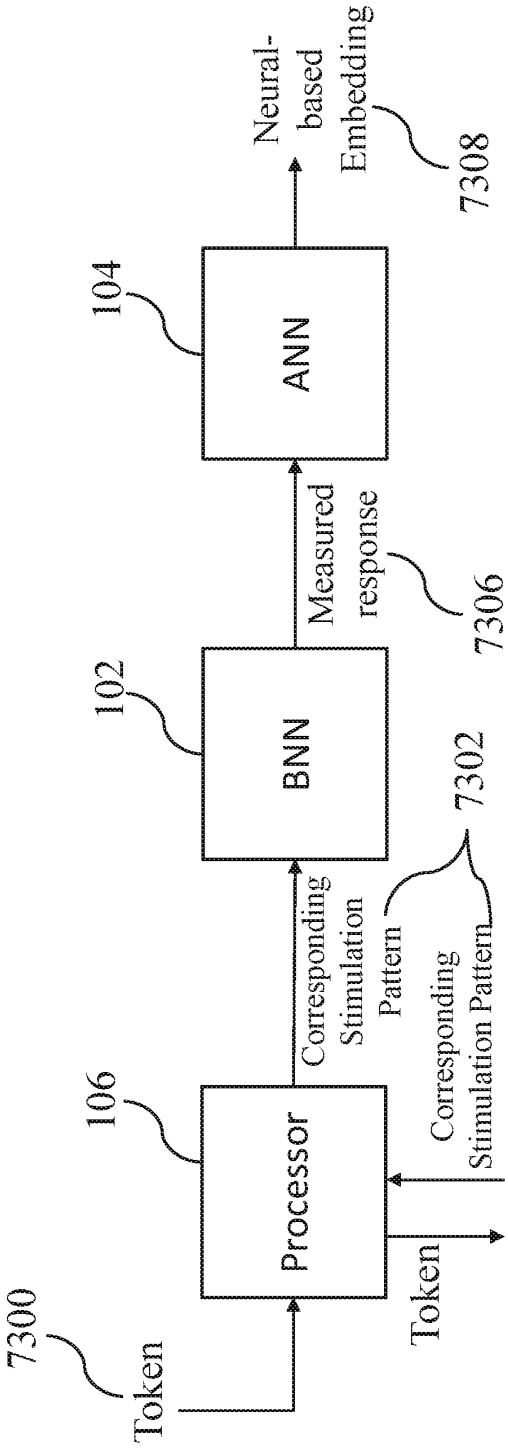

7300
Token
106
Processor
Token
Corresponding Stimulation Pattern
7302
Unique Stimulation Patterns
7304
Corresponding Stimulation Pattern
102
BNN
Measured response
7306
104
ANN
Neural-based Embedding
7308

FIG. 55

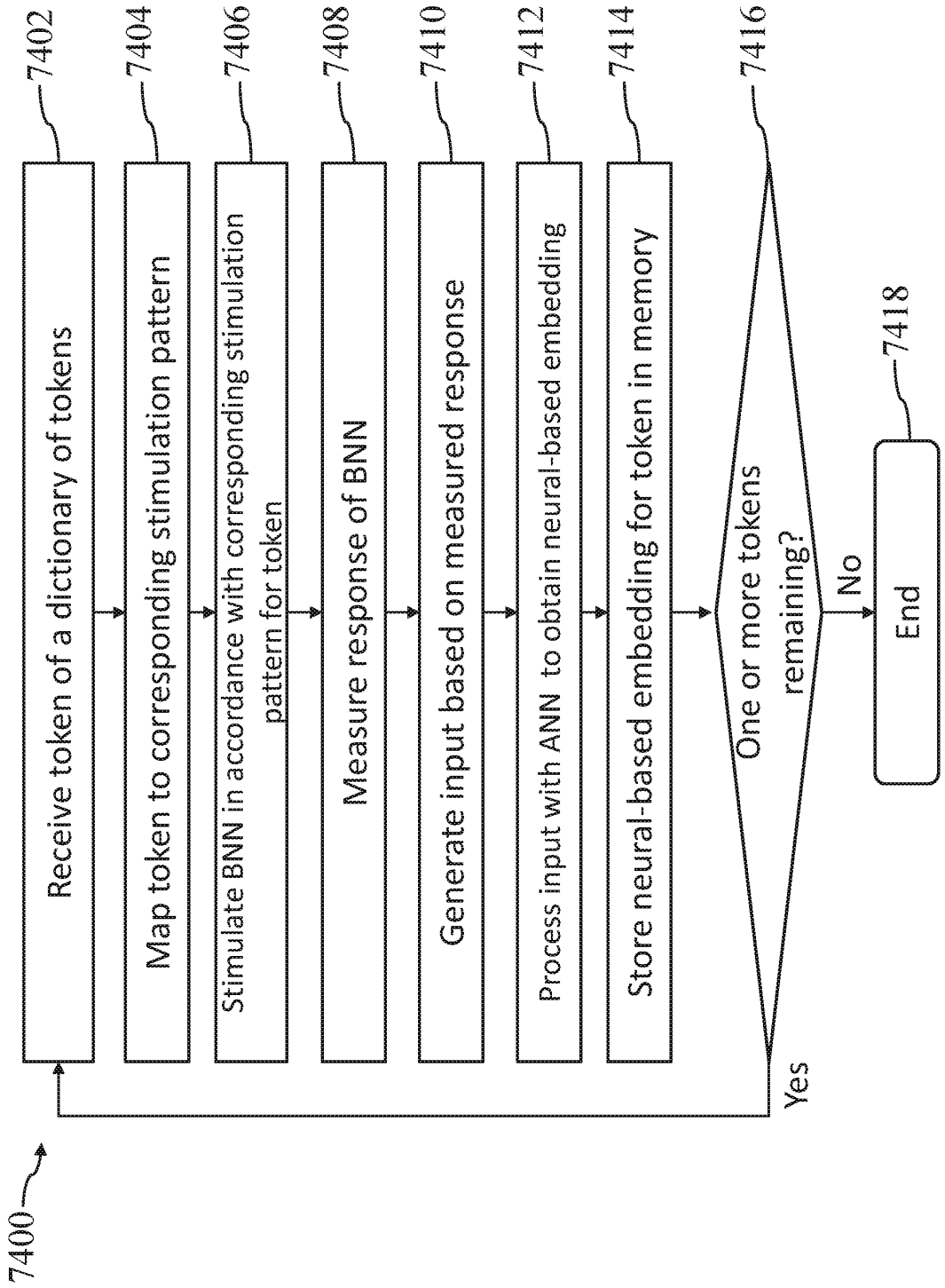

7400
7402
Receive token of a dictionary of tokens
7404
Map token to corresponding stimulation pattern
7406
Stimulate BNN in accordance with corresponding stimulation pattern for token
7408
Measure response of BNN
7410
Generate input based on measured response
7412
Process input with ANN to obtain neural-based embedding
7414
Store neural-based embedding for token in memory
7416
One or more tokens remaining?
Yes
No
7418
End

FIG. 56

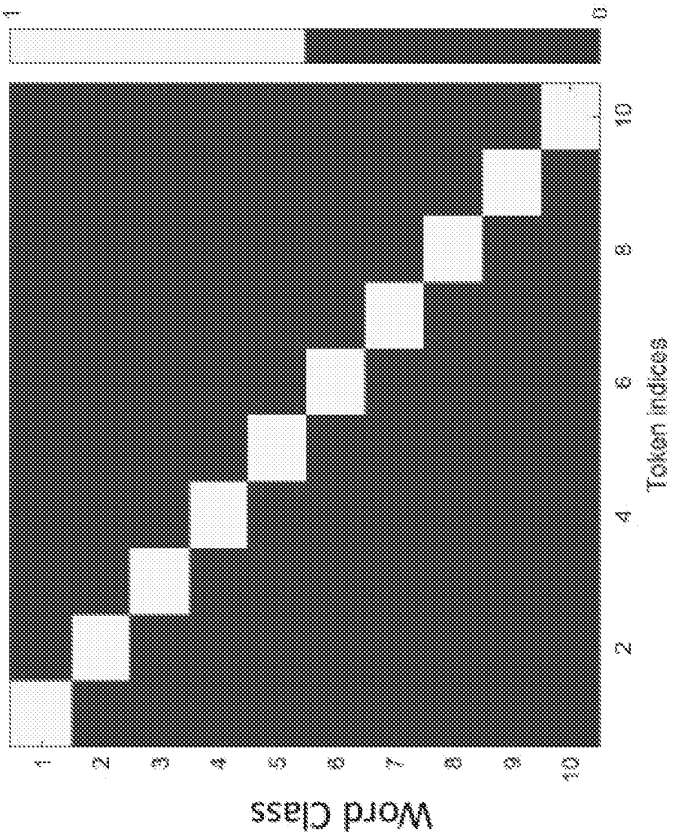


FIG. 57

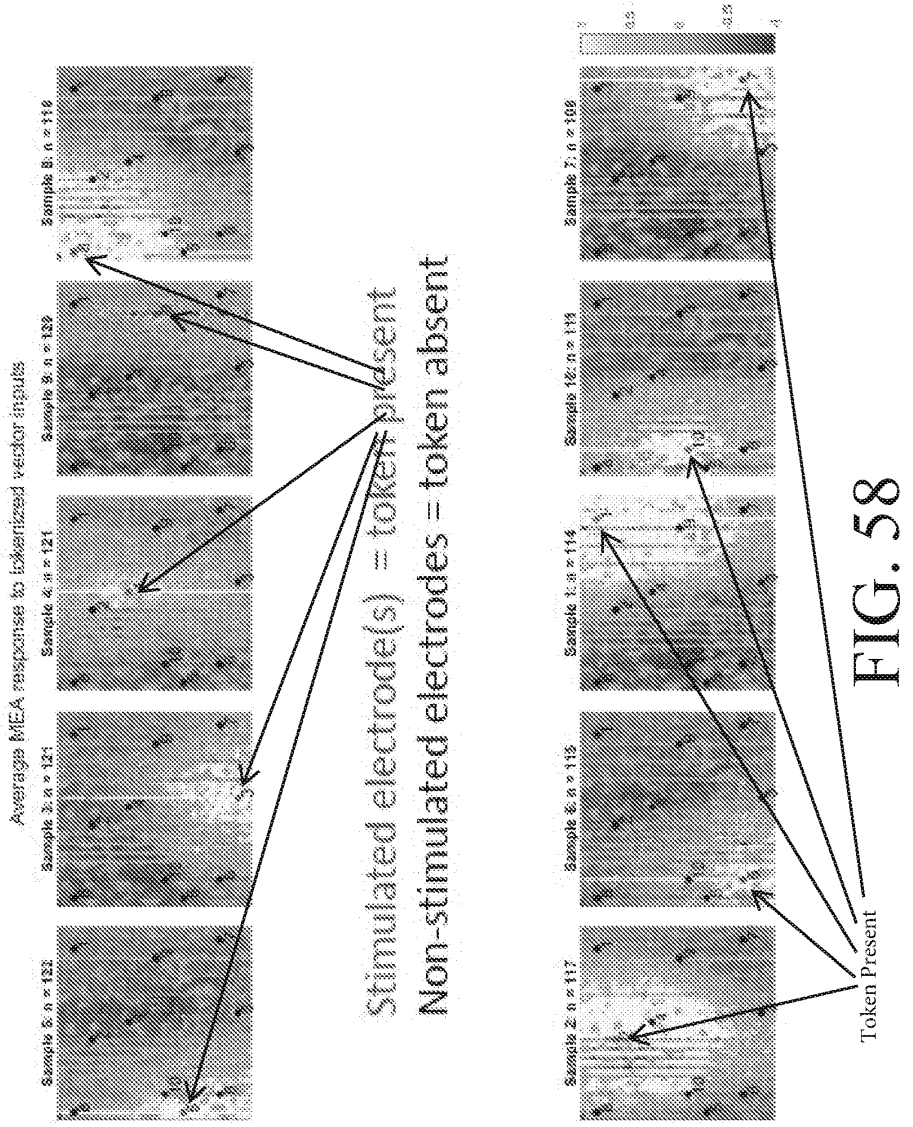

Average MEA response to tokenized vector inputs
Sample 8, n = 122
Sample 2, n = 121
Sample 4, n = 121
Sample 9, n = 120
Sample 8, n = 116
Stimulated electrode(s) = token present
Non-stimulated electrodes = token absent
Sample 2, n = 117
Sample 6, n = 115
Sample 1, n = 114
Sample 12, n = 111
Sample 7, n = 109
Token Present

FIG. 58

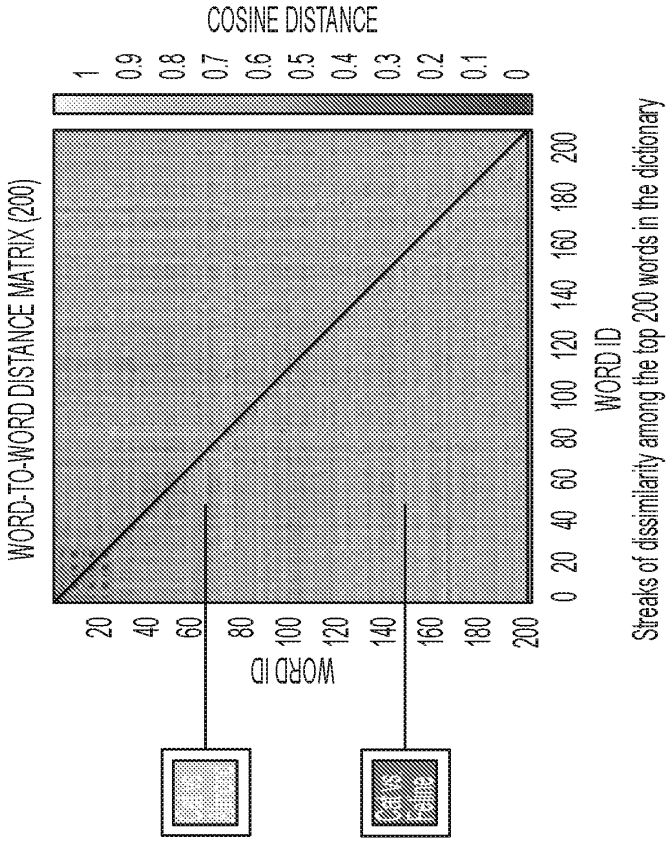

COSINE DISTANCE
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
WORD-TO-WORD DISTANCE MATRIX (200)
20
40
60
80
100
120
140
160
180
200
WORD ID
0 20 40 60 80 100 120 140 160 180 200
WORD ID
Streaks of dissimilarity among the top 200 words in the dictionary

FIG. 59

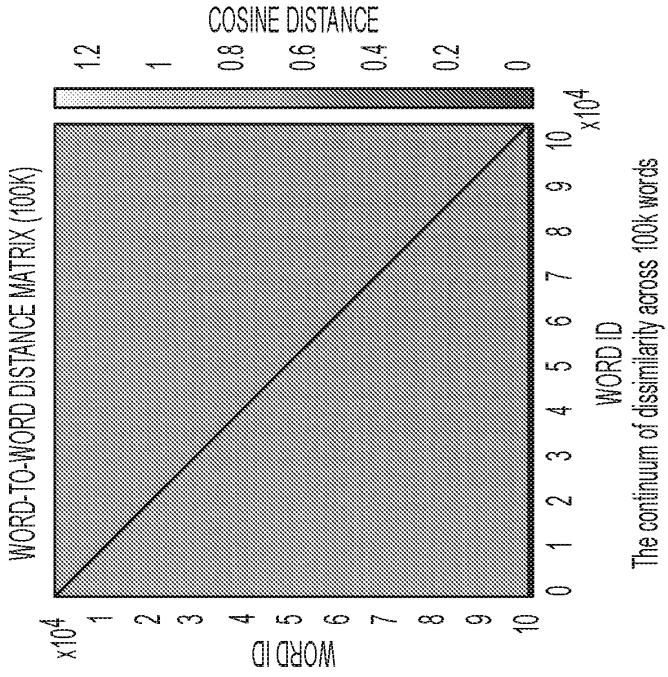

COSINE DISTANCE
1.2
1
0.8
0.6
0.4
0.2
0
WORD-TO-WORD DISTANCE MATRIX (100K)
x10^4
WORD ID
0 1 2 3 4 5 6 7 8 9 10
x10^4
WORD ID
The continuum of dissimilarity across 100k words

FIG. 60

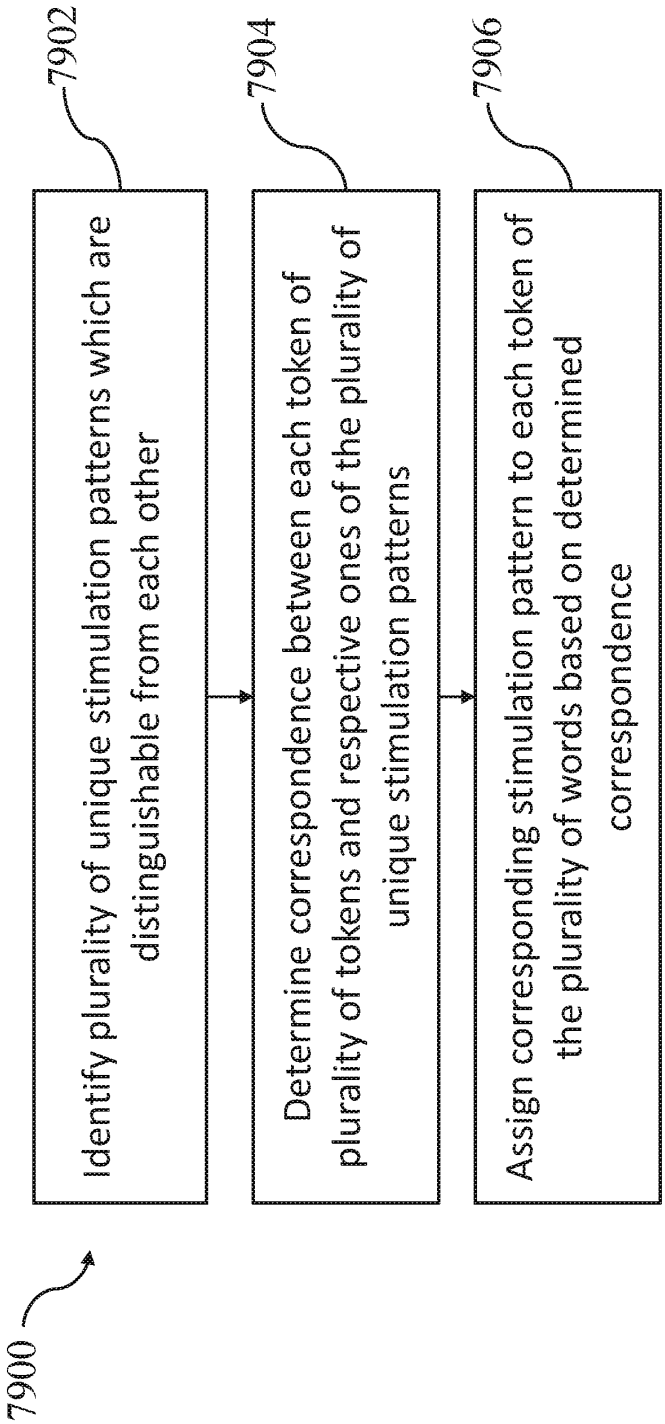

7900
7902
Identify plurality of unique stimulation patterns which are distinguishable from each other
7904
Determine correspondence between each token of plurality of tokens and respective ones of the plurality of unique stimulation patterns
7906
Assign corresponding stimulation pattern to each token of the plurality of words based on determined correspondence

FIG. 61

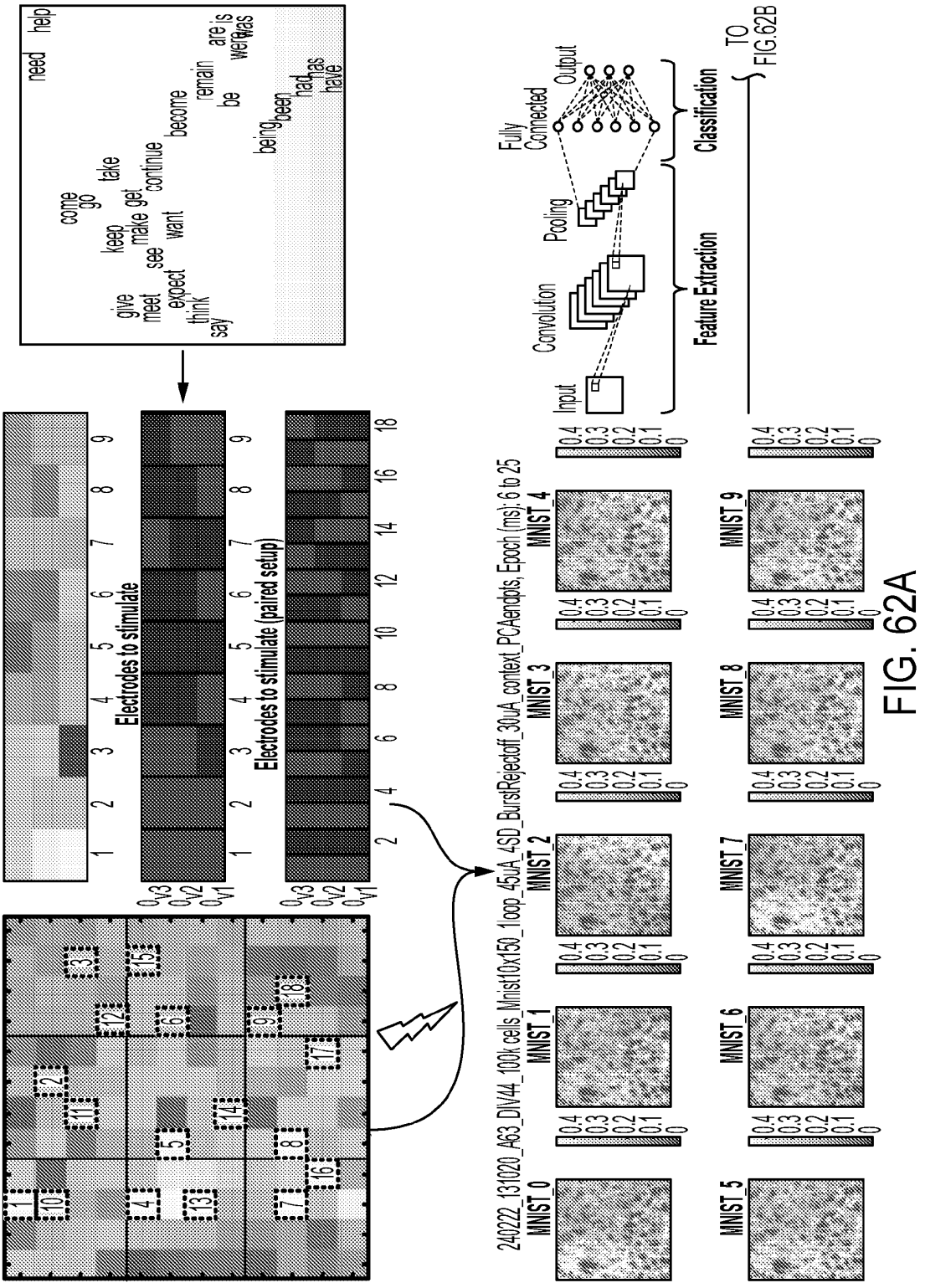

need help
come go take
keep make get continue become
see want remain
give meet expect be
think say being been had has have
are is were was
Electrodes to stimulate
Electrodes to stimulate (paired setup)
240222_131020_A63_DIV44_100k cells_Mnist10x150_1loop_45uA_4SD_BurstRejetoff_30uA_context_PCAendpts, Epoch (ms): 6 to 25
MNIST_0
MNIST_1
MNIST_2
MNIST_3
MNIST_4
MNIST_5
MNIST_6
MNIST_7
MNIST_8
MNIST_9
Input
Convolution
Pooling
Fully Connected
Output
Feature Extraction
Classification
TO FIG.62B

FIG. 62A

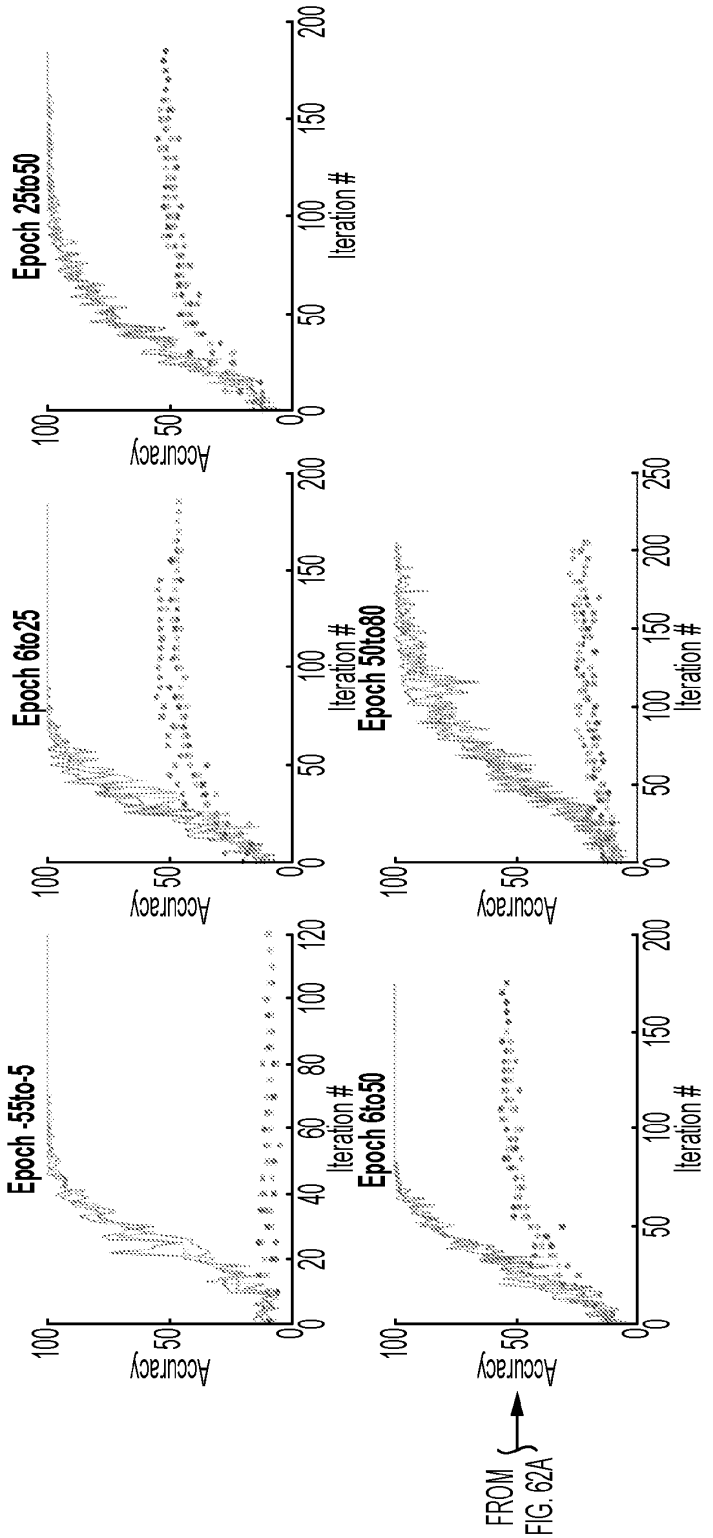

Epoch -55to-5
Epoch 6to25
Epoch 25to50
Epoch 6to50
Epoch 50to80
Accuracy
Iteration #
FROM FIG. 62A

FIG. 62B

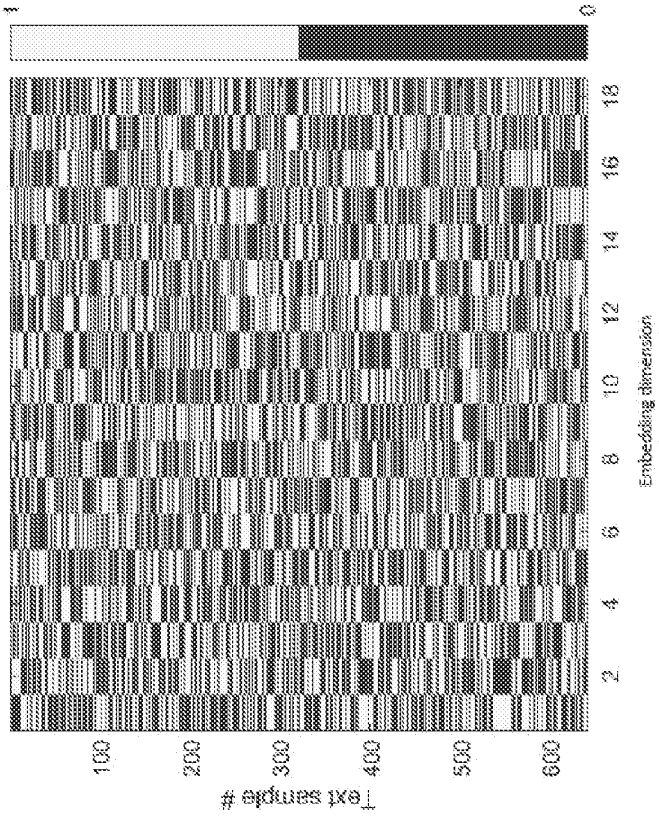

1
0
Text sample #
100
200
300
400
500
600
Embedding dimension
2
4
6
8
10
12
14
16
18

FIG. 63

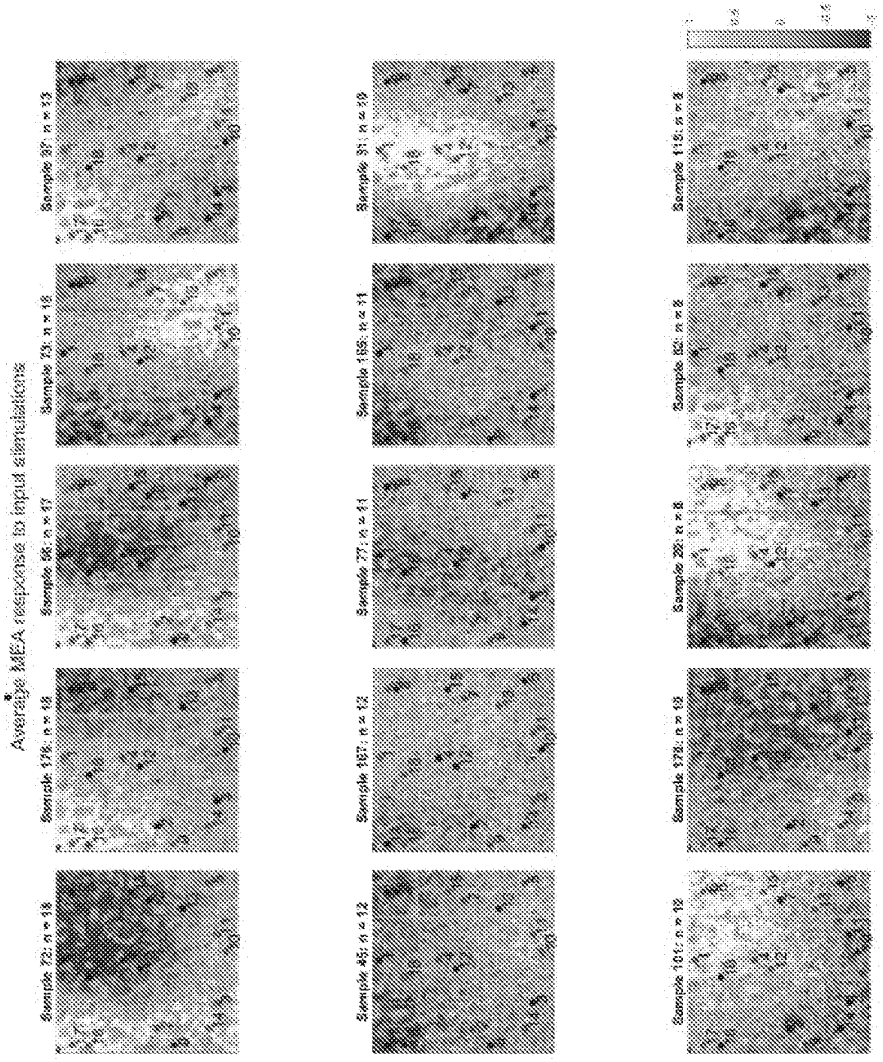

Average MEA response to input stimulations
Sample 72: n = 18
Sample 178: n = 18
Sample 56: n = 17
Sample 73: n = 18
Sample 87: n = 13
Sample 85: n = 12
Sample 167: n = 12
Sample 77: n = 11
Sample 185: n = 11
Sample 91: n = 10
Sample 101: n = 10
Sample 173: n = 10
Sample 29: n = 8
Sample 82: n = 8
Sample 118: n = 8

FIG. 64

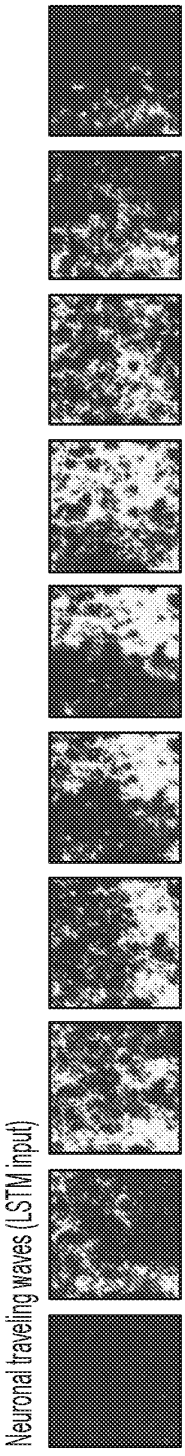


FIG. 65

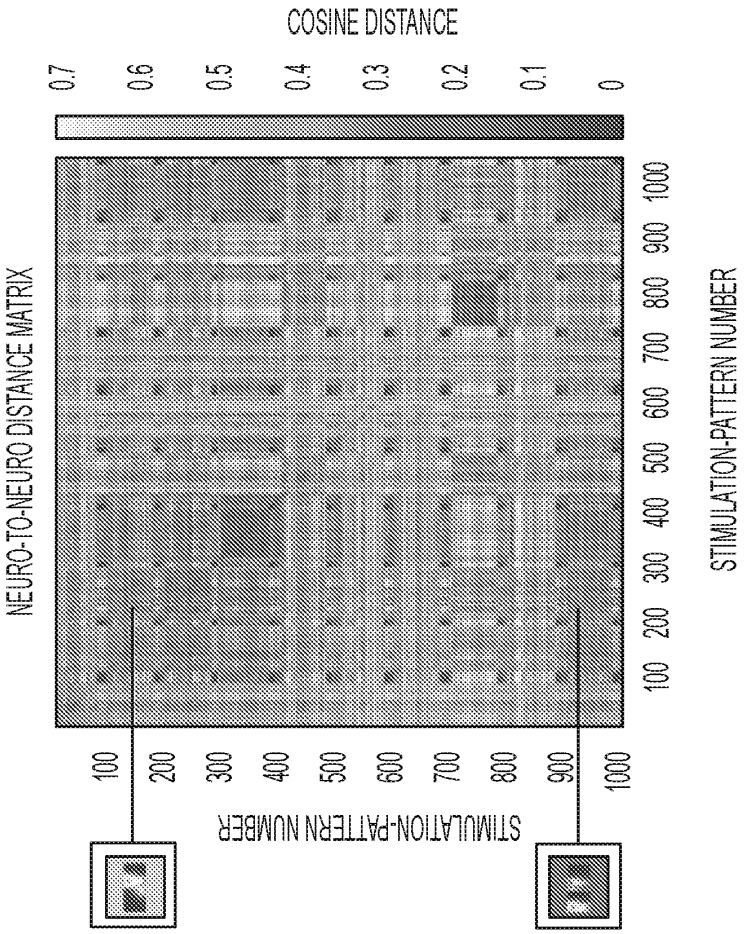

COSINE DISTANCE
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NEURO-TO-NEURO DISTANCE MATRIX
100
200
300
400
500
600
700
800
900
1000
STIMULATION-PATTERN NUMBER
100
200
300
400
500
600
700
800
900
1000
STIMULATION-PATTERN NUMBER

FIG. 66

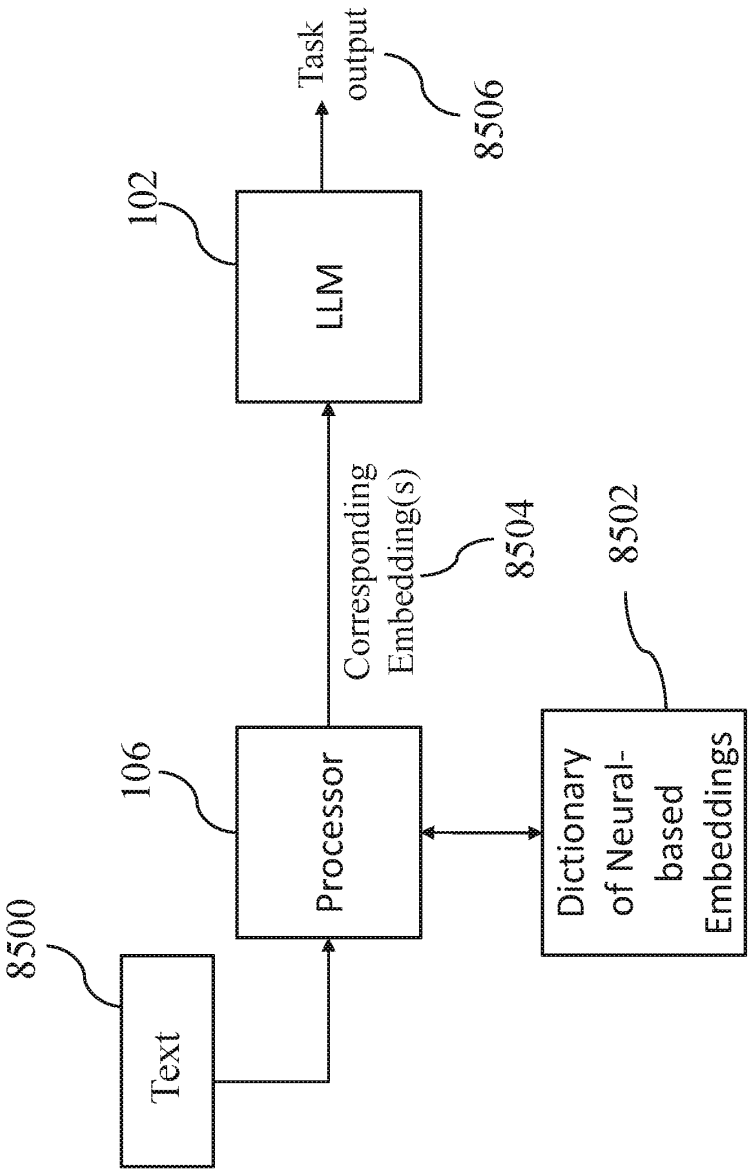

8500
Text
106
Processor
Corresponding Embedding(s)
8504
8502
Dictionary of Neural-based Embeddings
102
LLM
Task output
8506

FIG. 67

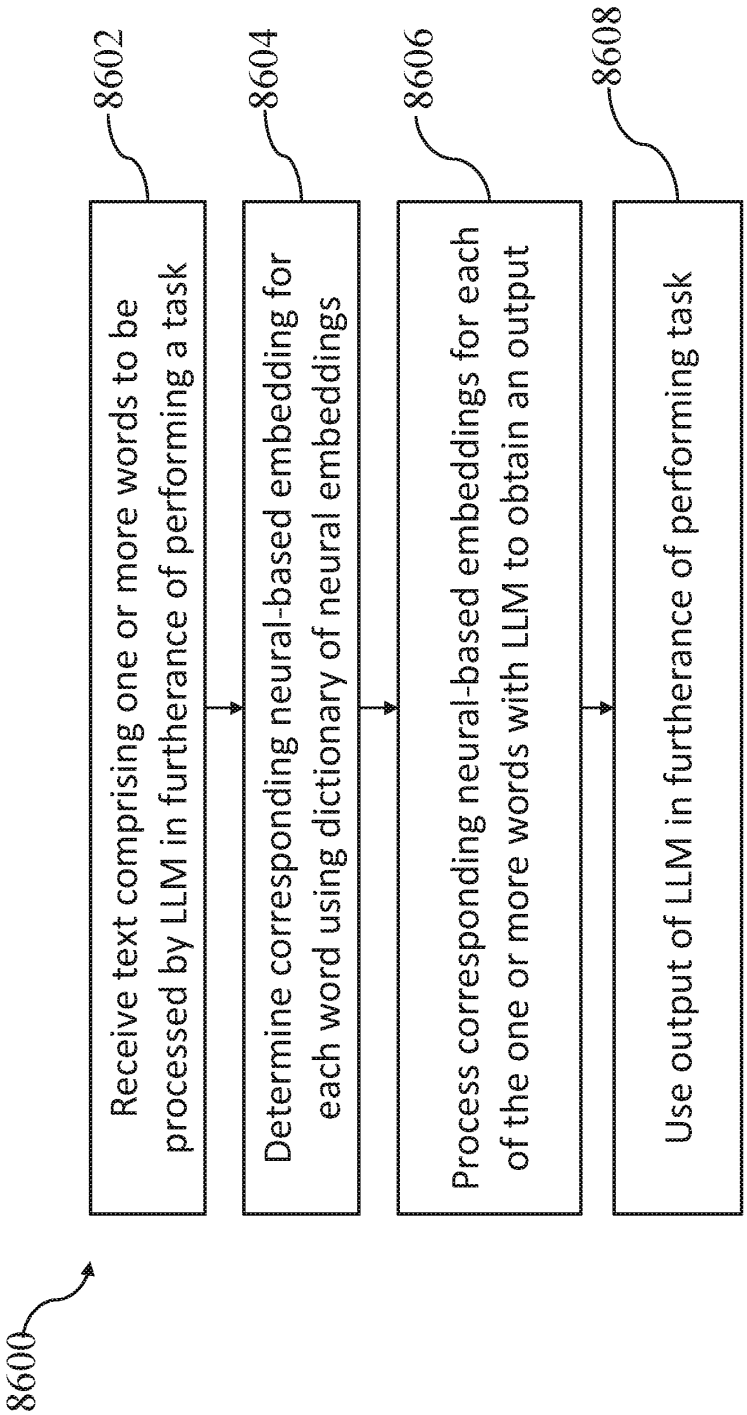

8600
8602
Receive text comprising one or more words to be processed by LLM in furtherance of performing a task
8604
Determine corresponding neural-based embedding for each word using dictionary of neural embeddings
8606
Process corresponding neural-based embeddings for each of the one or more words with LLM to obtain an output
8608
Use output of LLM in furtherance of performing task

FIG. 68

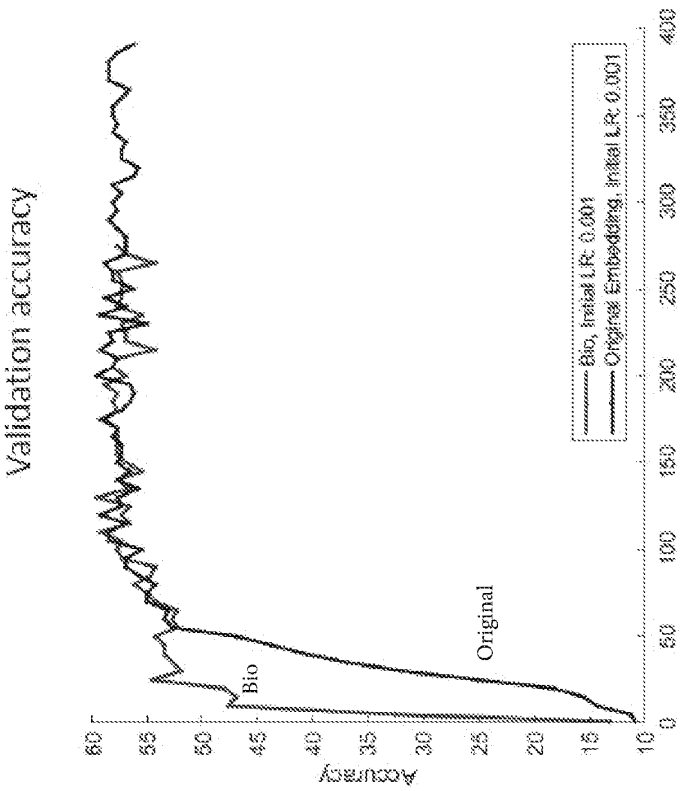

Validation accuracy
Accuracy
Iteration #
Bio
Original
Bio, Initial LR: 0.001
Original Embedding, Initial LR: 0.001
60
55
50
45
40
35
30
25
20
15
10
0
50
100
150
200
250
300
350
400

FIG. 69A

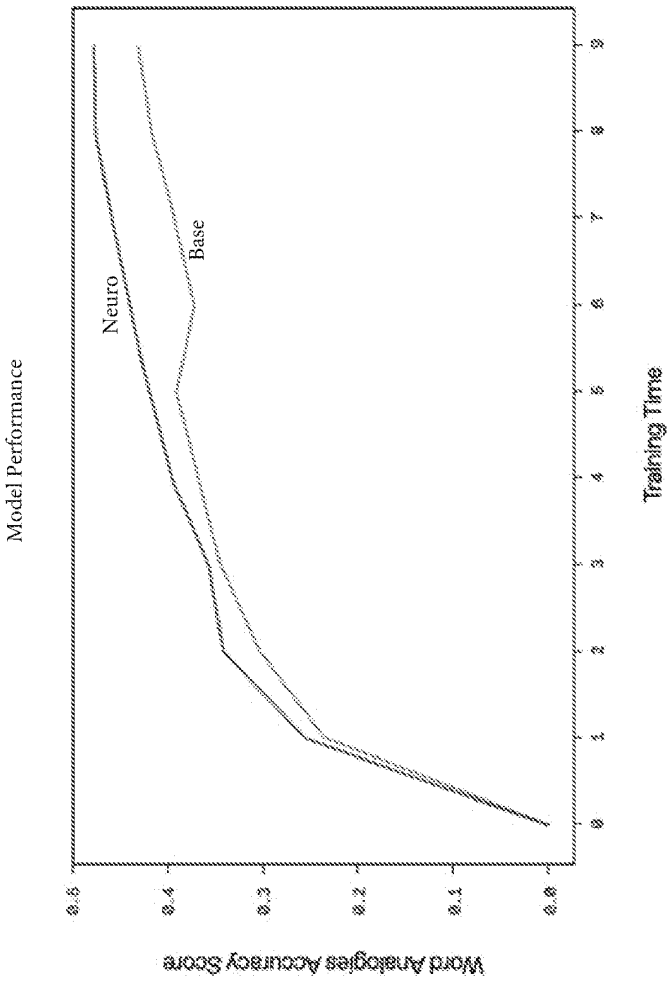

Model Performance
Neuro
Base
Training Time
Word Analogies Accuracy Score
0.0
0.1
0.2
0.3
0.4
0.5
0
1
2
3
4
5
6
7
8
9

FIG. 69B

GPT2 model performance
"Reborn, issuing, Lily," Tom said "it's not a good Metatron. It's a compound. It's a massage for you." Lily smiled and said, "I'm sorry, Tom. I unbeat. I
Lily was sad because she had lost her favorite toy. She wanted to help her mom find the toy. She went to her room and found her toyef. It was a big bag of toys and a big Each day. Lily was very
Model Confidence
0.04
0.03
0.02
0.01
0.0
Base
Neuro
Neuro
Base
0
10000
20000
30000
40000
50000
Training time

FIG. 69C

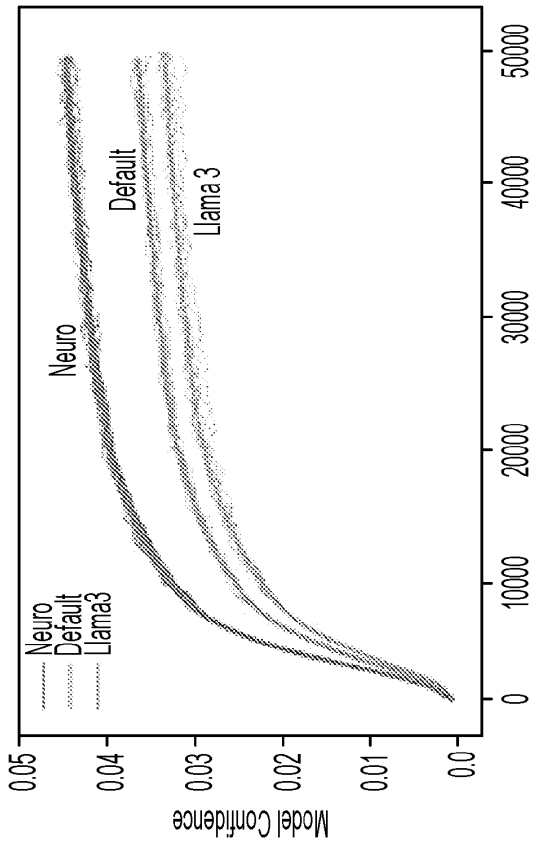


FIG. 69D

GPT2 model performance

> 5x improvement in GPT-2 training efficiency

10% gain in inference based on validation loss

Reproducible across multiple trials

In contrast, pretrained Llama 3 embeddings offered no advantage over random initialization or neural embeddings and needed extra pre-processing to meet industry standards

RECTIFIED SHEET (RULE 91)

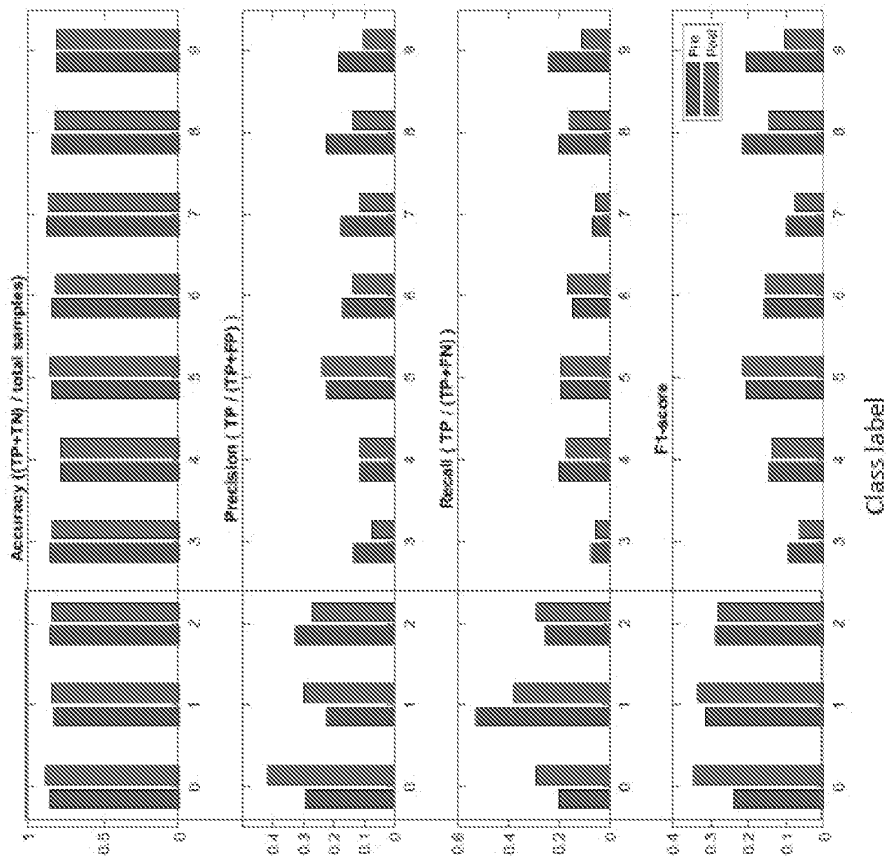

Accuracy ((TP+TN) / total samples)
Precision (TP / (TP+FP))
Recall (TP / (TP+FN))
F1-score
Fire
Food
Class label

FIG. 70

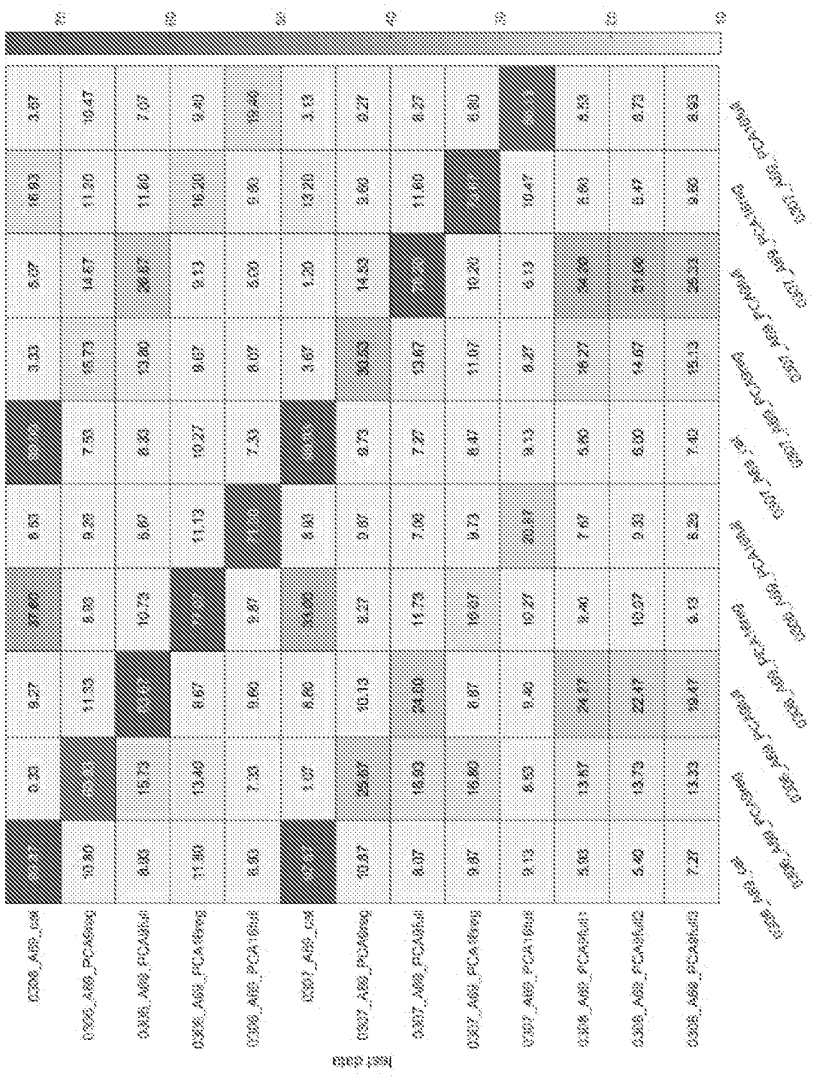

best case
training ANN
0308_ANN_pca
0306_ANN_PCA4reg
0308_ANN_PCA4bal
0308_ANN_PCA16reg
0306_ANN_PCA16bal
0307_ANN_pca
0307_ANN_PCA4reg
0307_ANN_PCA4bal
0307_ANN_PCA16reg
0307_ANN_PCA16bal
0308_ANN_PCA4bal1
0308_ANN_PCA4bal2
0308_ANN_PCA16bal
ann_best_0308
ann_best_0306
ann_best_0307
0306_best_PCA4reg
0306_best_PCA4bal
0306_best_PCA16reg
0306_best_PCA16bal
0307_best_PCA4reg
0307_best_PCA4bal
0307_best_PCA16reg
0307_best_PCA16bal
0308_best_PCA4bal1
0308_best_PCA4bal2
0308_best_PCA16bal

FIG. 71

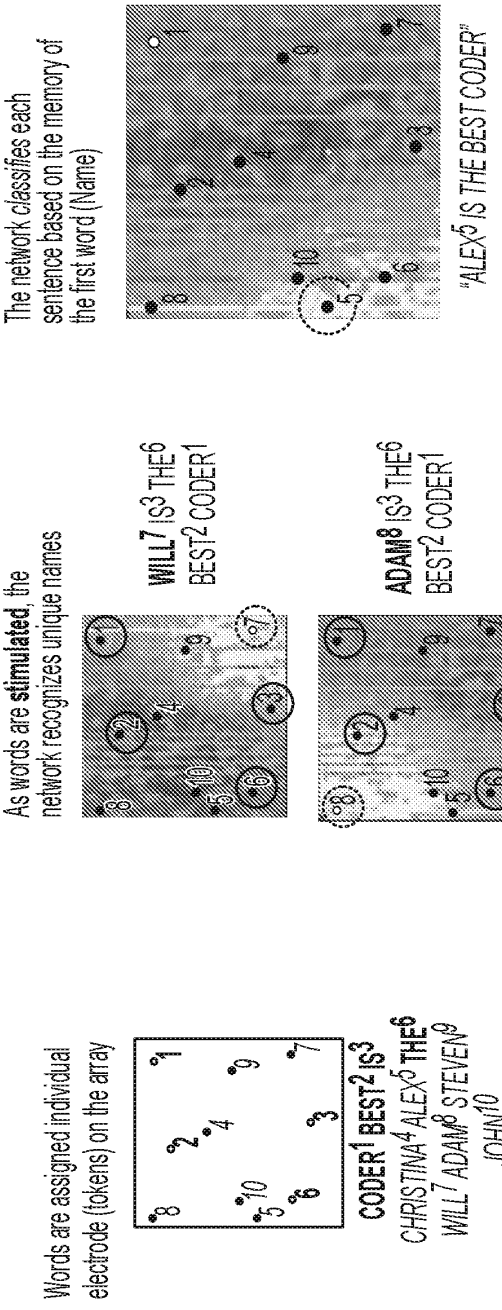

Words are assigned individual electrode (tokens) on the array
CODER1 BEST2 IS3
CHRISTINA4 ALEX5 THE6
WILL7 ADAM8 STEVEN9
JOHN10
As words are stimulated, the network recognizes unique names
WILL7 IS3 THE6
BEST2 CODER1
ADAM8 IS3 THE6
BEST2 CODER1
The network classifies each sentence based on the memory of the first word (Name)
"ALEX5 IS THE BEST CODER"

FIG. 72

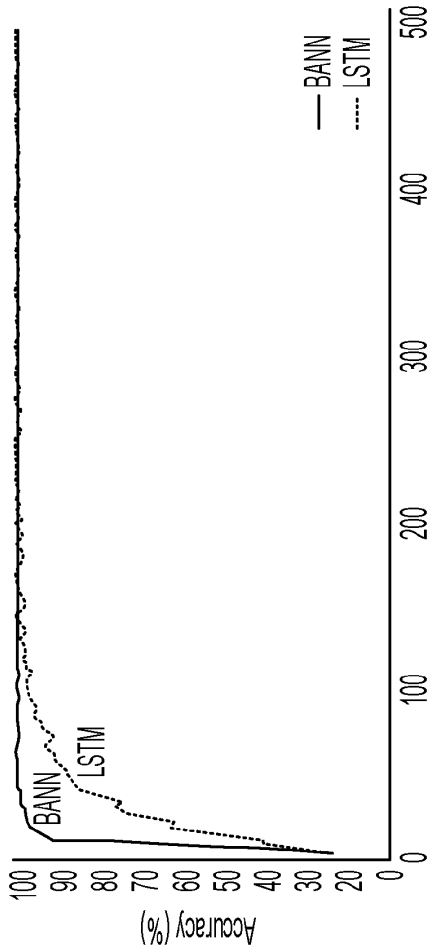

BANN
LSTM
Accuracy (%)
100
90
80
70
60
50
40
30
20
0
100
200
300
400
500
Iteration #
BANN
LSTM

FIG. 73

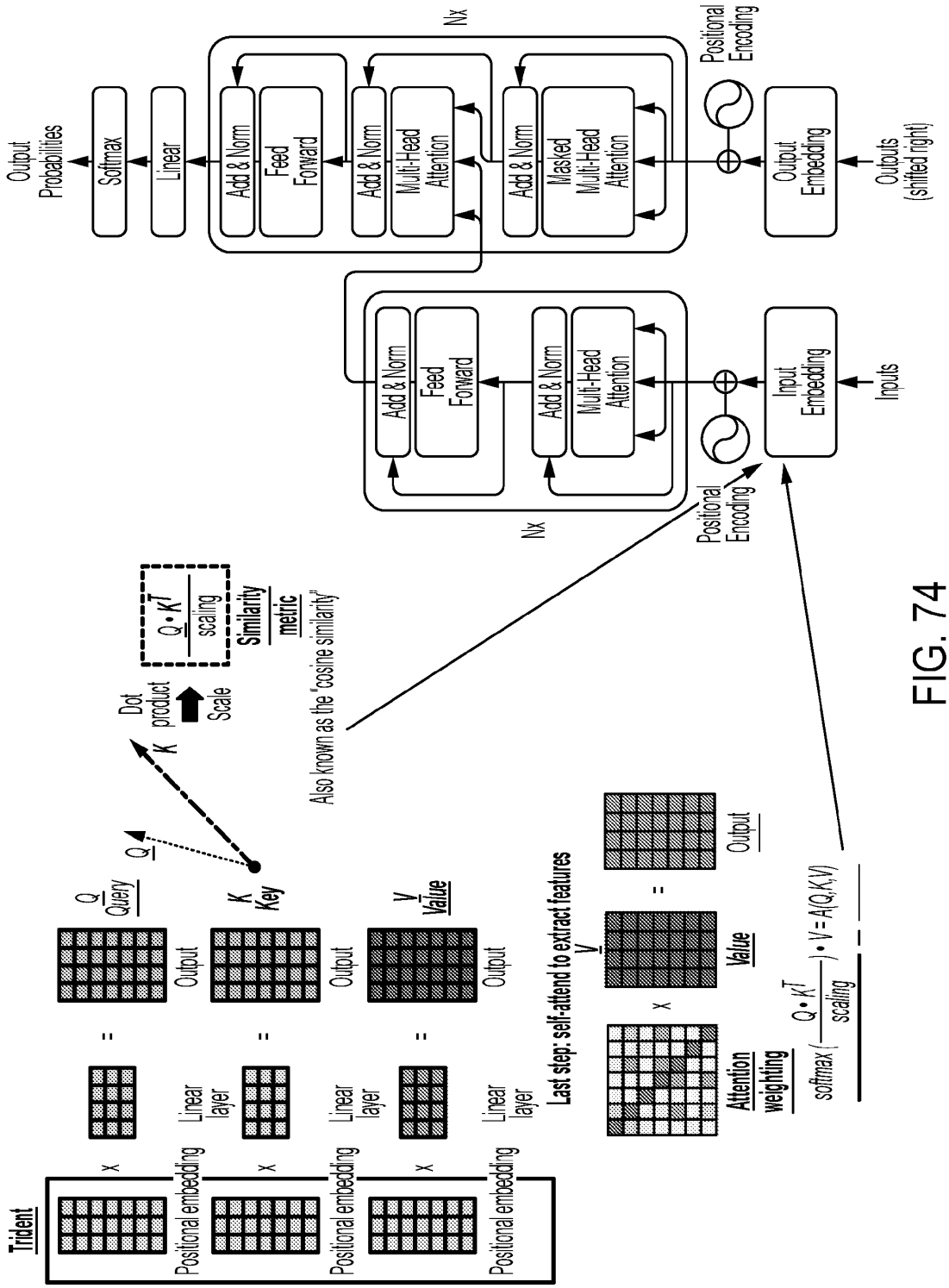

Output Probabilities
Softmax
Linear
Add & Norm
Feed Forward
Add & Norm
Multi-Head Attention
Add & Norm
Masked Multi-Head Attention
Nx
Positional Encoding
Output Embedding
Outputs (shifted right)
Input Embedding
Inputs
Positional Encoding
Nx
Also known as the "cosine similarity"
Dot product
Scale
Similarity metric
Q Query
K Key
V Value
Output
Linear layer
Positional embedding
Trident
Last step: self-attend to extract features
Attention weighting
Value
Output

FIG. 74

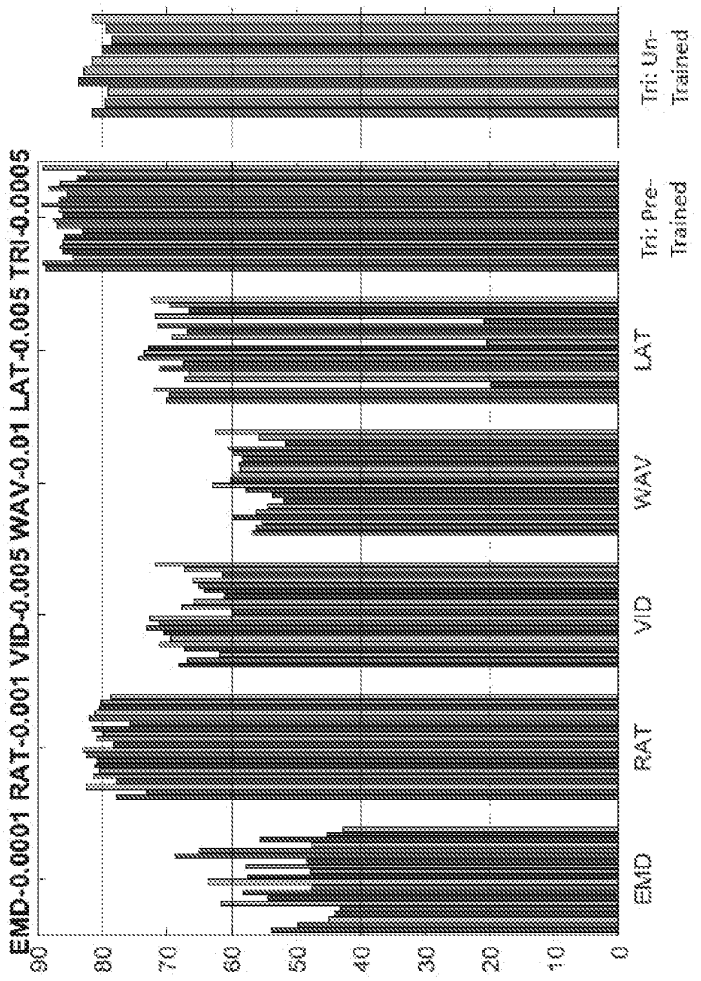

EMD-0.0001 RAT-0.001 VID-0.005 WAV-0.01 LAT-0.005 TRI-0.0005
90
80
70
60
50
40
30
20
10
0
EMD
RAT
VID
WAV
LAT
Tri: Pre-Trained
Tri: Un-Trained

FIG. 75

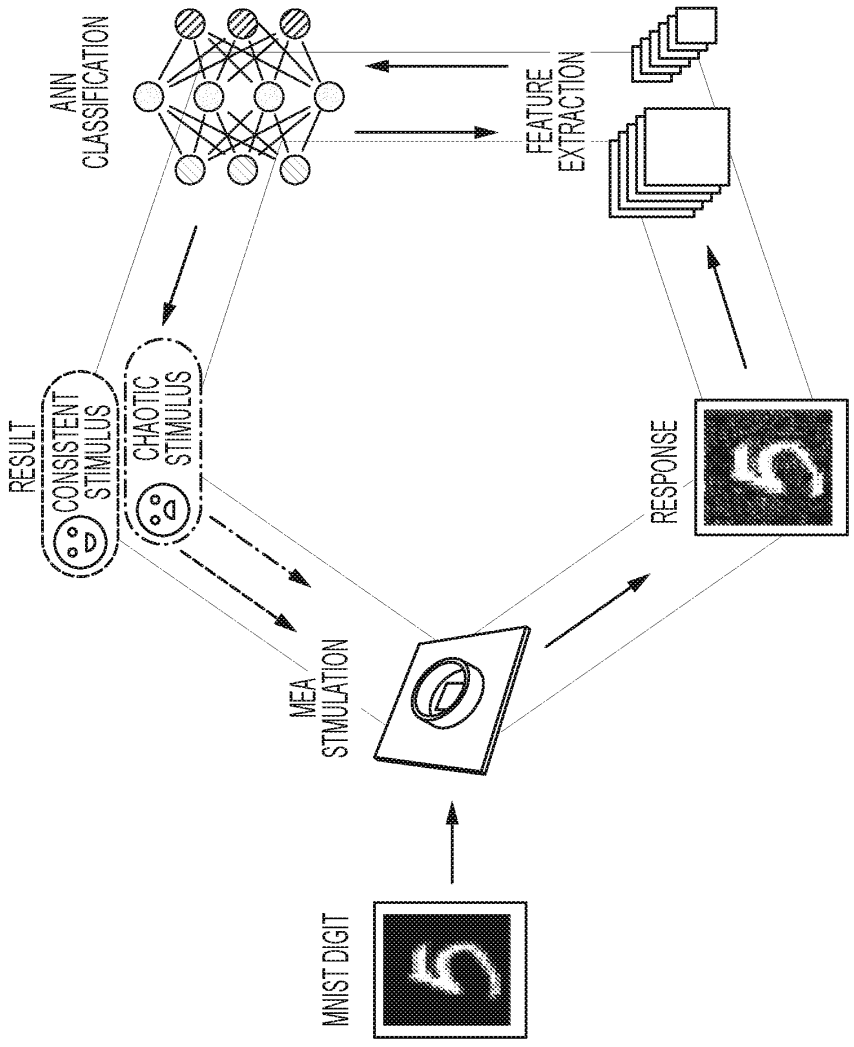

ANN CLASSIFICATION
FEATURE EXTRACTION
RESULT
CONSISTENT STIMULUS
CHAOTIC STIMULUS
RESPONSE
MEA STIMULATION
MNIST DIGIT

FIG. 76A

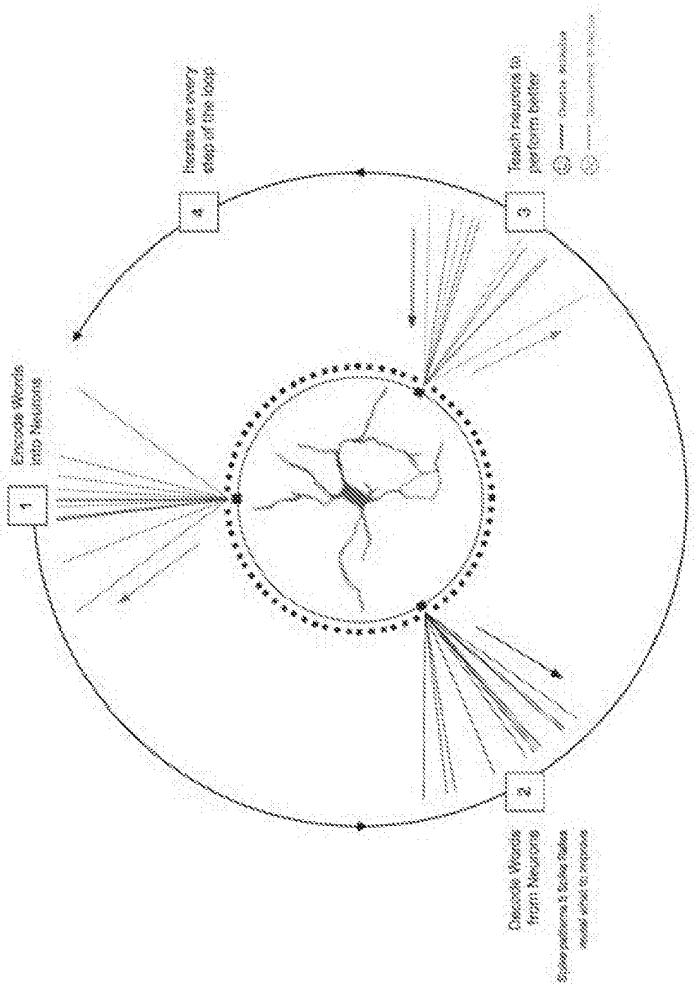

Encode Words into Neurons
Iterate on every step of the task
Teach neurons to perform better
Decode Words from Neurons

FIG. 76B

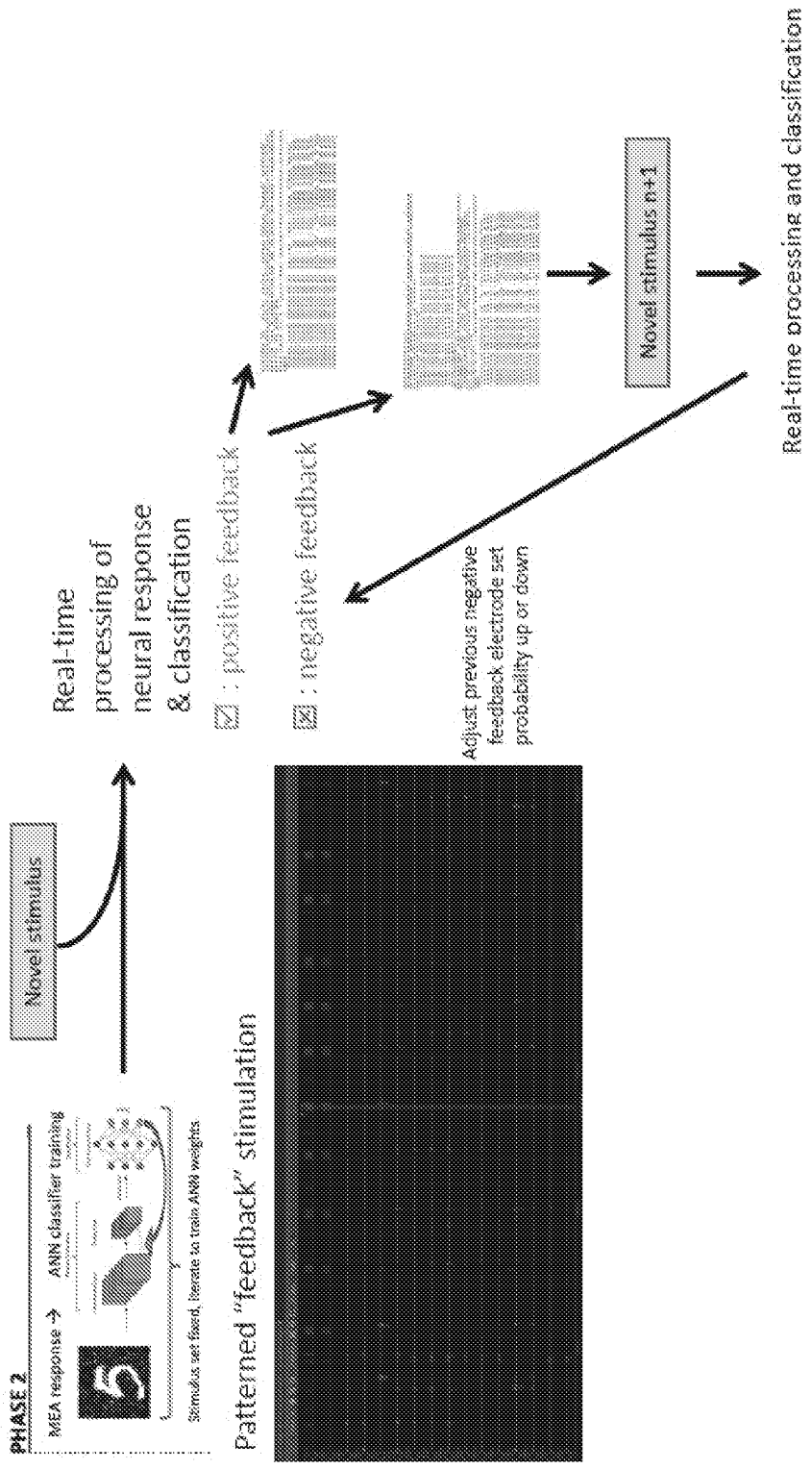

PHASE 2
MEA response →
ANN classifier training
Stimulus set fixed, iterate to train ANN weights
Novel stimulus
Real-time processing of neural response & classification
☑ : positive feedback
☒ : negative feedback
Patterned "feedback" stimulation
Adjust previous negative feedback electrode set probability up or down
Novel stimulus n+1
Real-time processing and classification

FIG. 77

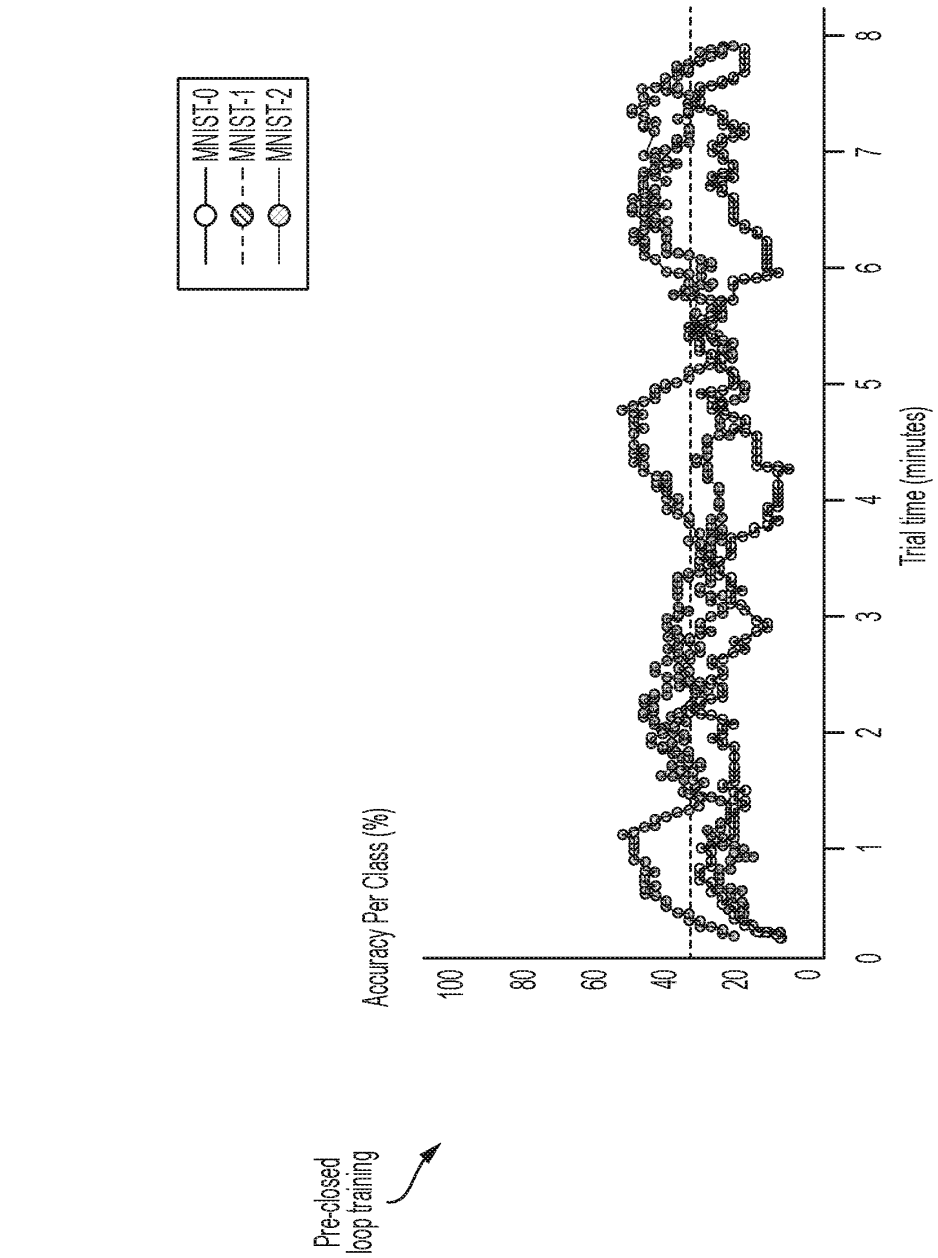

MNIST-0
MNIST-1
MNIST-2
Accuracy Per Class (%)
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
Trial time (minutes)
Pre-closed loop training

FIG. 78A

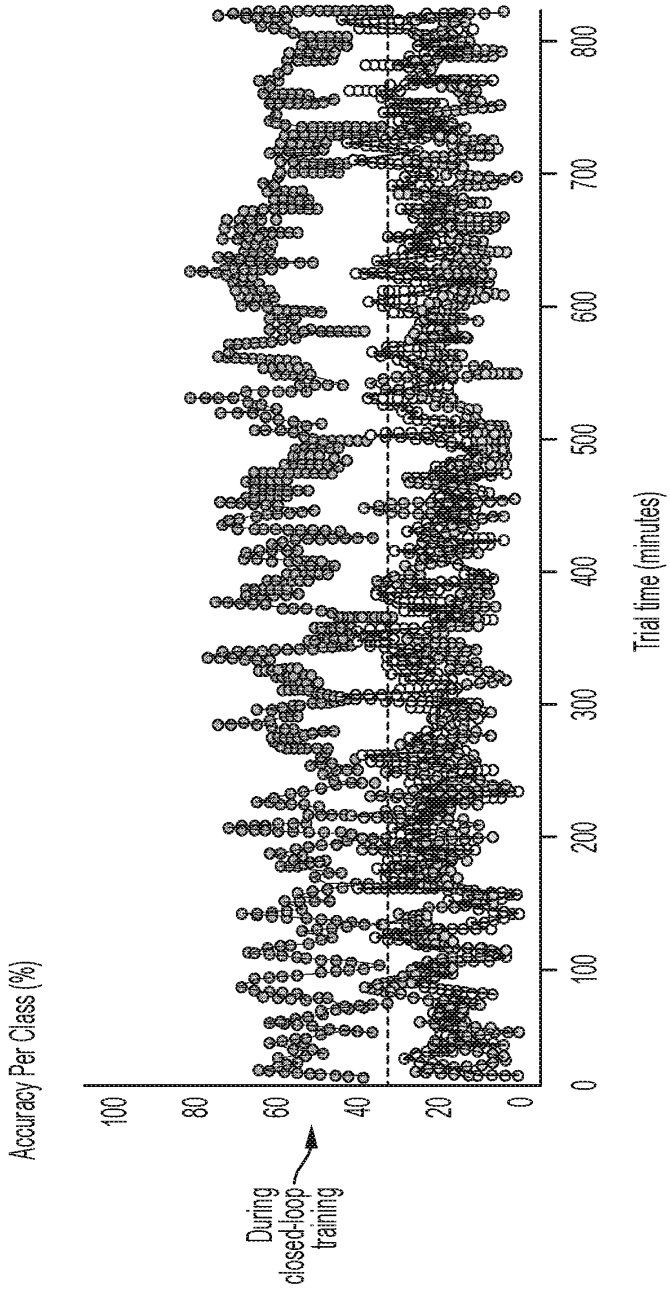

Accuracy Per Class (%)
100
80
60
40
20
0
During closed-loop training
0
100
200
300
400
500
600
700
800
Trial time (minutes)

FIG. 78B

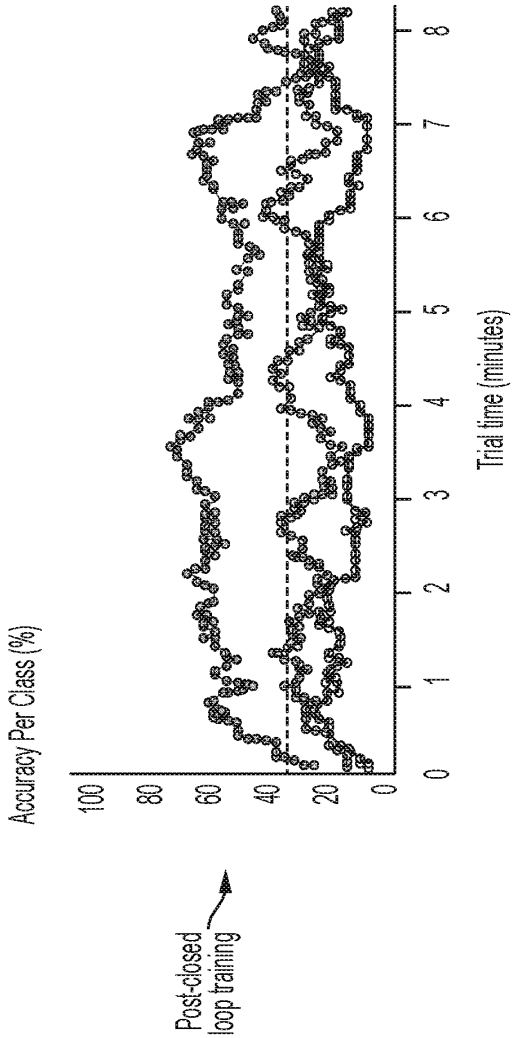

Accuracy Per Class (%)
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
Trial time (minutes)
Post-closed loop training

FIG. 78C

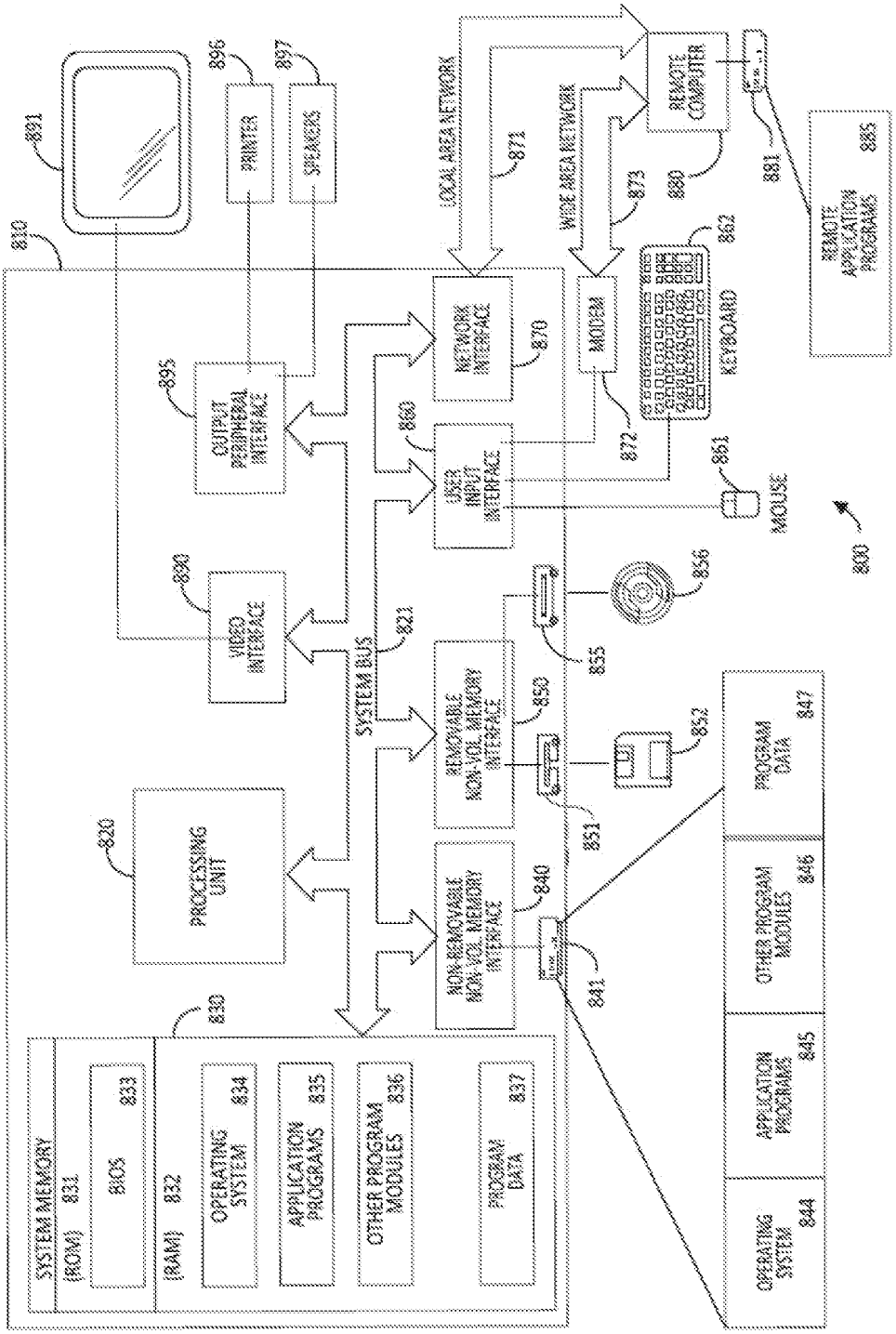

800
810
820
821
830
831
832
833
834
835
836
837
840
841
844
845
846
847
850
851
852
855
860
861
862
870
871
872
873
880
881
885
890
891
895
896
897
SYSTEM MEMORY
(ROM)
BIOS
(RAM)
OPERATING SYSTEM
APPLICATION PROGRAMS
OTHER PROGRAM MODULES
PROGRAM DATA
PROCESSING UNIT
SYSTEM BUS
NON-REMOVABLE NON-VOL MEMORY INTERFACE
REMOVABLE NON-VOL MEMORY INTERFACE
VIDEO INTERFACE
OUTPUT PERIPHERAL INTERFACE
USER INPUT INTERFACE
NETWORK INTERFACE
MODEM
KEYBOARD
MOUSE
PRINTER
SPEAKERS
LOCAL AREA NETWORK
WIDE AREA NETWORK
REMOTE COMPUTER
REMOTE APPLICATION PROGRAMS
OPERATING SYSTEM
APPLICATION PROGRAMS
OTHER PROGRAM MODULES
PROGRAM DATA

FIG. 79