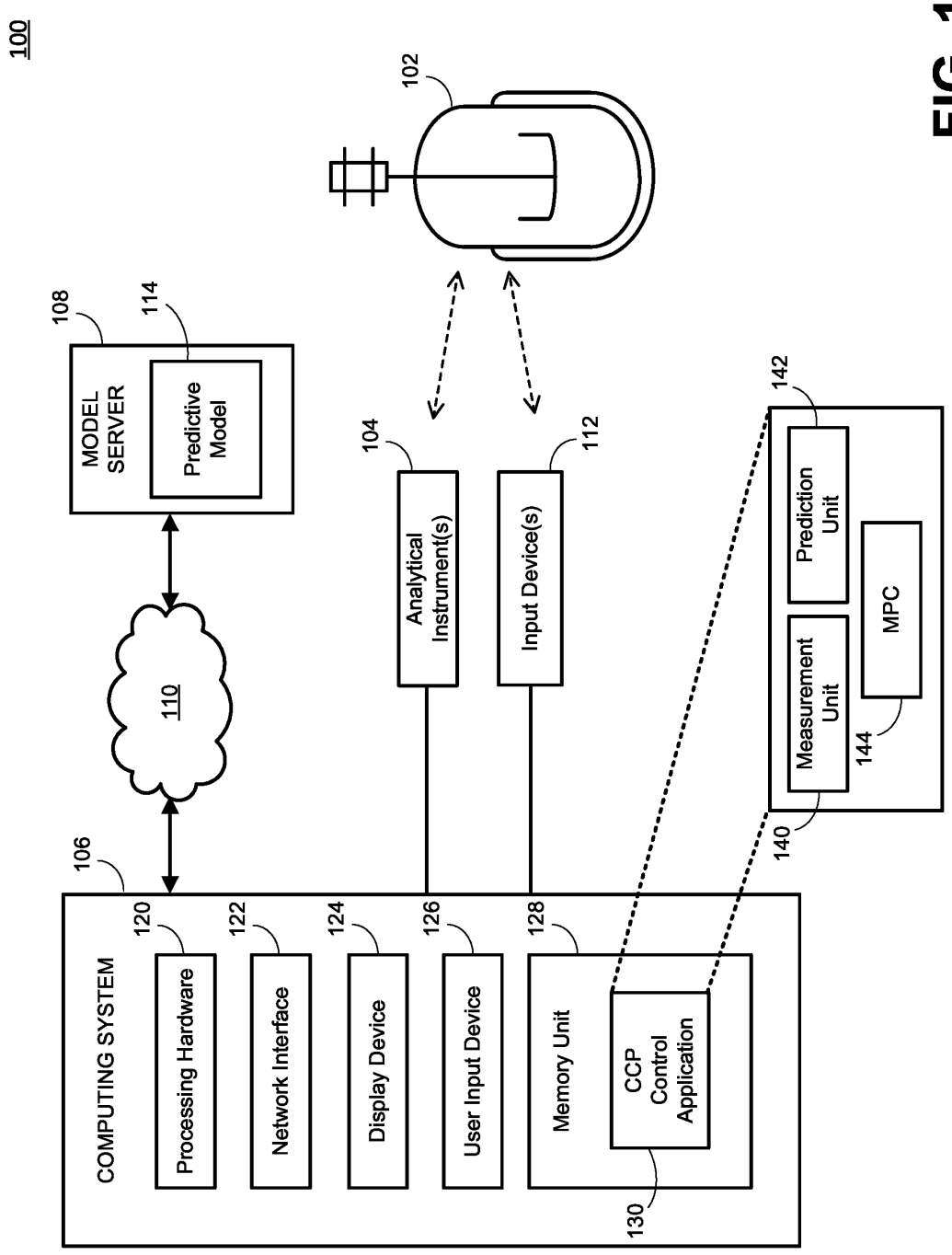
100
102
108
MODEL SERVER
114
Predictive Model
104
Analytical Instrument(s)
112
Input Device(s)
142
Prediction Unit
MPC
Measurement Unit
144
140
110
106
COMPUTING SYSTEM
120
Processing Hardware
122
Network Interface
124
Display Device
126
User Input Device
128
Memory Unit
CCP Control Application
130

FIG. 1

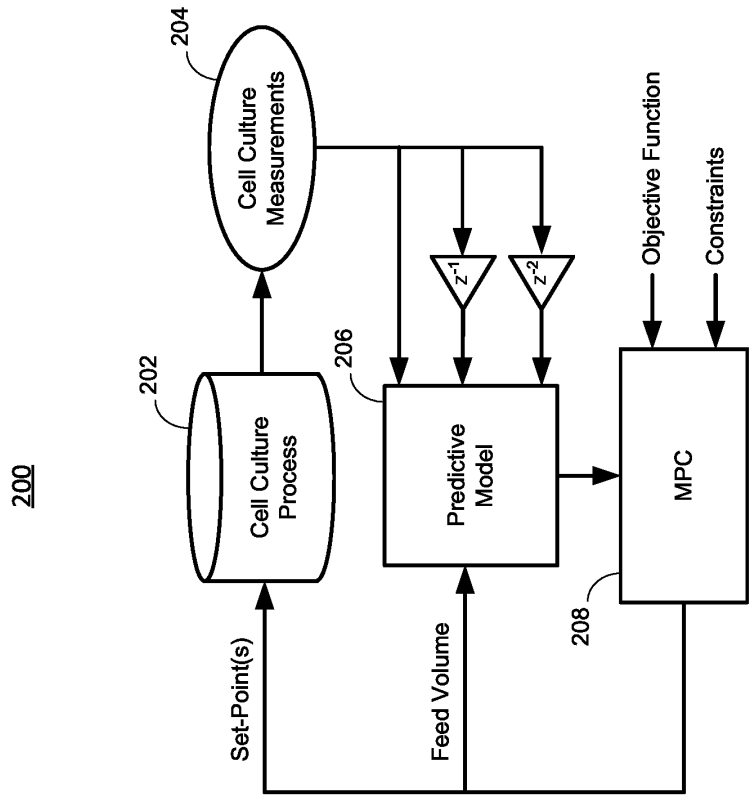
200
204
Cell Culture Measurements
202
Cell Culture Process
206
Predictive Model
z^{-1}
z^{-2}
Objective Function
Constraints
MPC
208
Set-Point(s)
Feed Volume

FIG. 2

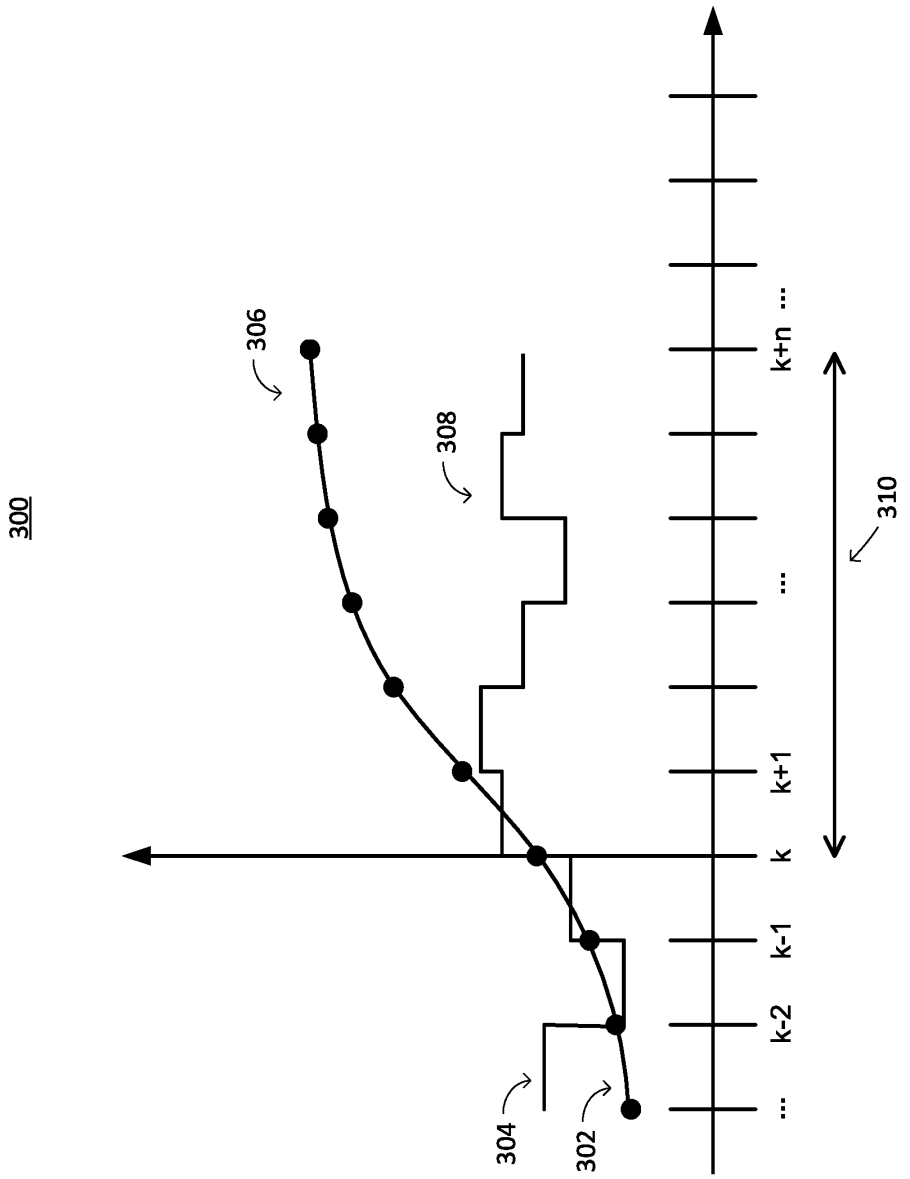

FIG. 3

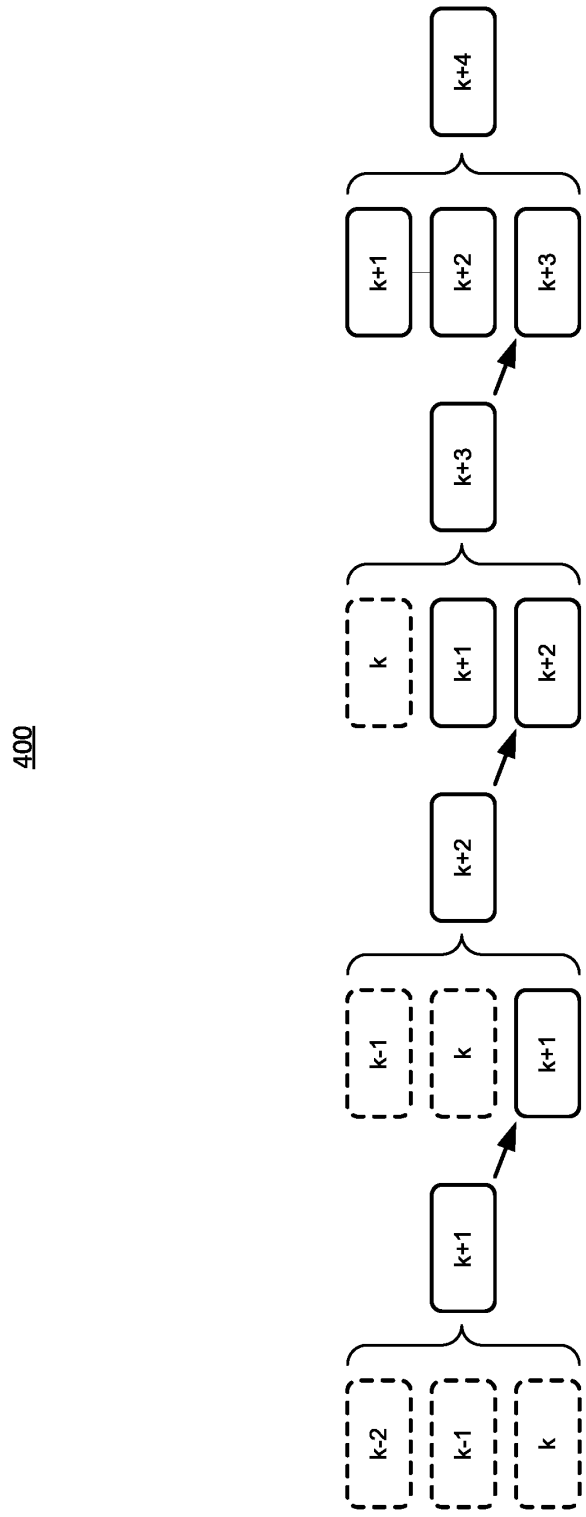

FIG. 4

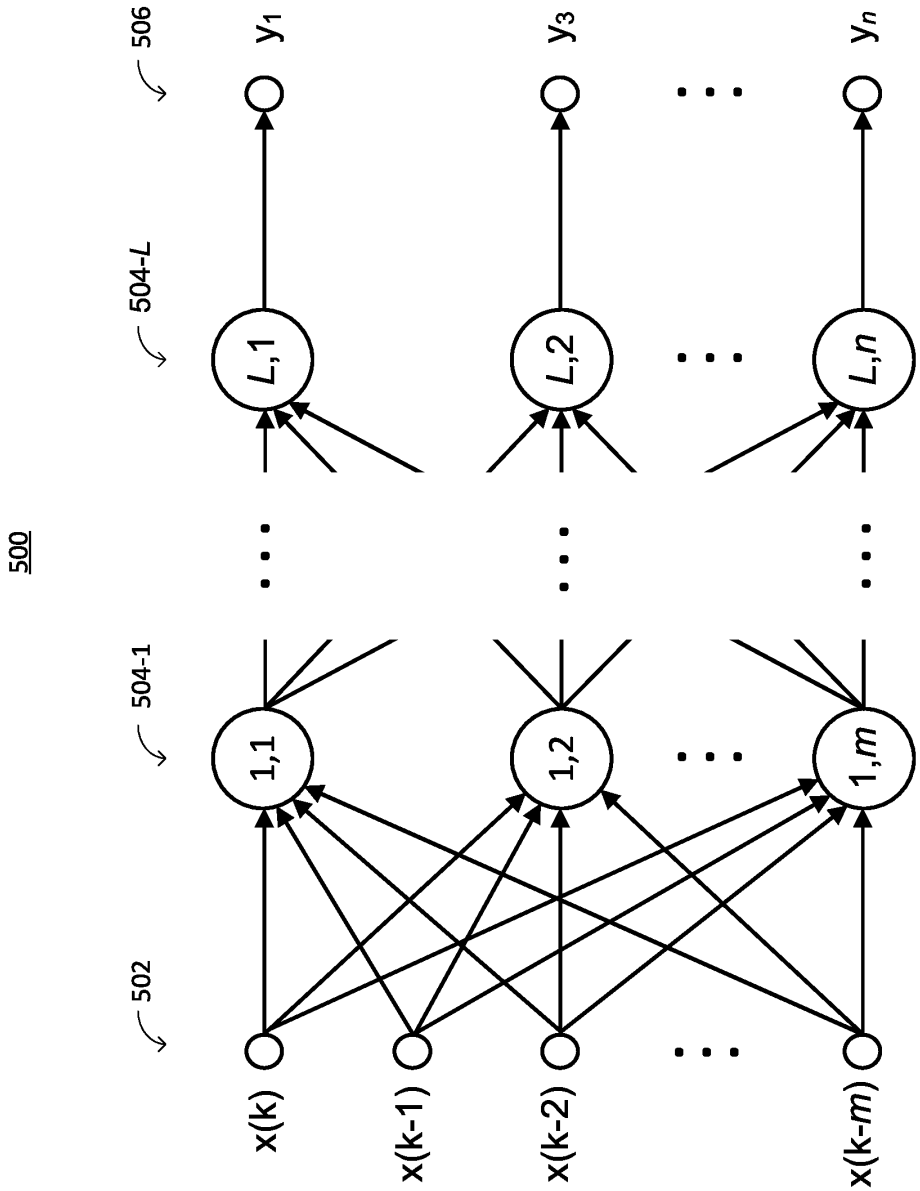

FIG. 5

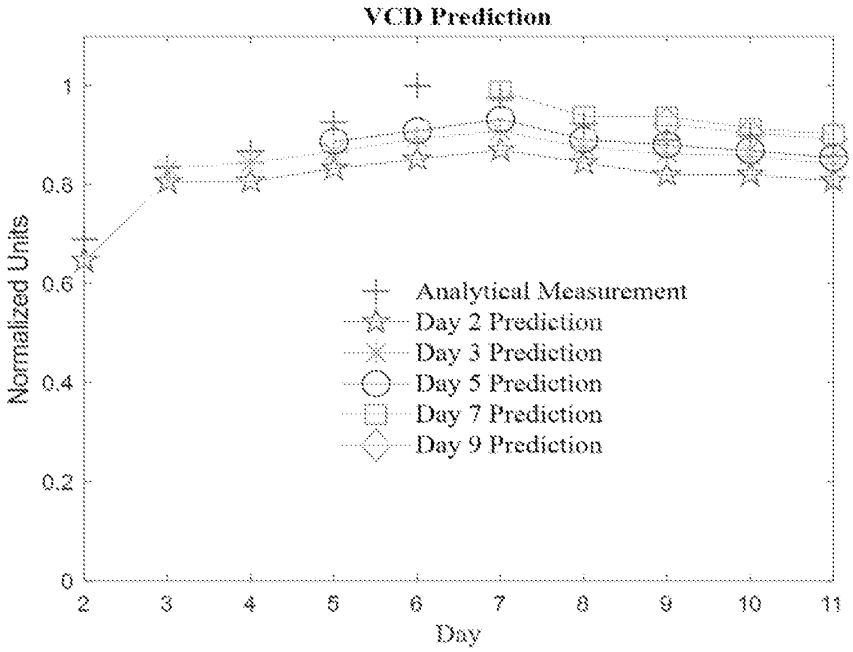
VCD Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction

FIG. 6A

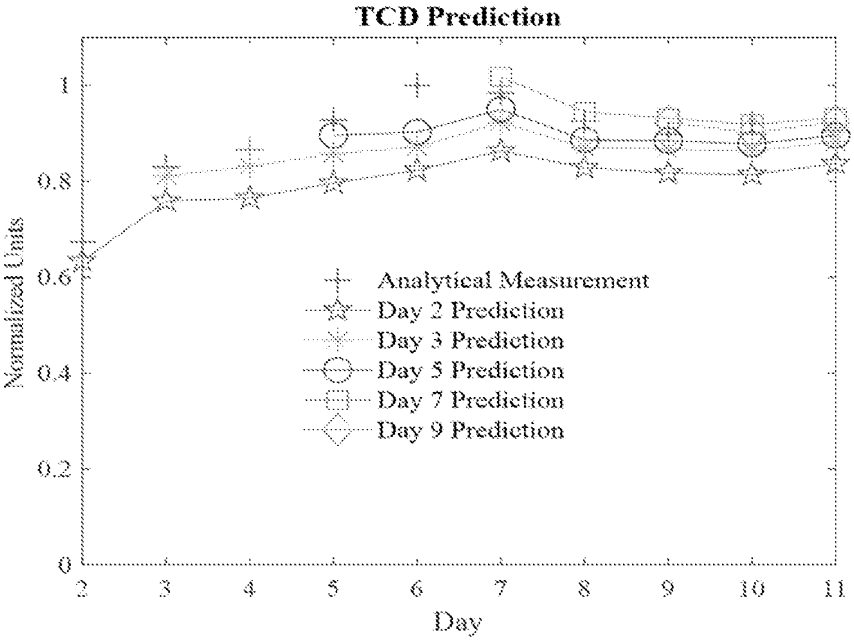
TCD Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction

FIG. 6B

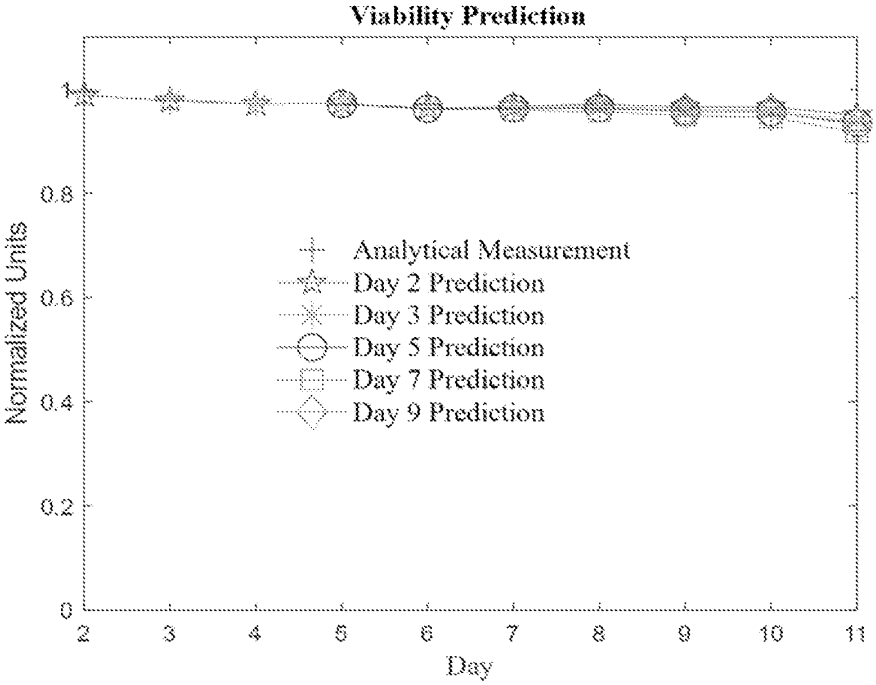
Viability Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 6C

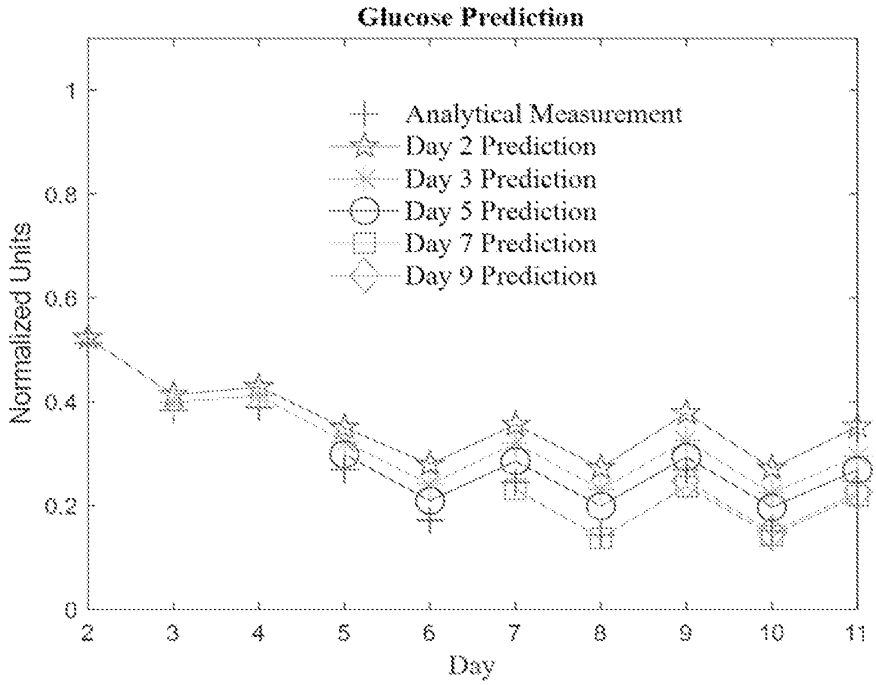
Glucose Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 6D

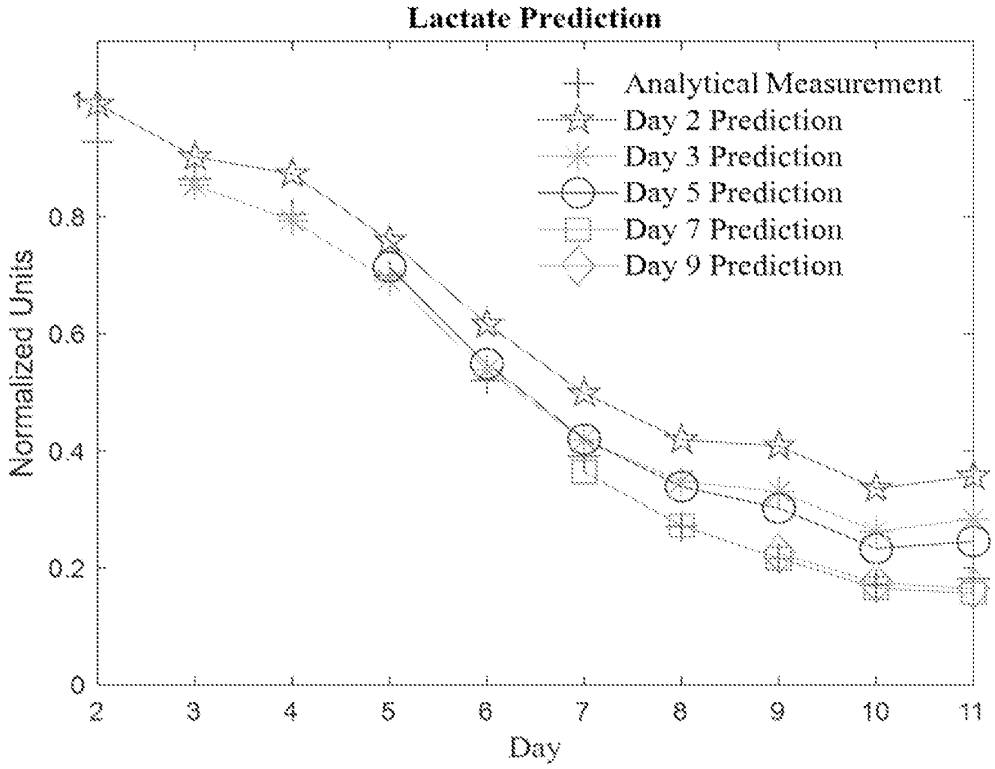
Lactate Prediction
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
Normalized Units
0
0.2
0.4
0.6
0.8
2
3
4
5
6
7
8
9
10
11
Day

FIG. 6E

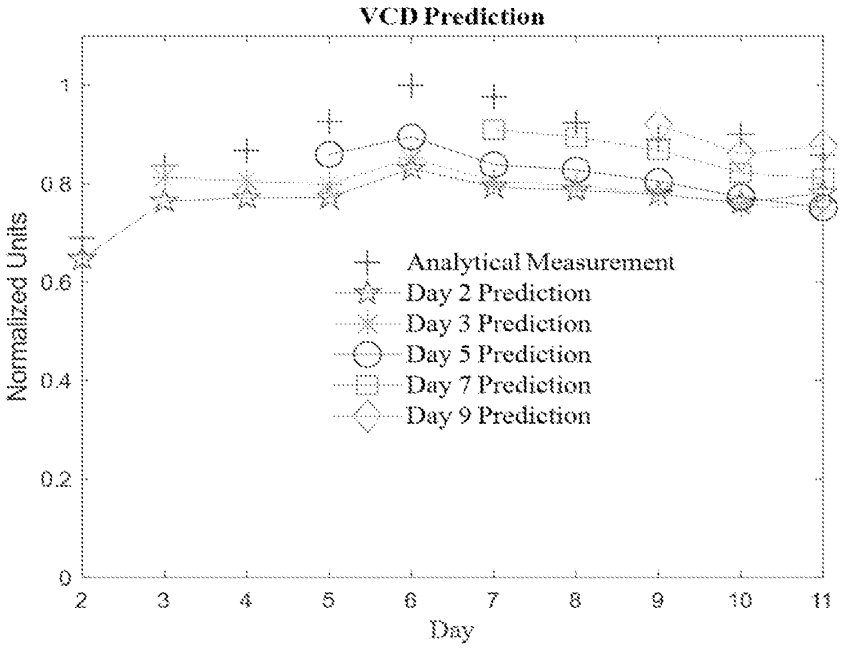
VCD Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 7A

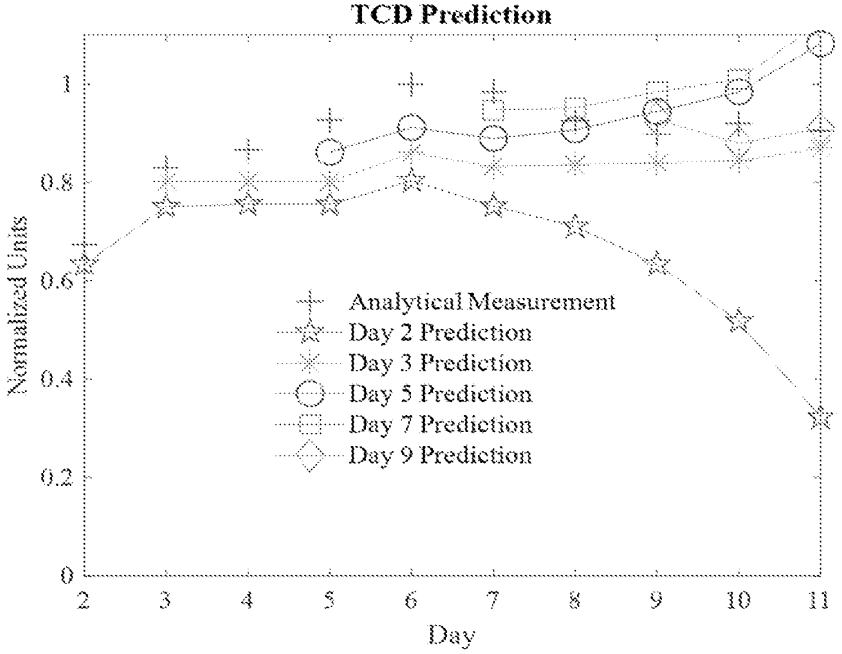
TCD Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 7B

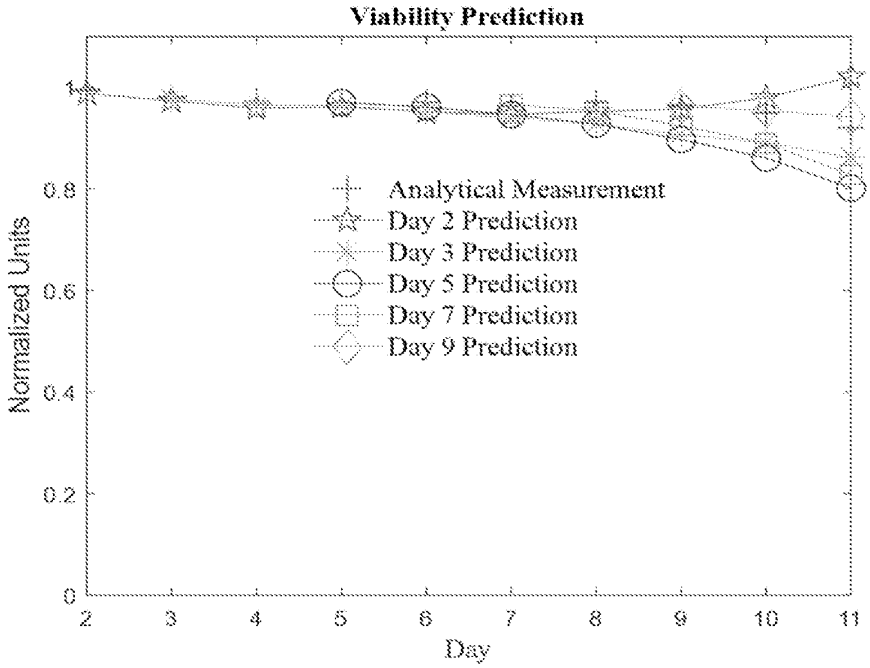
Viability Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 7C

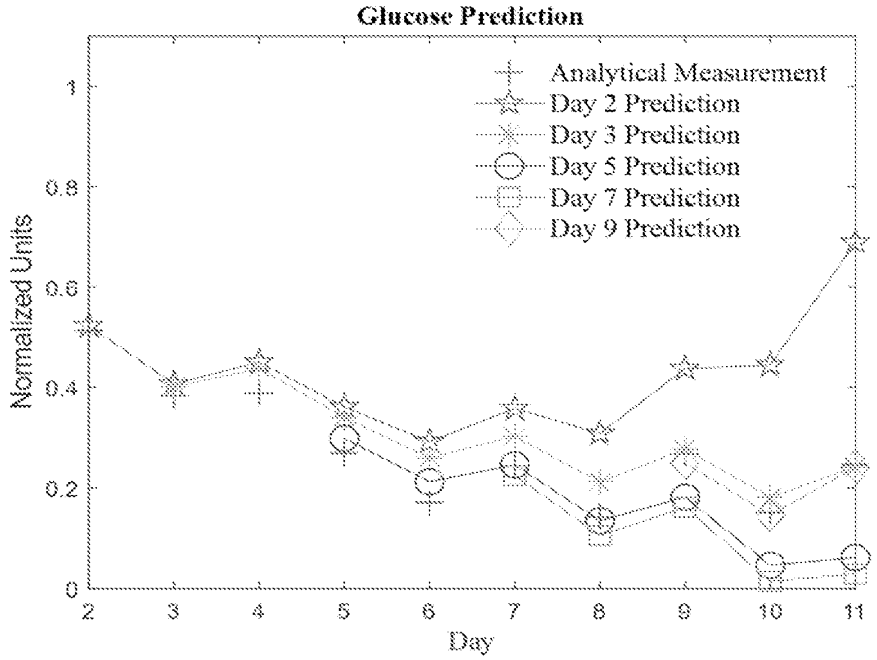
Glucose Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 7D

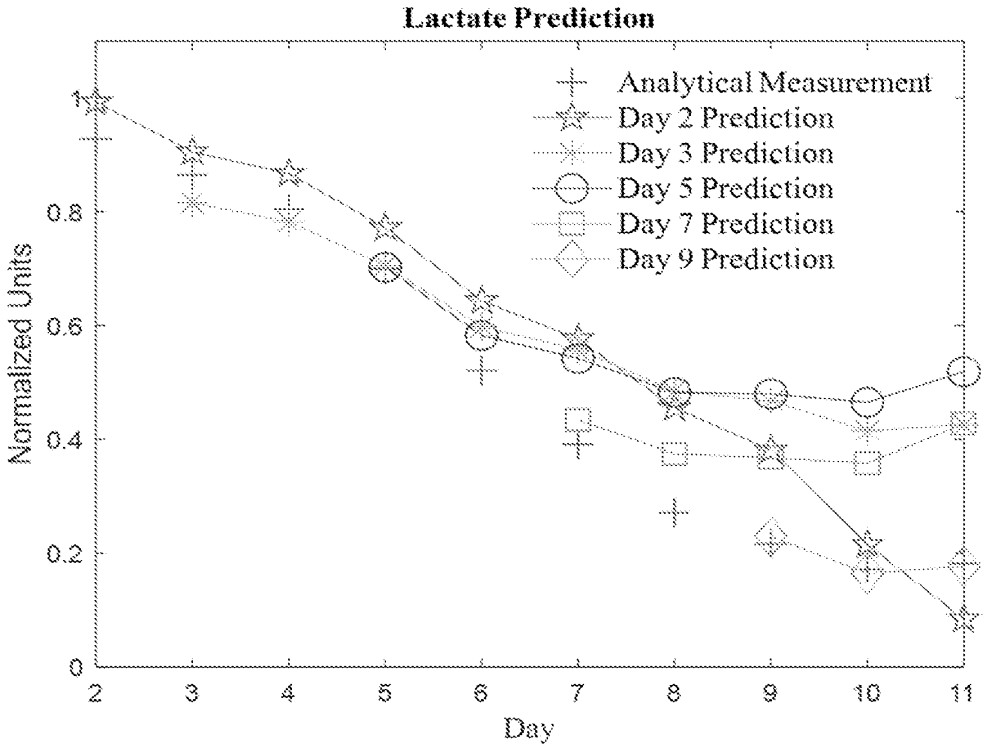
Lactate Prediction
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
Normalized Units
Day
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 7E

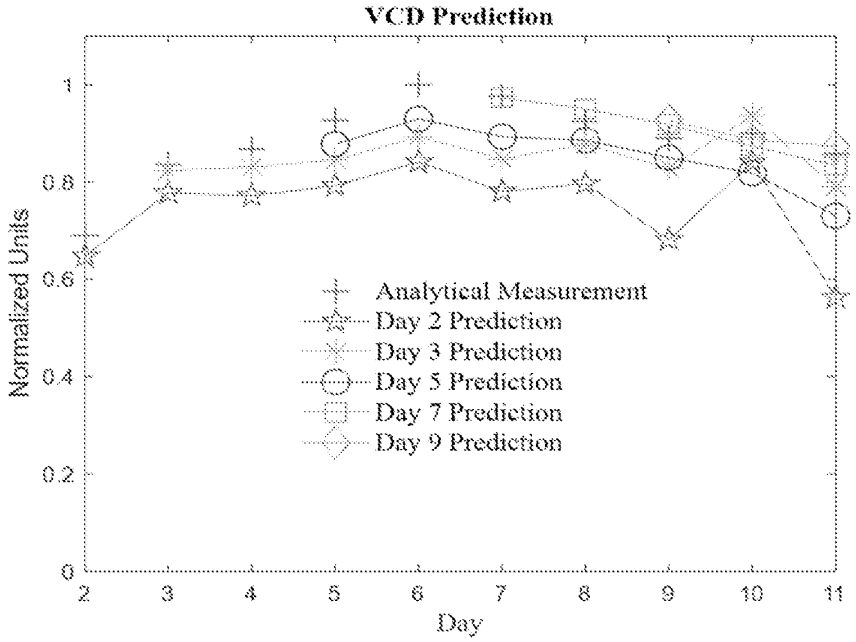
VCD Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction

FIG. 8A

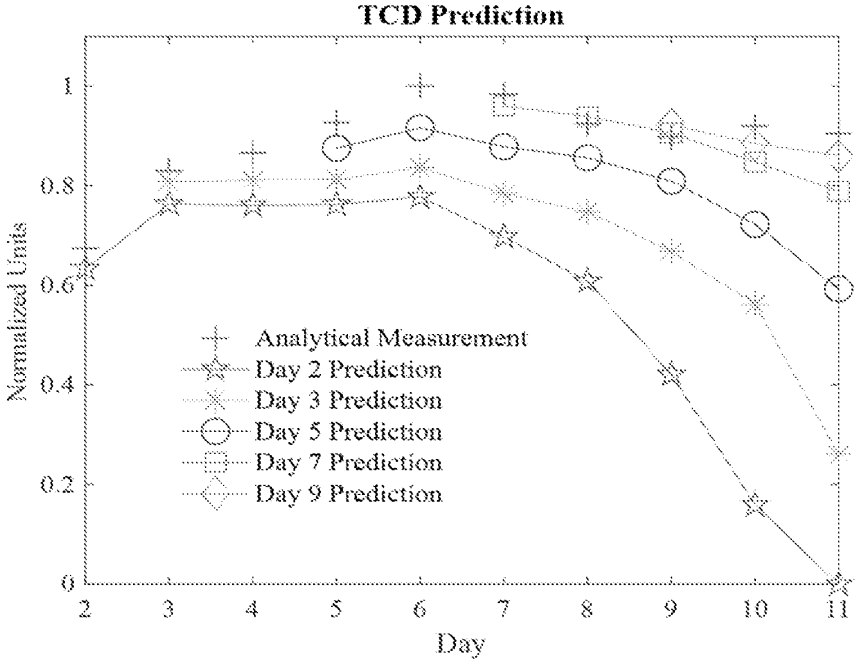
TCD Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction

FIG. 8B

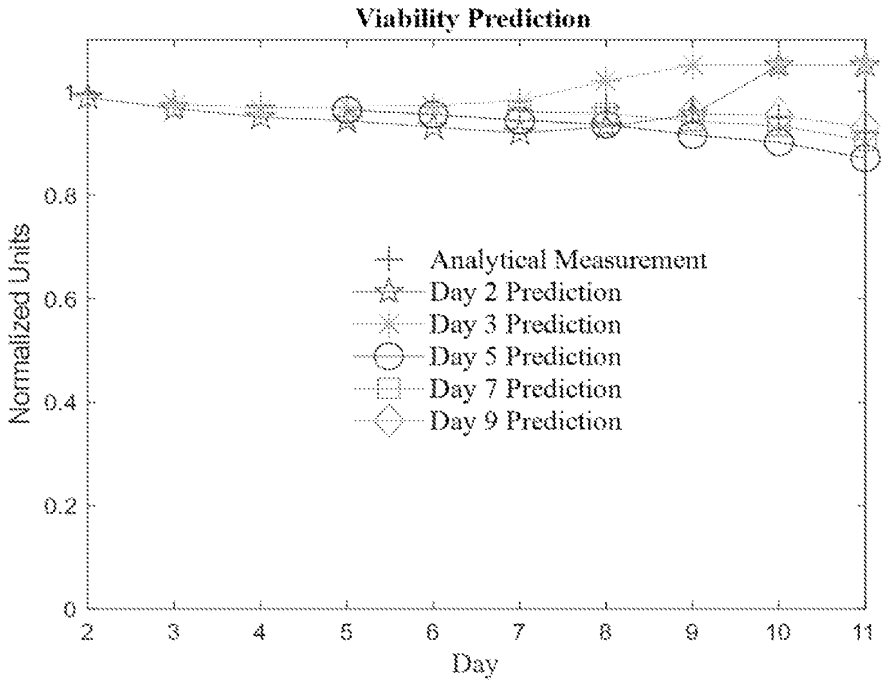
Viability Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.6
1
2
3
4
5
6
7
8
9
10
11

FIG. 8C

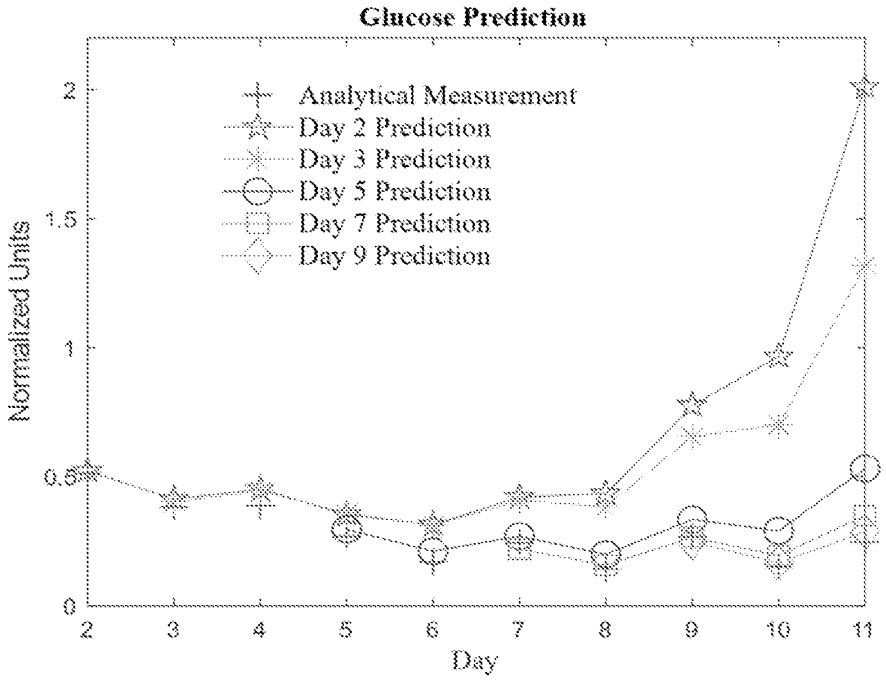
Glucose Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.5
1
1.5
2
2
3
4
5
6
7
8
9
10
11

FIG. 8D

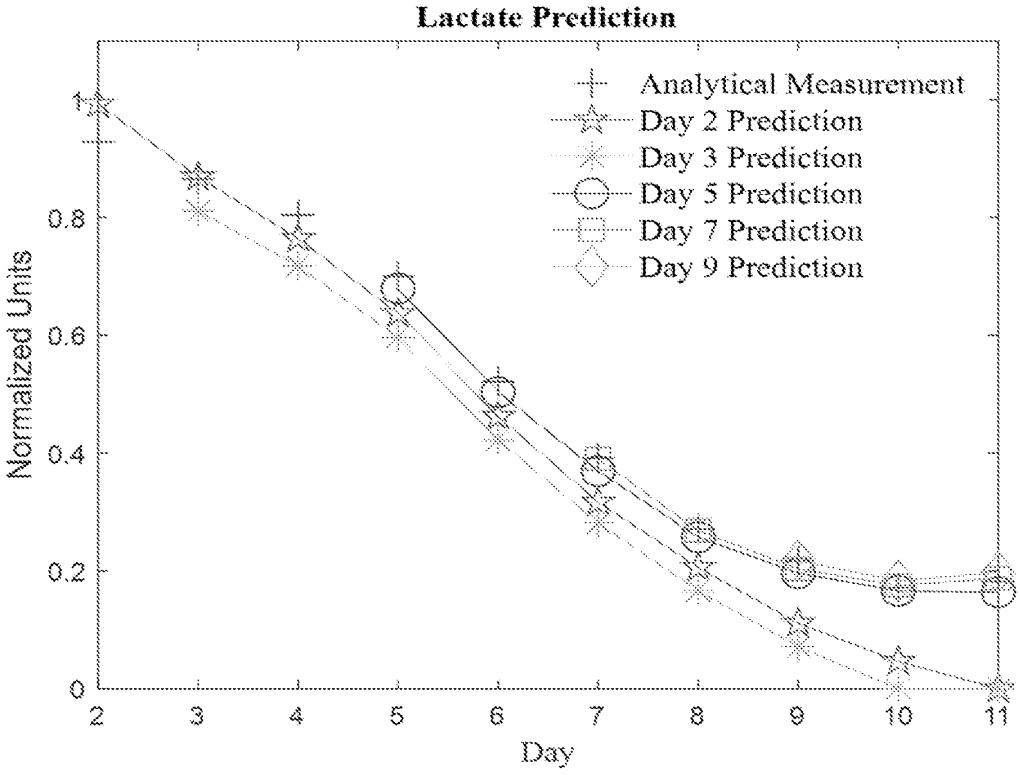
Lactate Prediction
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
Normalized Units
Day
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 8E

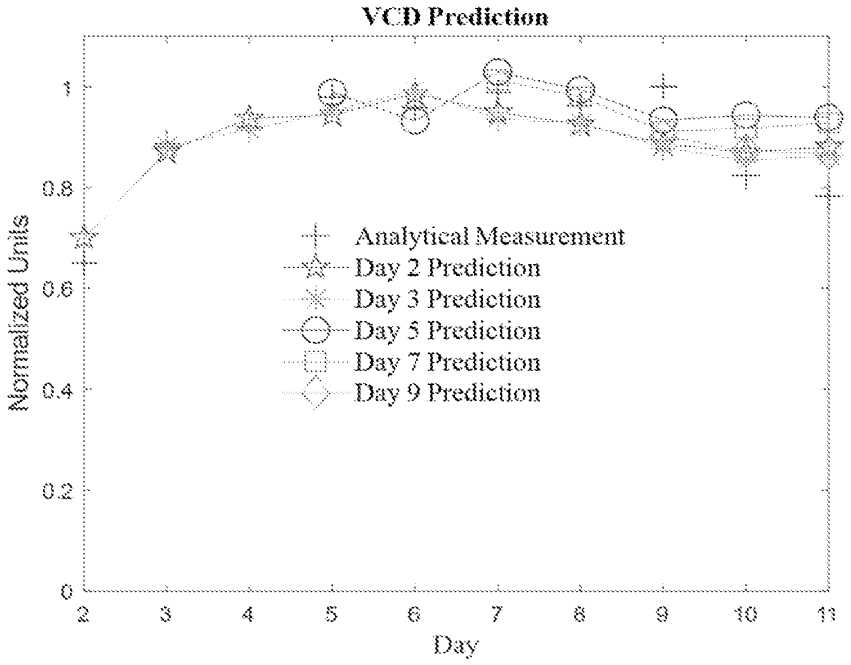
VCD Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 9A

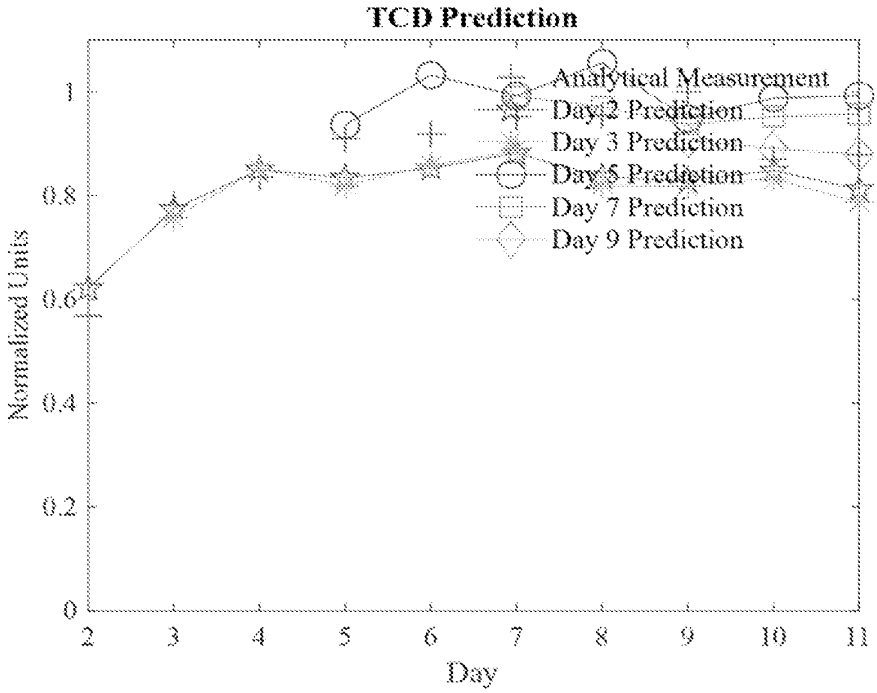
TCD Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 9B

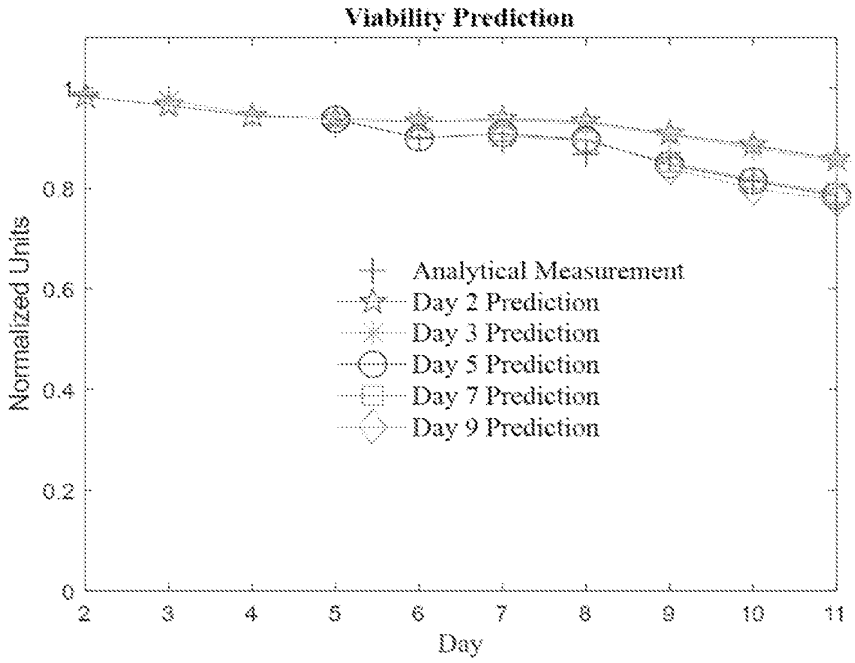
Viability Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 9C

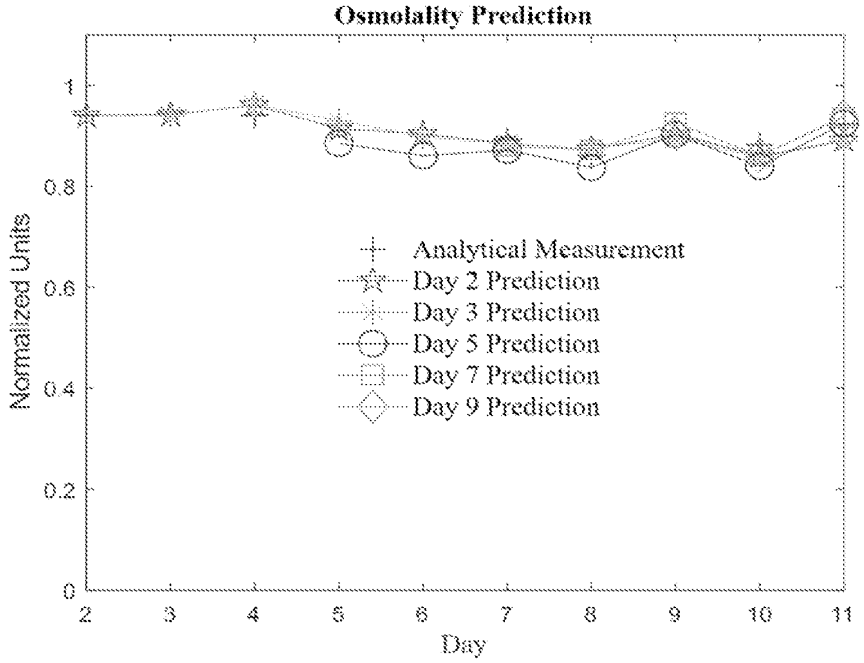
Osmolality Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 9D

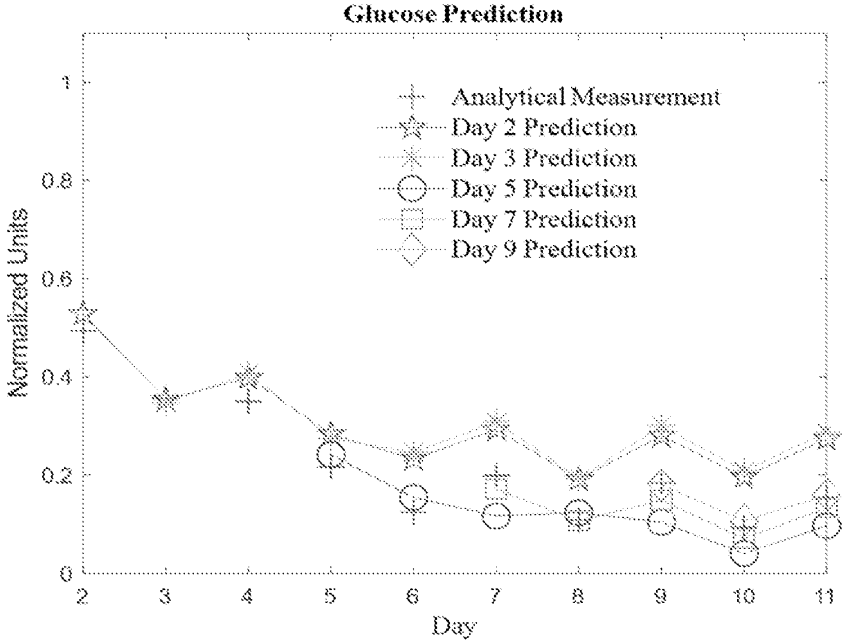
Glucose Prediction
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
Normalized Units
Day
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 9E

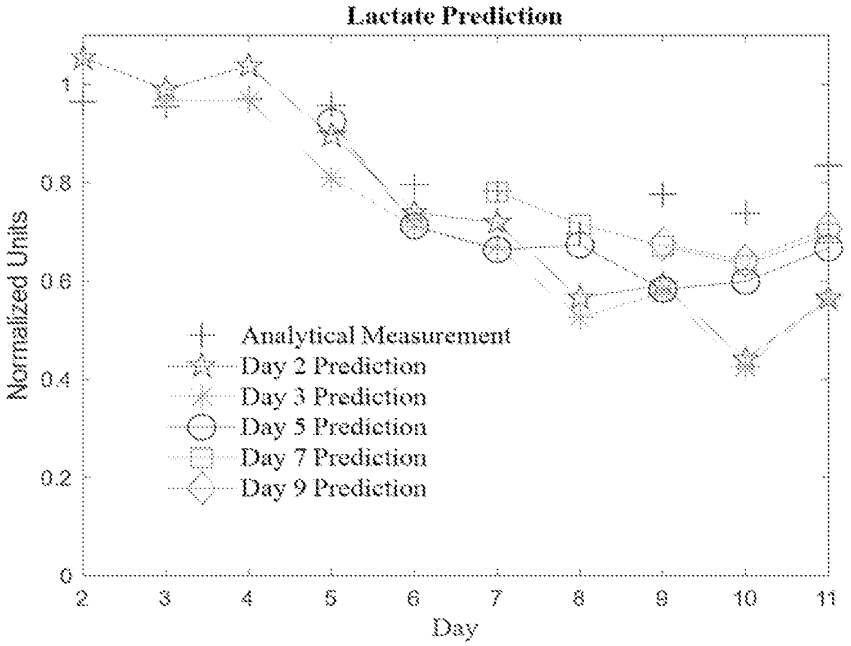
Lactate Prediction
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
Normalized Units
Day
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 9F

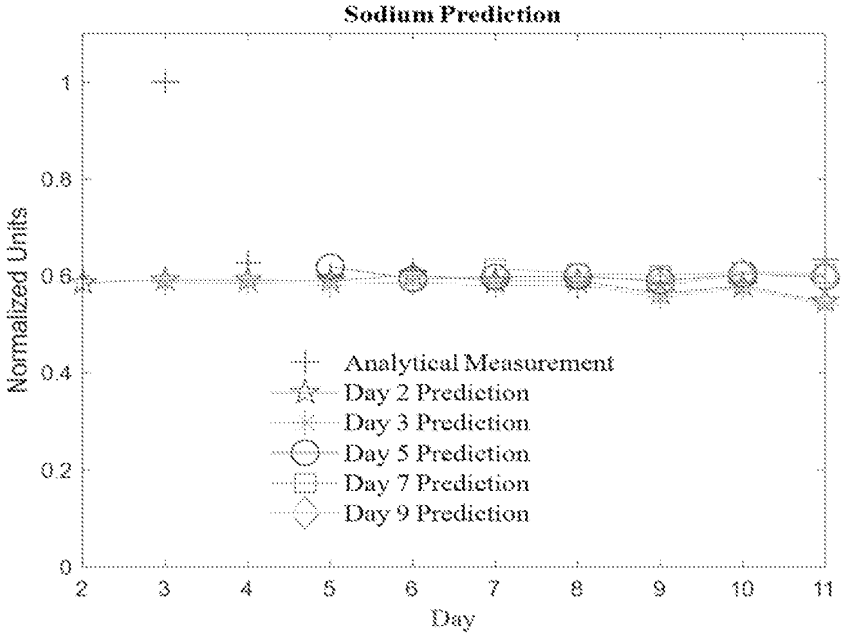
Sodium Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction

FIG. 9G

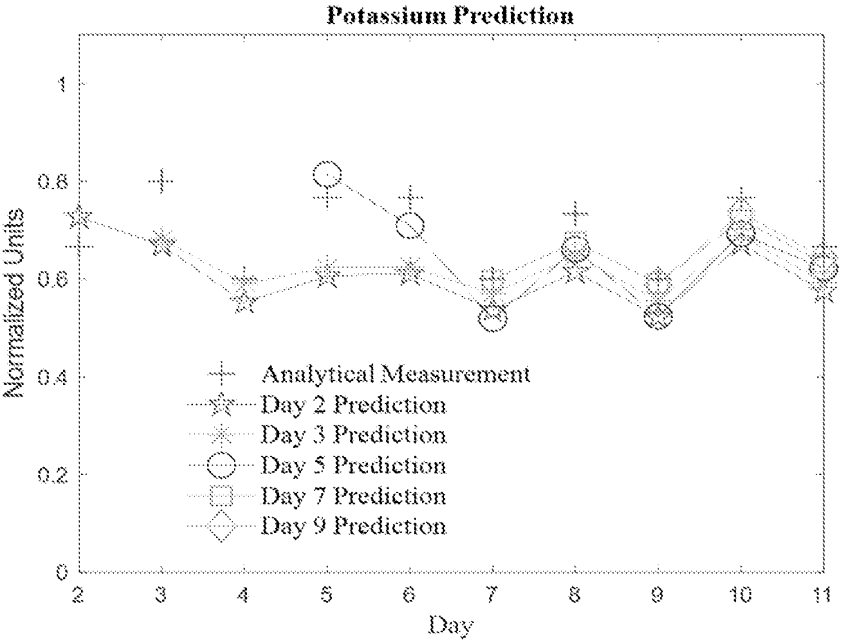
Potassium Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction

FIG. 9H

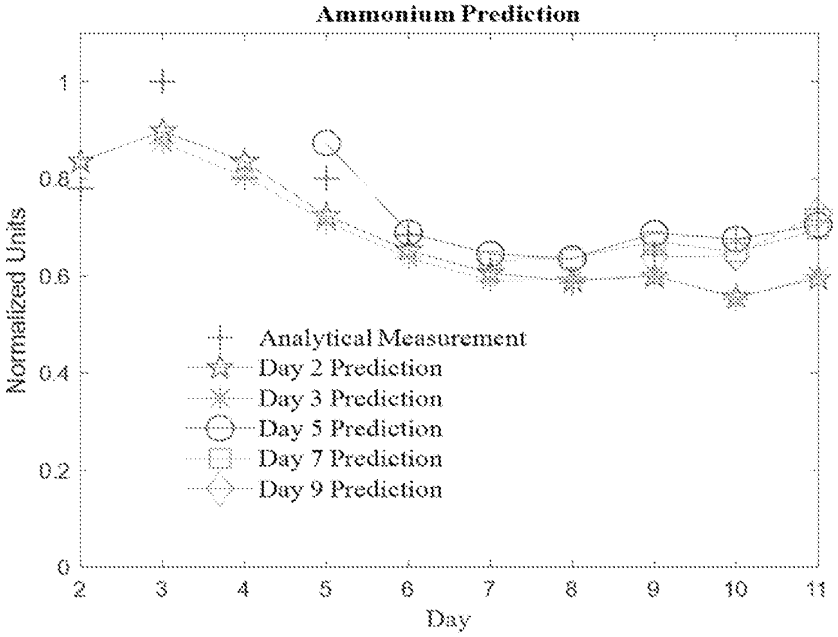
Ammonium Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 9I

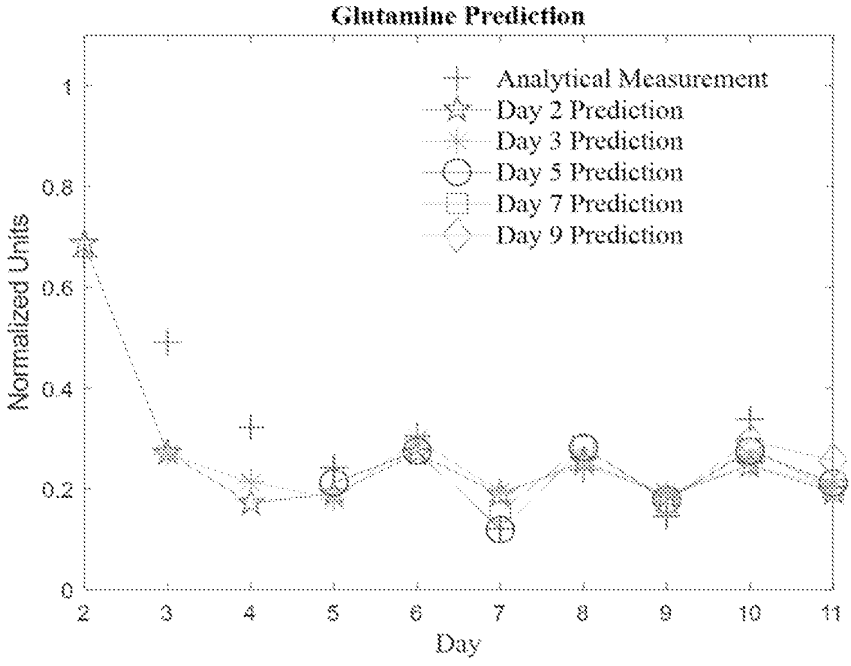
Glutamine Prediction
Normalized Units
Day
Analytical Measurement
Day 2 Prediction
Day 3 Prediction
Day 5 Prediction
Day 7 Prediction
Day 9 Prediction
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11

FIG. 9J

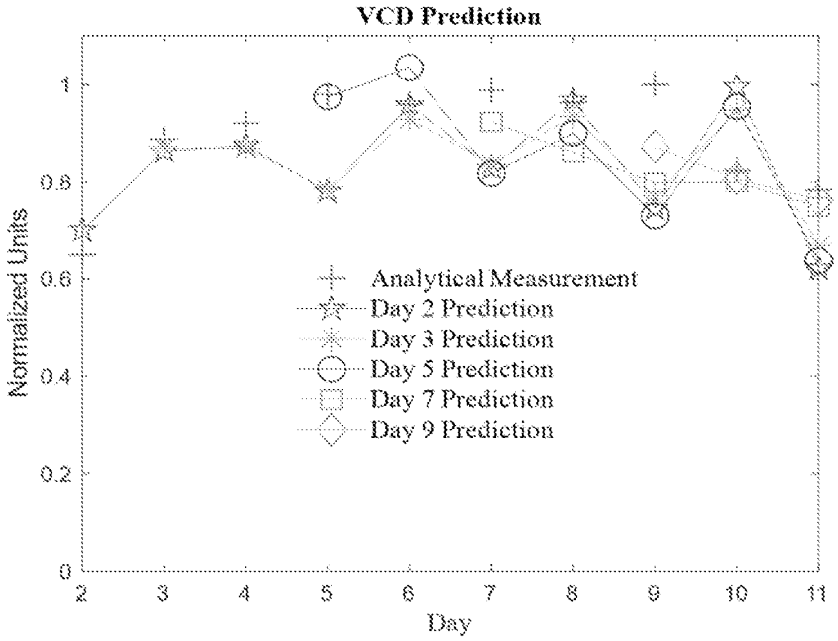

FIG. 10A

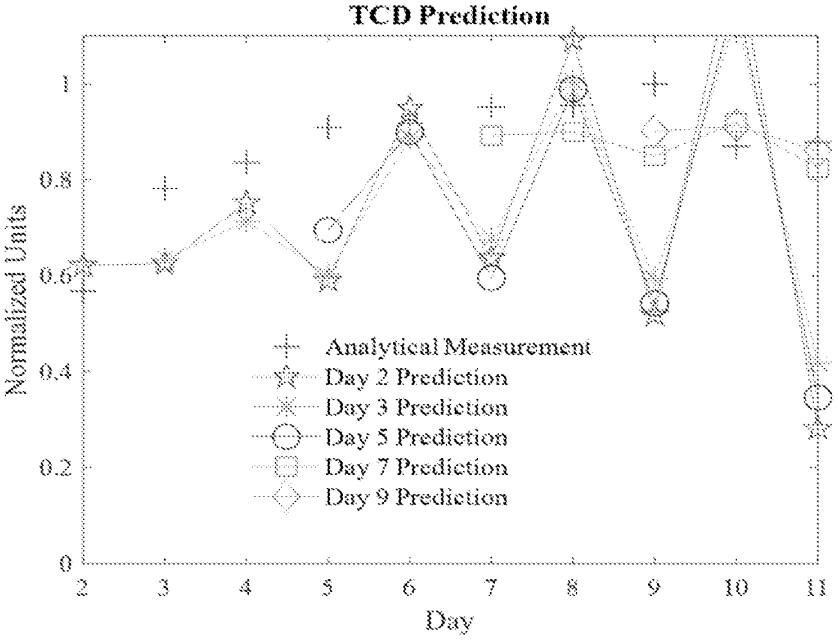

FIG. 10B

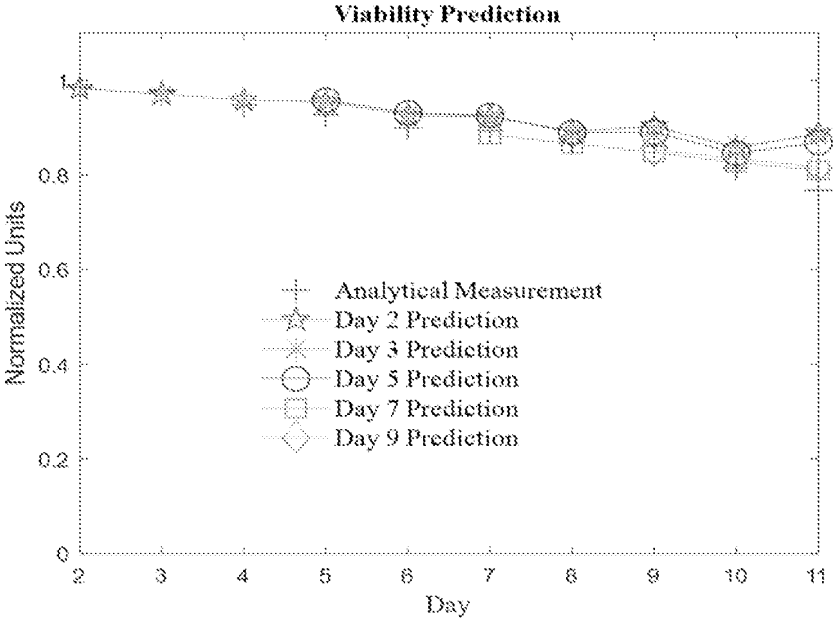

FIG. 10C

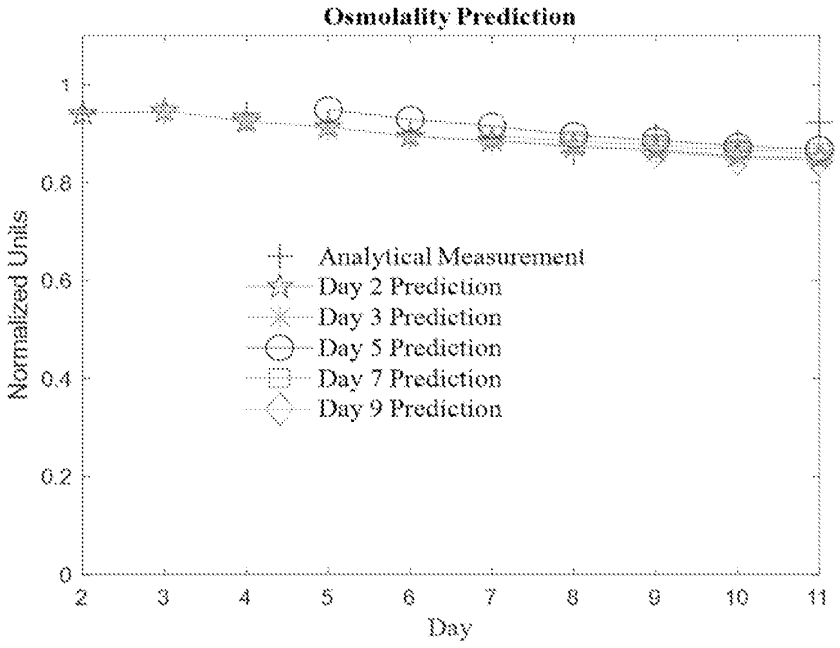

FIG. 10D

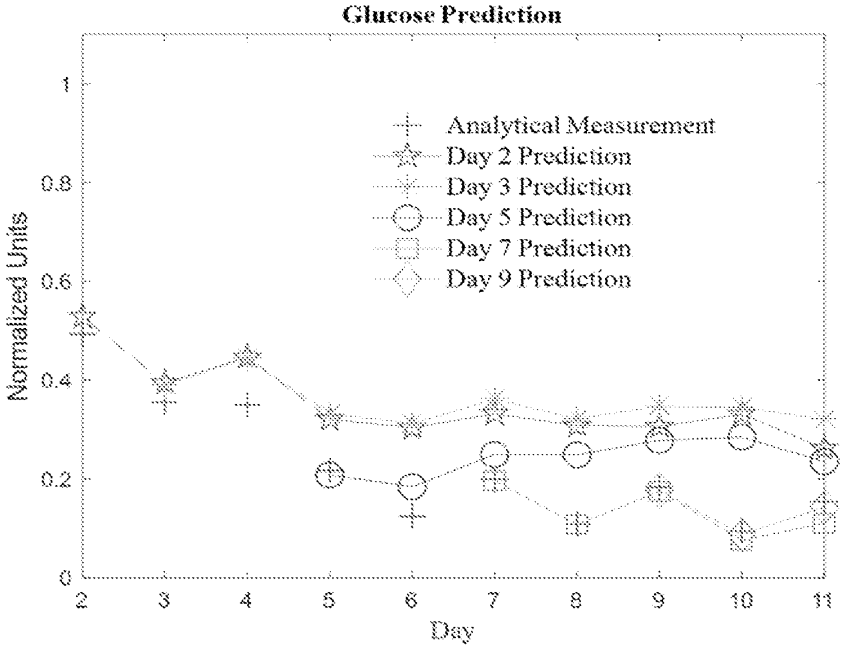

FIG. 10E

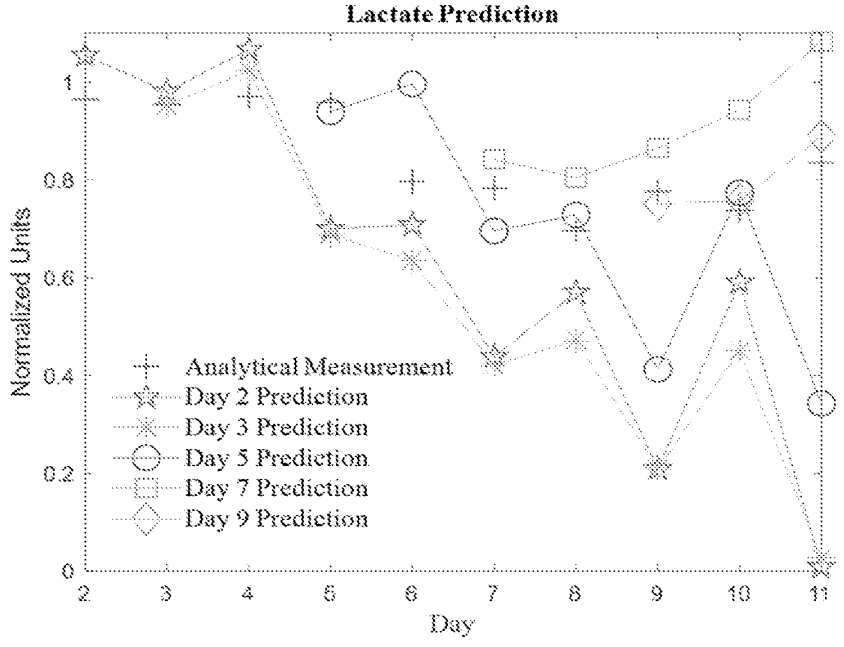

FIG. 10F

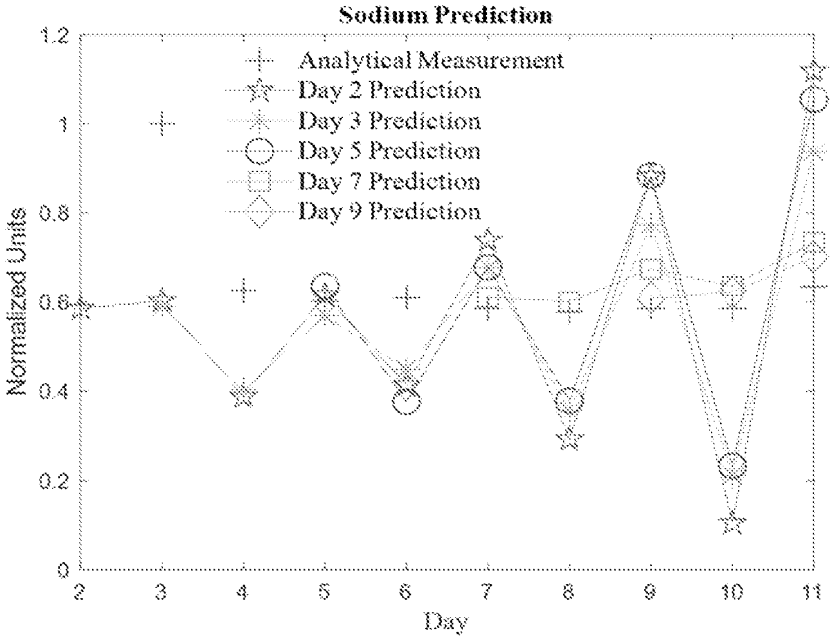

FIG. 10G

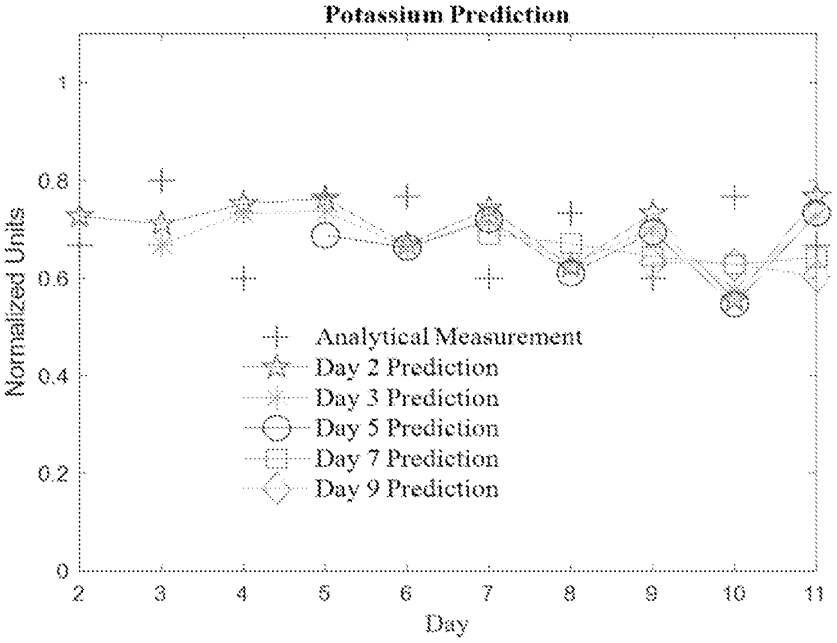

FIG. 10H

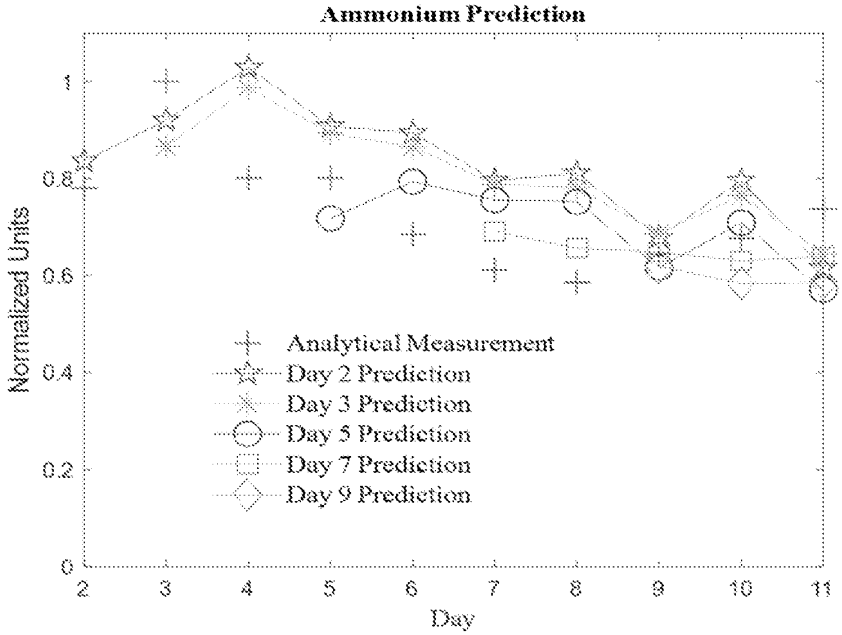

FIG. 10I

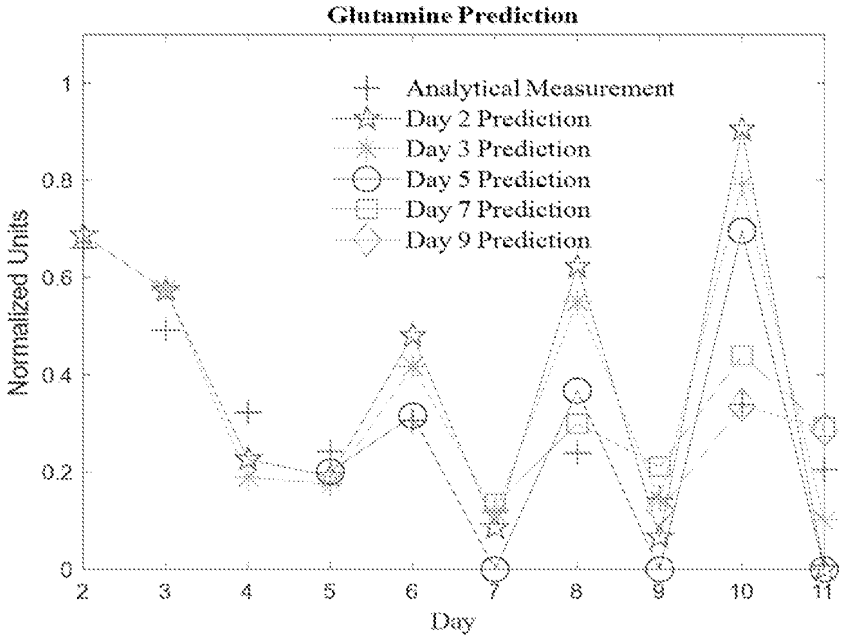

FIG. 10J

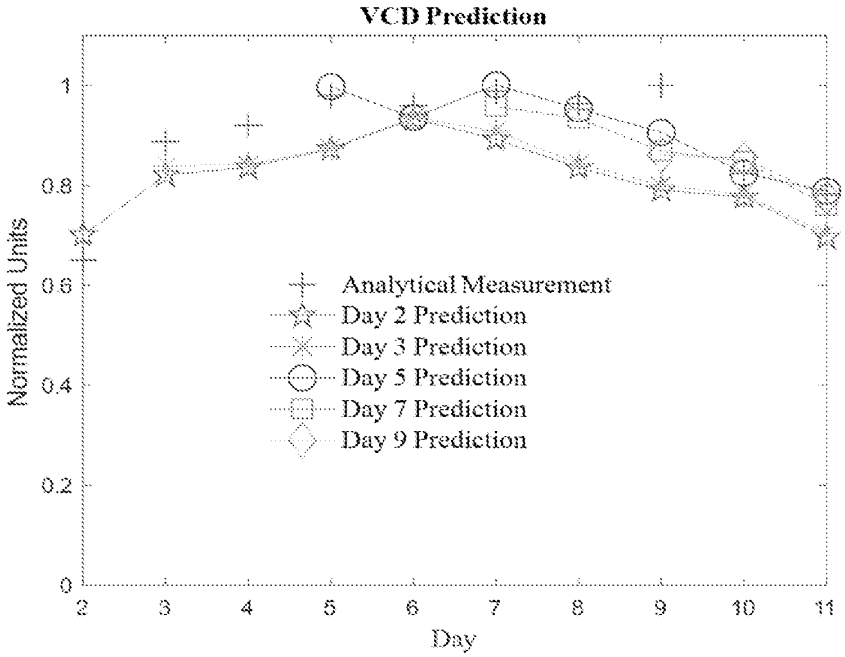

FIG. 11A

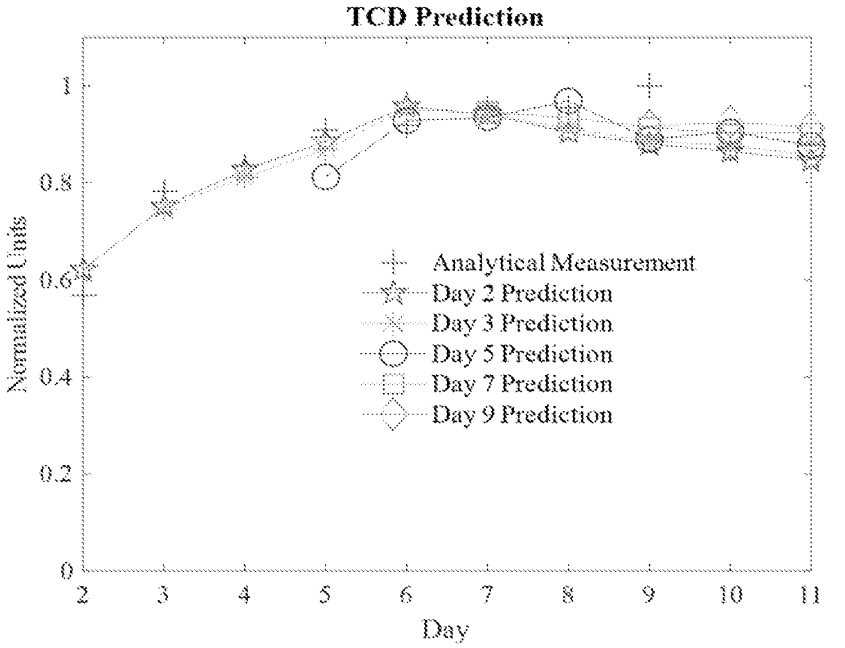

FIG. 11B

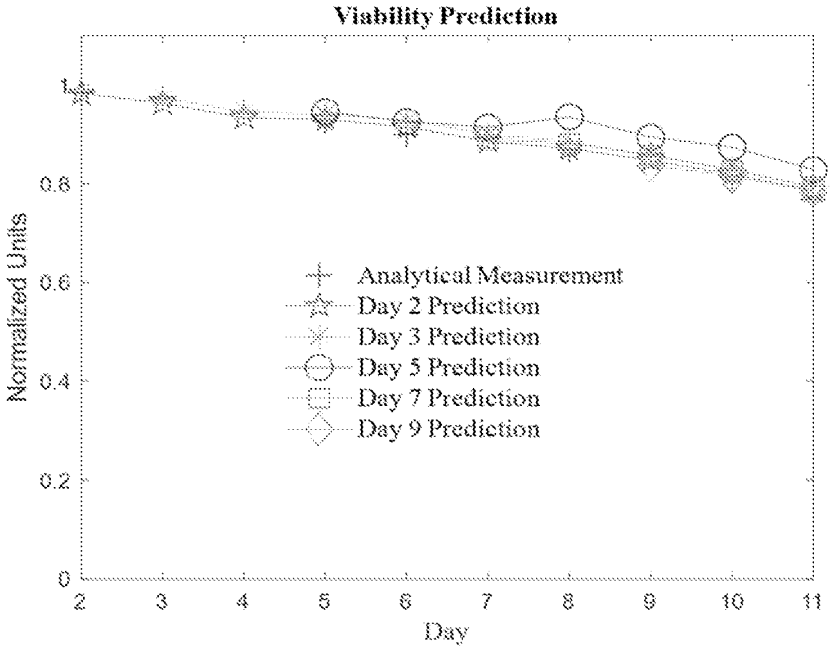

FIG. 11C

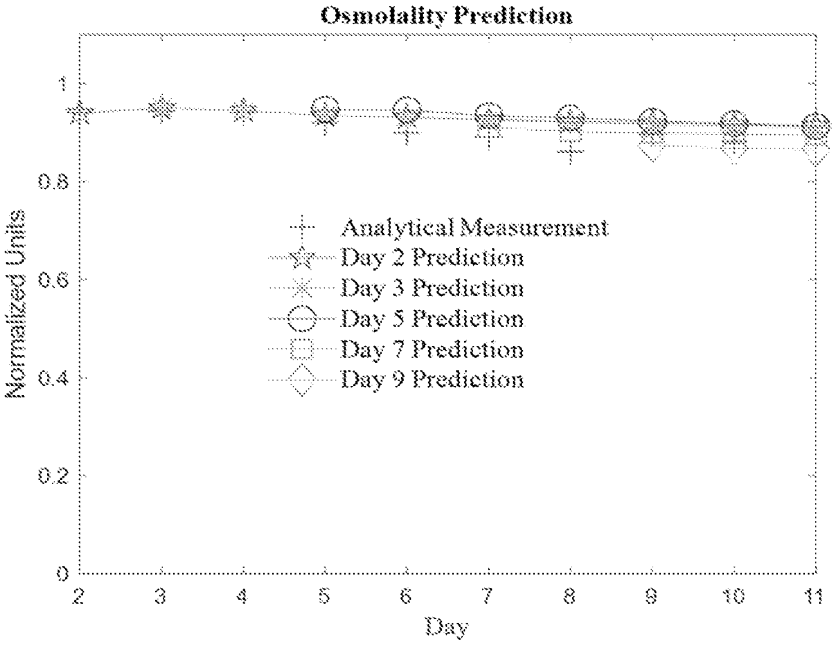

FIG. 11D

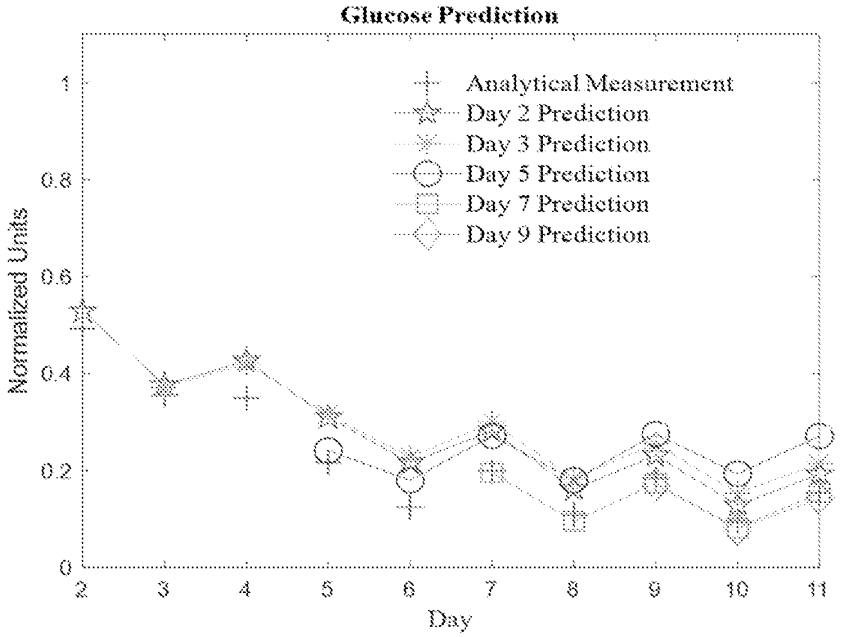

FIG. 11E

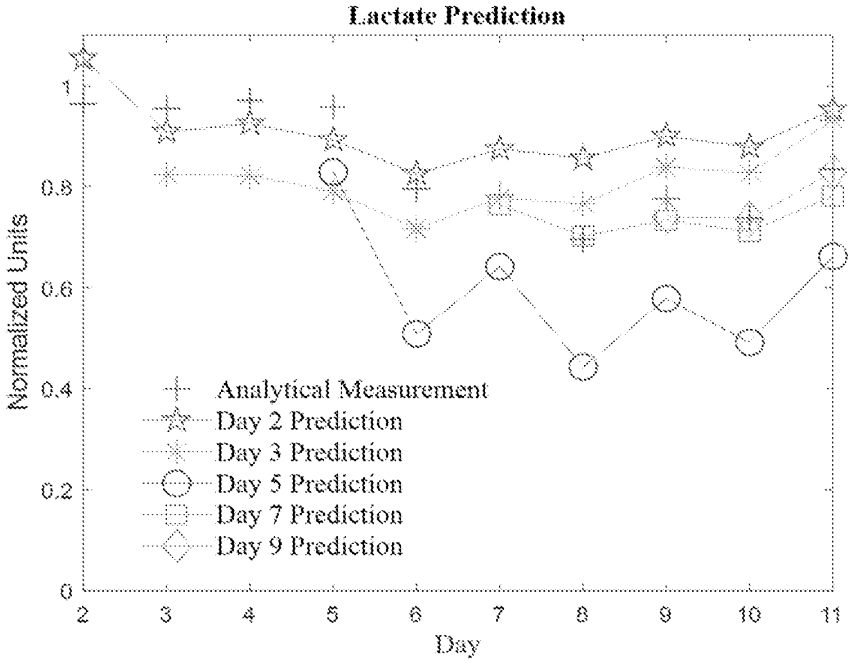

FIG. 11F

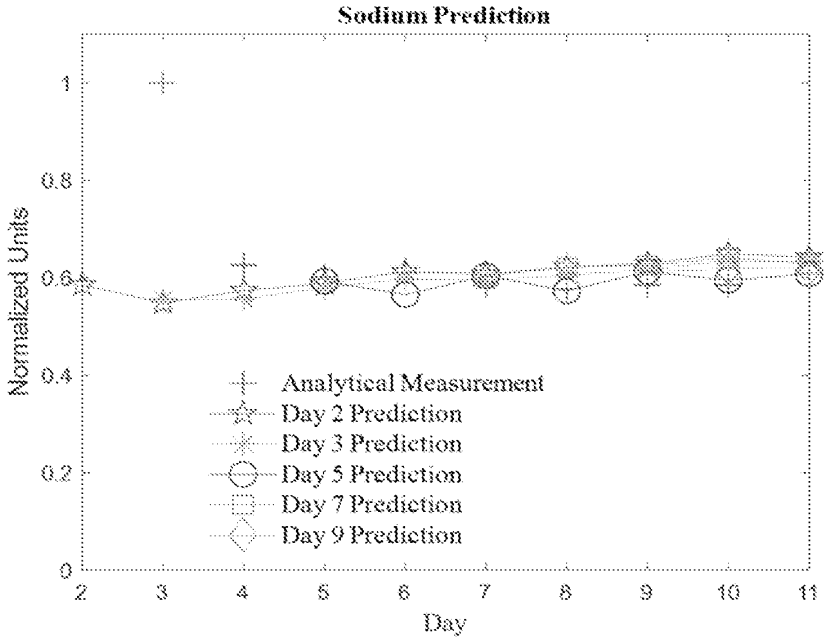

FIG. 11G

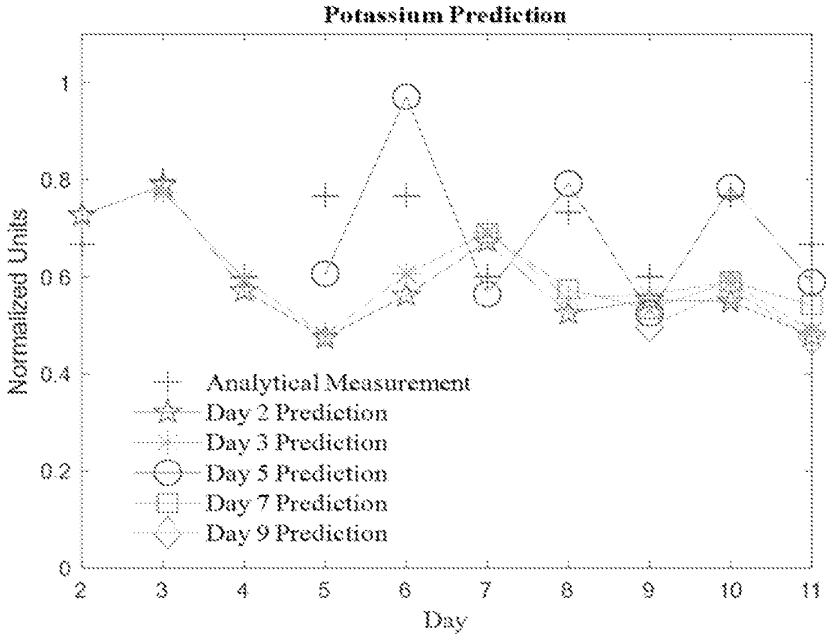

FIG. 11H

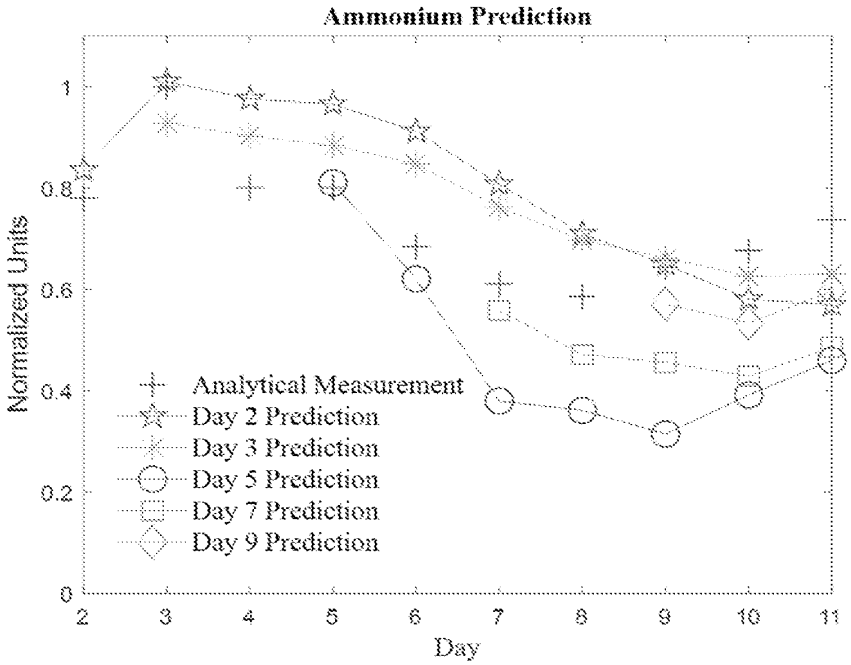

FIG. 11I

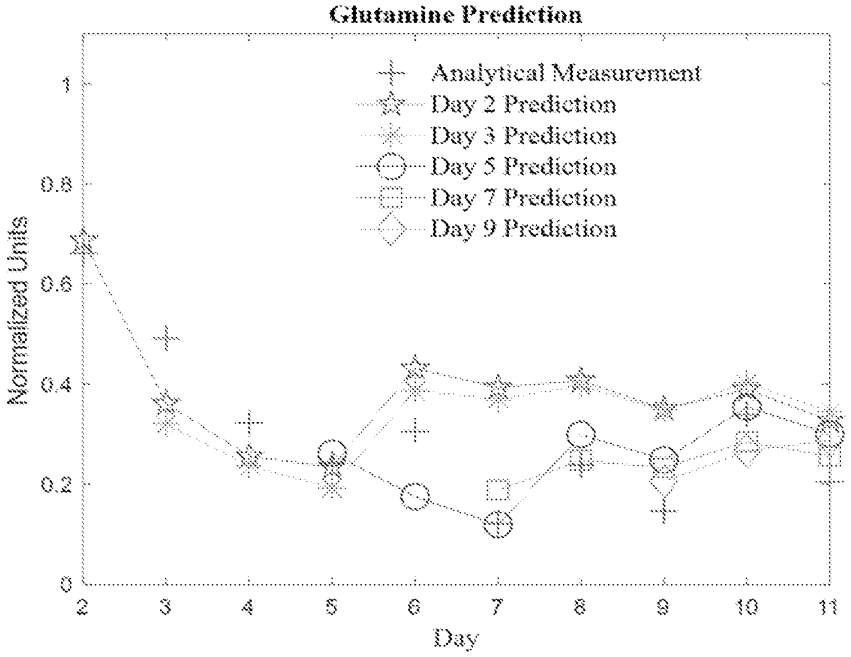

FIG. 11J

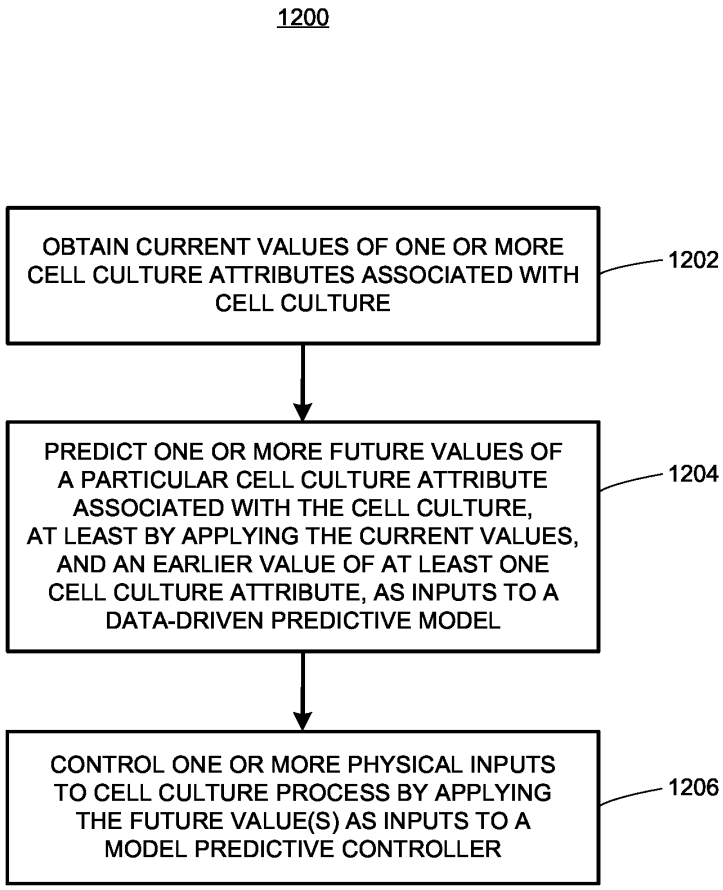
1200
OBTAIN CURRENT VALUES OF ONE OR MORE CELL CULTURE ATTRIBUTES ASSOCIATED WITH CELL CULTURE
1202
PREDICT ONE OR MORE FUTURE VALUES OF A PARTICULAR CELL CULTURE ATTRIBUTE ASSOCIATED WITH THE CELL CULTURE, AT LEAST BY APPLYING THE CURRENT VALUES, AND AN EARLIER VALUE OF AT LEAST ONE CELL CULTURE ATTRIBUTE, AS INPUTS TO A DATA-DRIVEN PREDICTIVE MODEL
1204
CONTROL ONE OR MORE PHYSICAL INPUTS TO CELL CULTURE PROCESS BY APPLYING THE FUTURE VALUE(S) AS INPUTS TO A MODEL PREDICTIVE CONTROLLER
1206

FIG. 12