US010322803B2

(12) **United States Patent**
Flood et al.

(10) **Patent No.: US 10,322,803 B2**
(45) **Date of Patent: Jun. 18, 2019**

(54) **USING UNMANNED AERIAL VEHICLES (UAVS OR DRONES) IN FORESTRY PRODUCTIVITY AND CONTROL APPLICATIONS**

(71) Applicant: **Deere & Company**, Moline, IL (US)

(72) Inventors: **Matthew J. Flood**, Dubuque, IA (US); **Mark J. Cherney**, Dubuque, IA (US); **Andrew W. Kahler**, Moline, IL (US); **Richard Lawler**, Dubuque, IA (US)

(73) Assignee: **Deere & Company**, Moline, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/812,405**

(22) Filed: **Nov. 14, 2017**

(65) **Prior Publication Data**

US 2019/0100309 A1 Apr. 4, 2019

Related U.S. Application Data

(60) Provisional application No. 62/565,863, filed on Sep. 29, 2017.

(51) **Int. Cl.**

B64C 39/02	(2006.01)
B64D 47/08	(2006.01)
A01G 23/00	(2006.01)

(52) **U.S. Cl.**

CPC ***B64C 39/024*** (2013.01); ***A01G 23/00*** (2013.01); ***B64D 47/08*** (2013.01); *B64C 2201/127* (2013.01); *B64C 2201/146* (2013.01)

(58) **Field of Classification Search**

CPC B64C 39/024; B64C 2201/127; B64C 2201/146; A01G 23/00; B64D 47/08

USPC 701/3

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0087110	A1*	4/2005	Kobayashi	A01C 21/00 111/200
2014/0077969	A1*	3/2014	Vian	H04Q 9/00 340/870.02
2014/0163781	A1*	6/2014	Vian	A01G 23/00 701/3
2016/0292626	A1	10/2016	Green et al.	
2016/0360562	A1	12/2016	Chong et al.	
2016/0363932	A1	12/2016	Moriarity et al.	
2017/0031365	A1	2/2017	Sugumaran et al.	
2017/0032509	A1	2/2017	Mannar et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

SE	1530146 A1	9/2015
WO	9735433 A1	9/1997
WO	2016049217 A1	3/2016

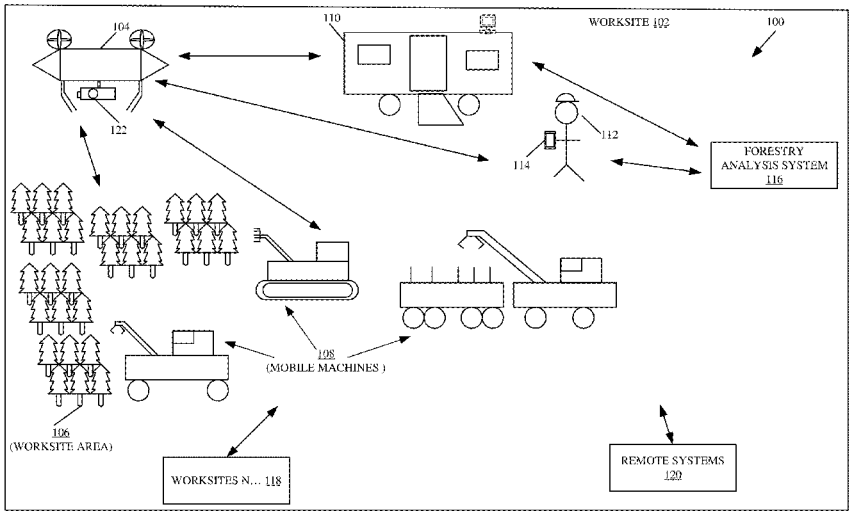
Primary Examiner — Marthe Y Marc-Coleman

(74) *Attorney, Agent, or Firm* — Joseph R. Kelly; Kelly, Holt & Christenson, PLLC

(57) **ABSTRACT**

A method includes generating an unmanned aerial vehicle (UAV) control signal to fly the UAV over a worksite and capture imagery information at different geographic locations. The imagery information is used to generate a tree inventory metric that indicates a tree inventory at the worksite, or is used to generate a productivity metric that identifies a productivity category for a geographic location at the worksite. The method also generates an action signal based on the tree inventory metric or productivity metric, such as an action signal to deploy machines to different geographic location, or an action signal to update a worksite completion metric.

14 Claims, 16 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2017/0041978	A1	2/2017	Radhakrishnan
2017/0103263	A1	4/2017	Prouty et al.
2017/0161972	A1	6/2017	Moloney et al.

* cited by examiner

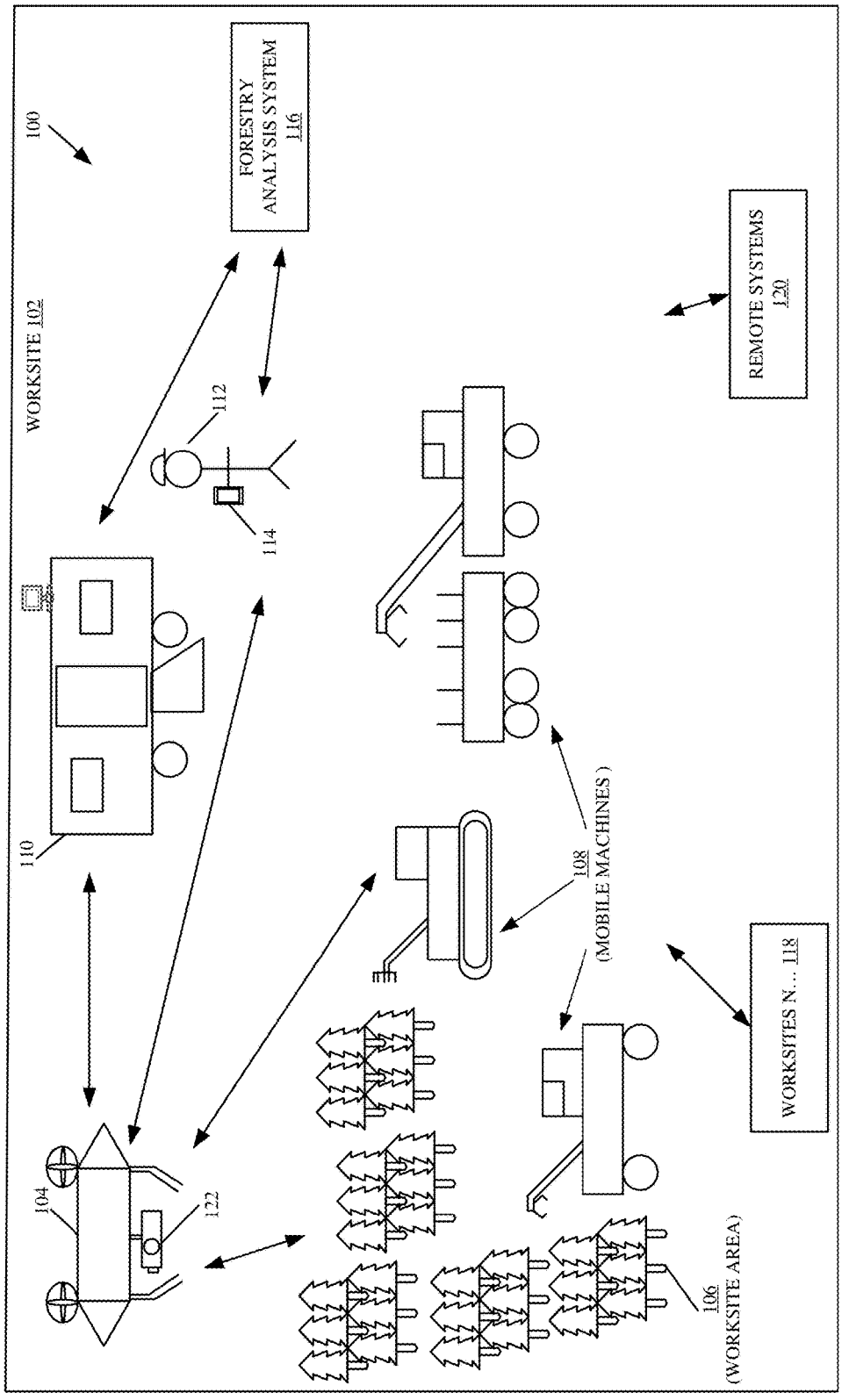

100
FORESTRY ANALYSIS SYSTEM 116
WORKSITE 102
REMOTE SYSTEMS 120
112
114
110
108 (MOBILE MACHINES)
104
122
106 (WORKSITE AREA)
WORKSITES N... 118

FIG. 1

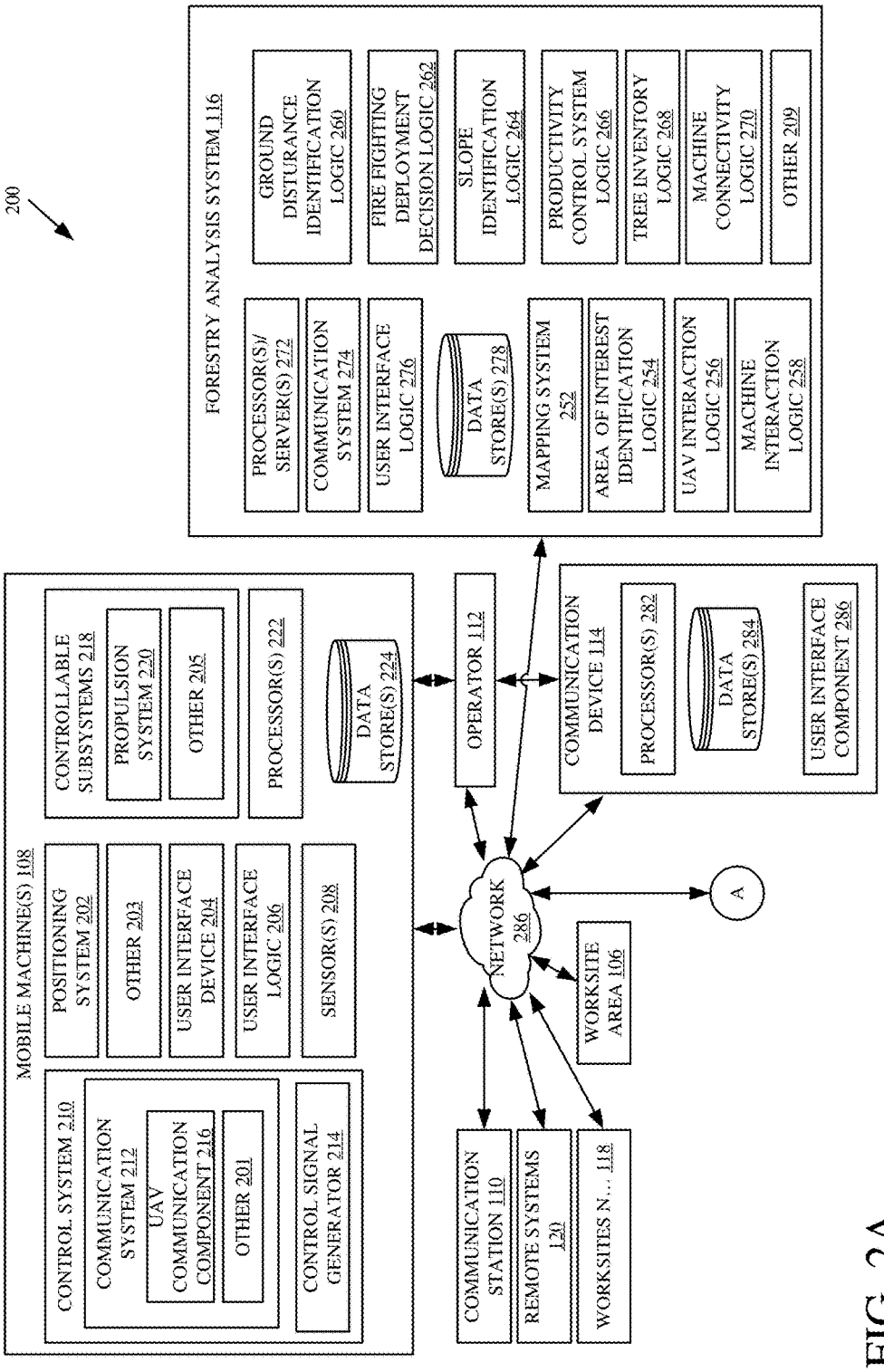

200
FORESTRY ANALYSIS SYSTEM 116
PROCESSOR(S)/ SERVER(S) 272
COMMUNICATION SYSTEM 274
USER INTERFACE LOGIC 276
DATA STORE(S) 278
MAPPING SYSTEM 252
AREA OF INTEREST IDENTIFICATION LOGIC 254
UAV INTERACTION LOGIC 256
MACHINE INTERACTION LOGIC 258
GROUND DISTURANCE IDENTIFICATION LOGIC 260
FIRE FIGHTING DEPLOYMENT DECISION LOGIC 262
SLOPE IDENTIFICATION LOGIC 264
PRODUCTIVITY CONTROL SYSTEM LOGIC 266
TREE INVENTORY LOGIC 268
MACHINE CONNECTIVITY LOGIC 270
OTHER 209
MOBILE MACHINE(S) 108
CONTROL SYSTEM 210
COMMUNICATION SYSTEM 212
UAV COMMUNICATION COMPONENT 216
OTHER 201
CONTROL SIGNAL GENERATOR 214
POSITIONING SYSTEM 202
OTHER 203
USER INTERFACE DEVICE 204
USER INTERFACE LOGIC 206
SENSOR(S) 208
CONTROLLABLE SUBSYSTEMS 218
PROPULSION SYSTEM 220
OTHER 205
PROCESSOR(S) 222
DATA STORE(S) 224
OPERATOR 112
COMMUNICATION DEVICE 114
PROCESSOR(S) 282
DATA STORE(S) 284
USER INTERFACE COMPONENT 286
NETWORK 286
A
COMMUNICATION STATION 110
REMOTE SYSTEMS 120
WORKSITES N... 118
WORKSITE AREA 106

FIG. 2A

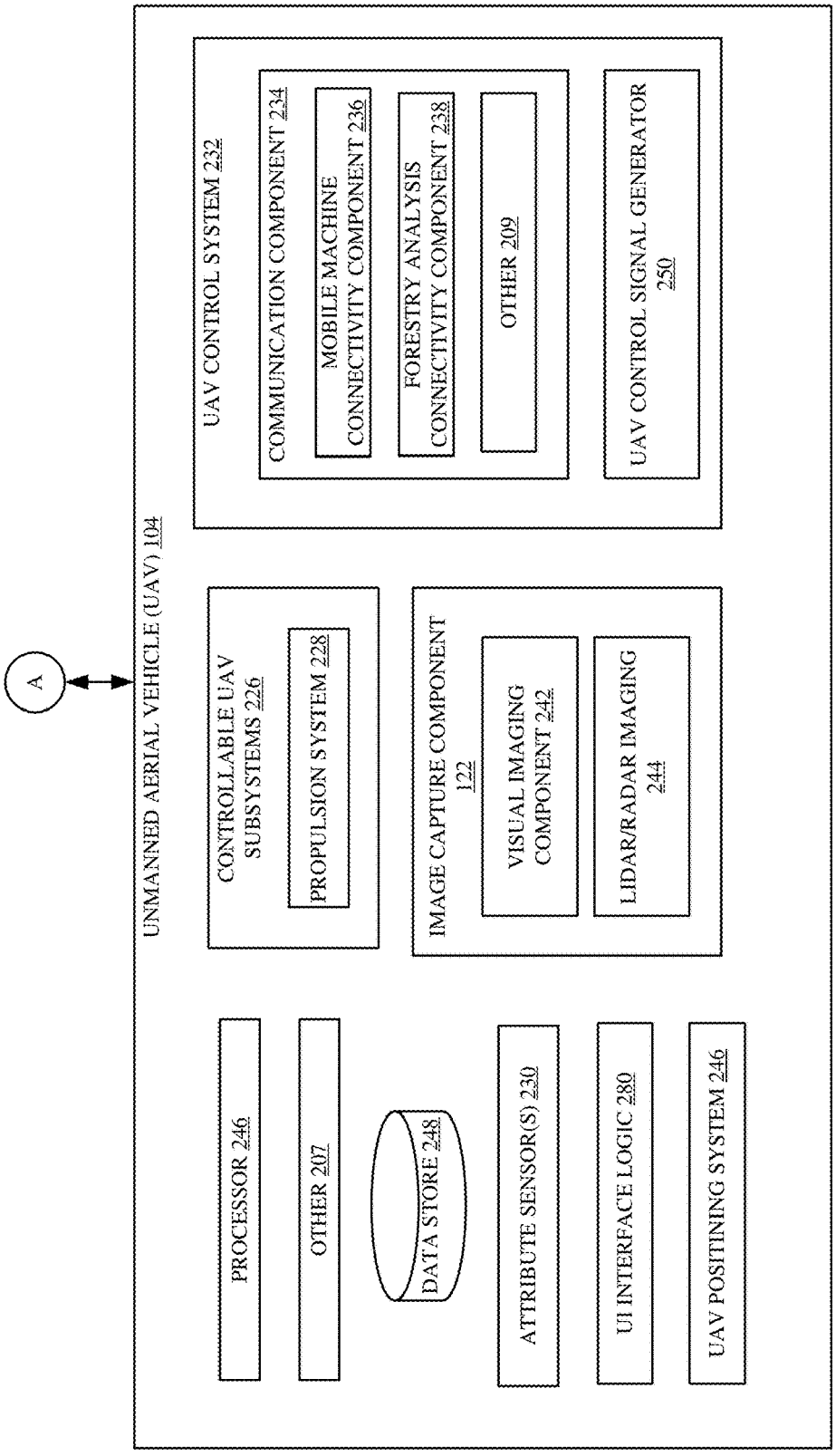

A
UNMANNED AERIAL VEHICLE (UAV) 104
UAV CONTROL SYSTEM 232
COMMUNICATION COMPONENT 234
MOBILE MACHINE CONNECTIVITY COMPONENT 236
FORESTRY ANALYSIS CONNECTIVITY COMPONENT 238
OTHER 209
UAV CONTROL SIGNAL GENERATOR 250
CONTROLLABLE UAV SUBSYSTEMS 226
PROPULSION SYSTEM 228
IMAGE CAPTURE COMPONENT 122
VISUAL IMAGING COMPONENT 242
LIDAR/RADAR IMAGING 244
PROCESSOR 246
OTHER 207
DATA STORE 248
ATTRIBUTE SENSOR(S) 230
UI INTERFACE LOGIC 280
UAV POSITINING SYSTEM 246

FIG. 2B

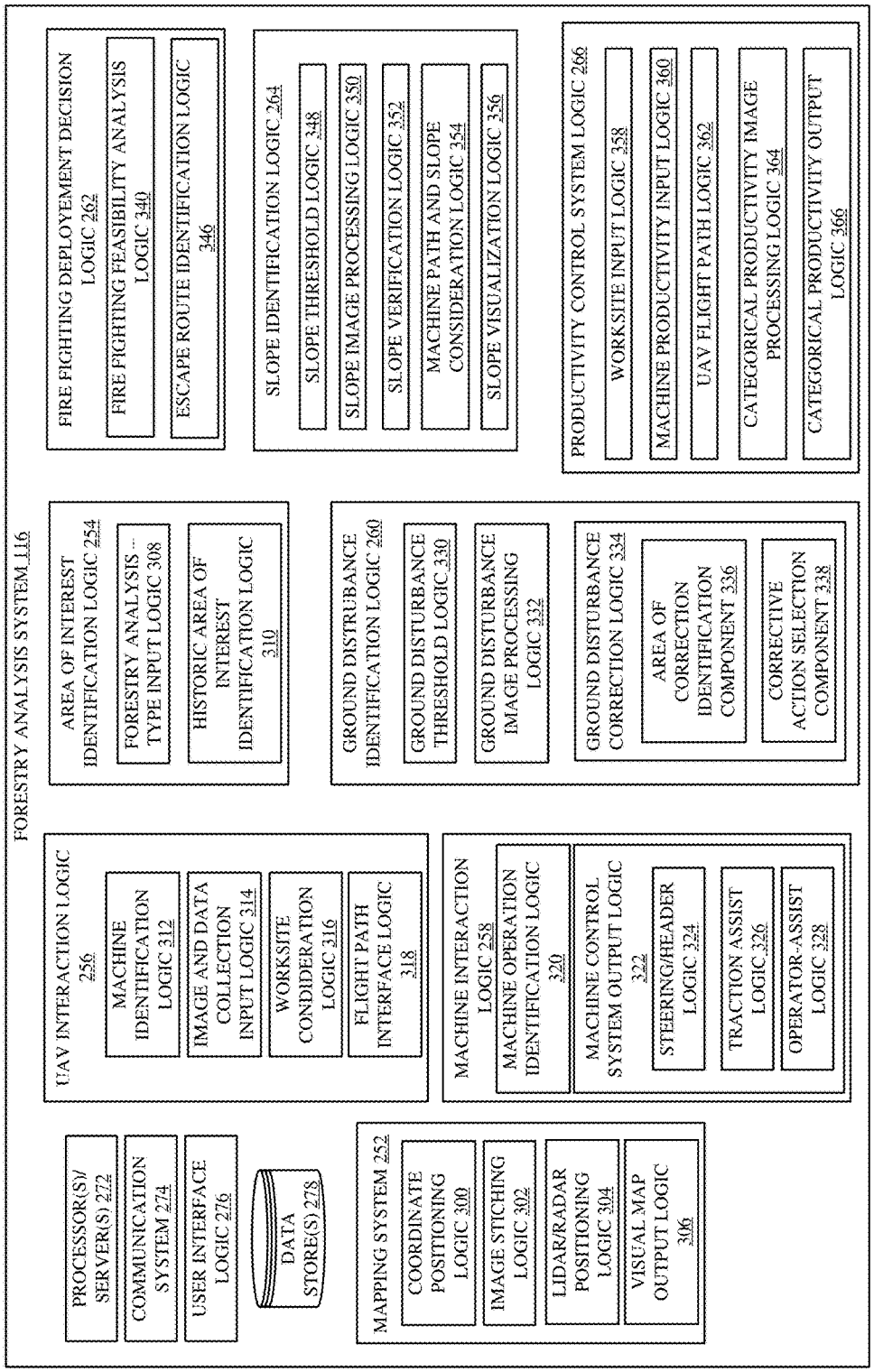

FORESTRY ANALYSIS SYSTEM 116
PROCESSOR(S)/ SERVER(S) 272
COMMUNICATION SYSTEM 274
USER INTERFACE LOGIC 276
DATA STORE(S) 278
MAPPING SYSTEM 252
COORDINATE POSITIONING LOGIC 300
IMAGE STICHING LOGIC 302
LIDAR/RADAR POSITIONING LOGIC 304
VISUAL MAP OUTPUT LOGIC 306
UAV INTERACTION LOGIC 256
MACHINE IDENTIFICATION LOGIC 312
IMAGE AND DATA COLLECTION INPUT LOGIC 314
WORKSITE CONDIDERATION LOGIC 316
FLIGHT PATH INTERFACE LOGIC 318
MACHINE INTERACTION LOGIC 258
MACHINE OPERATION IDENTIFICATION LOGIC 320
MACHINE CONTROL SYSTEM OUTPUT LOGIC 322
STEERING/HEADER LOGIC 324
TRACTION ASSIST LOGIC 326
OPERATOR-ASSIST LOGIC 328
AREA OF INTEREST IDENTIFICATION LOGIC 254
FORESTRY ANALYSIS -- TYPE INPUT LOGIC 308
HISTORIC AREA OF INTEREST IDENTIFICATION LOGIC 310
GROUND DISTRUBANCE IDENTIFICATION LOGIC 260
GROUND DISTURBANCE THRESHOLD LOGIC 330
GROUND DISTURBANCE IMAGE PROCESSING LOGIC 332
GROUND DISTURBANCE CORRECTION LOGIC 334
AREA OF CORRECTION IDENTIFICATION COMPONENT 336
CORRECTIVE ACTION SELECTION COMPONENT 338
FIRE FIGHTING DEPLOYEMENT DECISION LOGIC 262
FIRE FIGHTING FEASIBILITY ANALYSIS LOGIC 340
ESCAPE ROUTE IDENTIFICATION LOGIC 346
SLOPE IDENTIFICATION LOGIC 264
SLOPE THRESHOLD LOGIC 348
SLOPE IMAGE PROCESSING LOGIC 350
SLOPE VERIFICATION LOGIC 352
MACHINE PATH AND SLOPE CONSIDERATION LOGIC 354
SLOPE VISUALIZATION LOGIC 356
PRODUCTIVITY CONTROL SYSTEM LOGIC 266
WORKSITE INPUT LOGIC 358
MACHINE PRODUCTIVITY INPUT LOGIC 360
UAV FLIGHT PATH LOGIC 362
CATEGORICAL PRODUCTIVITY IMAGE PROCESSING LOGIC 364
CATEGORICAL PRODUCTIVITY OUTPUT LOGIC 366

FIG. 3A

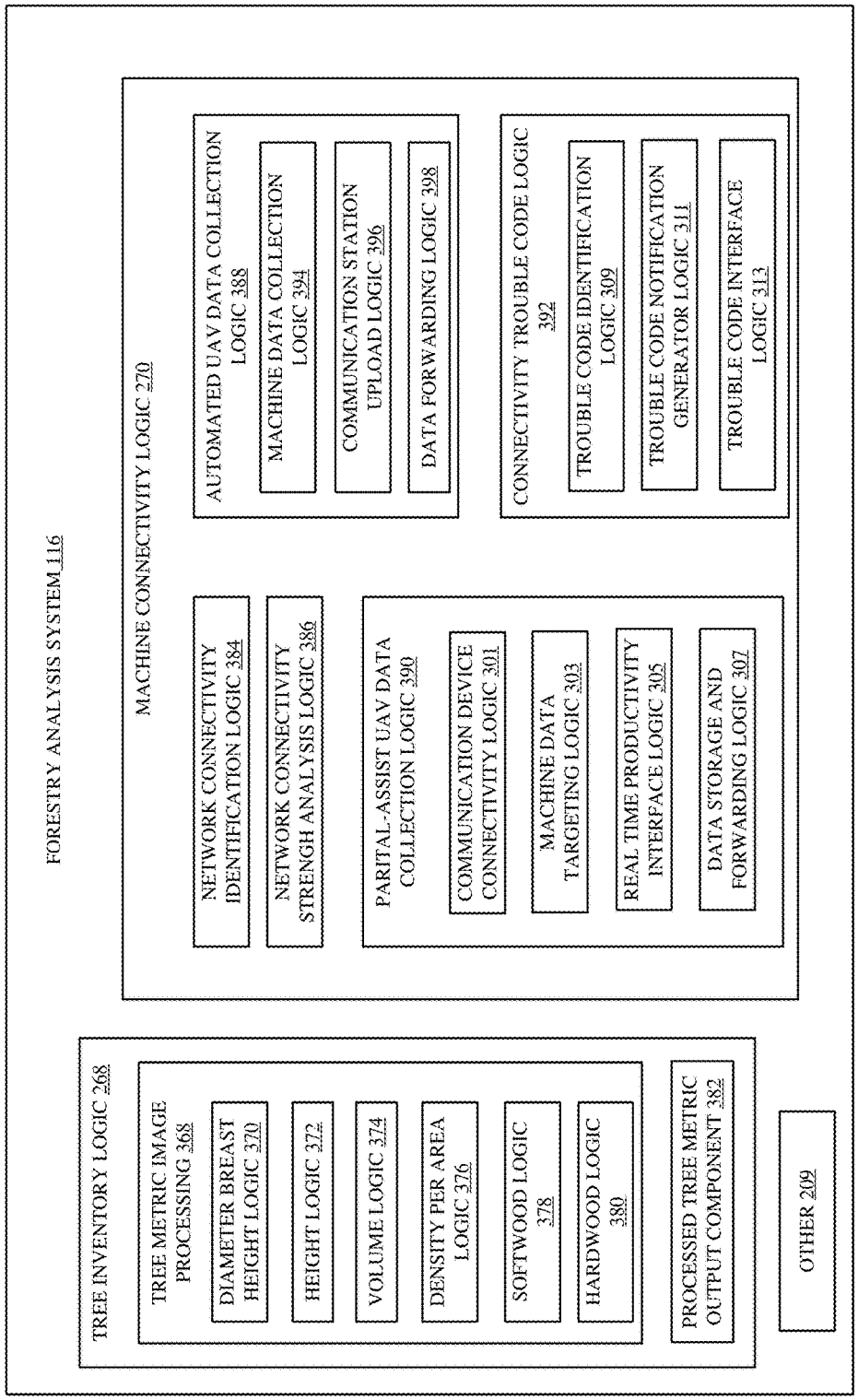

FORESTRY ANALYSIS SYSTEM 116
TREE INVENTORY LOGIC 268
TREE METRIC IMAGE PROCESSING 368
DIAMETER BREAST HEIGHT LOGIC 370
HEIGHT LOGIC 372
VOLUME LOGIC 374
DENSITY PER AREA LOGIC 376
SOFTWOOD LOGIC 378
HARDWOOD LOGIC 380
PROCESSED TREE METRIC OUTPUT COMPONENT 382
OTHER 209
MACHINE CONNECTIVITY LOGIC 270
NETWORK CONNECTIVITY IDENTIFICATION LOGIC 384
NETWORK CONNECTIVITY STRENGH ANALYSIS LOGIC 386
PARITAL-ASSIST UAV DATA COLLECTION LOGIC 390
COMMUNICATION DEVICE CONNECTIVITY LOGIC 301
MACHINE DATA TARGETING LOGIC 303
REAL TIME PRODUCTIVITY INTERFACE LOGIC 305
DATA STORAGE AND FORWARDING LOGIC 307
AUTOMATED UAV DATA COLLECTION LOGIC 388
MACHINE DATA COLLECTION LOGIC 394
COMMUNICATION STATION UPLOAD LOGIC 396
DATA FORWARDING LOGIC 398
CONNECTIVITY TROUBLE CODE LOGIC 392
TROUBLE CODE IDENTIFICATION LOGIC 309
TROUBLE CODE NOTIFICATION GENERATOR LOGIC 311
TROUBLE CODE INTERFACE LOGIC 313

FIG. 3B

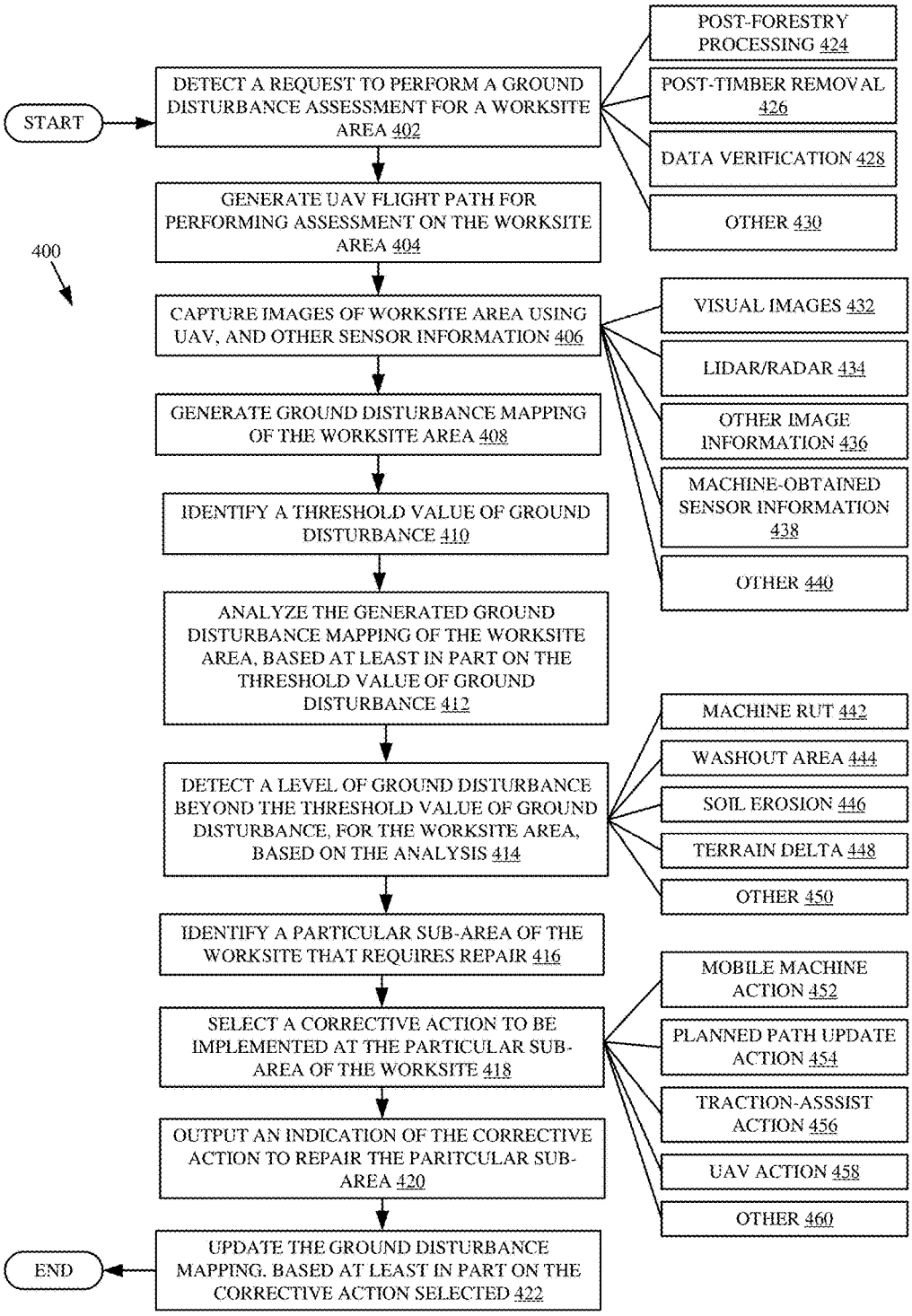

400
START
DETECT A REQUEST TO PERFORM A GROUND DISTURBANCE ASSESSMENT FOR A WORKSITE AREA 402
POST-FORESTRY PROCESSING 424
POST-TIMBER REMOVAL 426
DATA VERIFICATION 428
OTHER 430
GENERATE UAV FLIGHT PATH FOR PERFORMING ASSESSMENT ON THE WORKSITE AREA 404
CAPTURE IMAGES OF WORKSITE AREA USING UAV, AND OTHER SENSOR INFORMATION 406
VISUAL IMAGES 432
LIDAR/RADAR 434
OTHER IMAGE INFORMATION 436
MACHINE-OBTAINED SENSOR INFORMATION 438
OTHER 440
GENERATE GROUND DISTURBANCE MAPPING OF THE WORKSITE AREA 408
IDENTIFY A THRESHOLD VALUE OF GROUND DISTURBANCE 410
ANALYZE THE GENERATED GROUND DISTURBANCE MAPPING OF THE WORKSITE AREA, BASED AT LEAST IN PART ON THE THRESHOLD VALUE OF GROUND DISTURBANCE 412
DETECT A LEVEL OF GROUND DISTURBANCE BEYOND THE THRESHOLD VALUE OF GROUND DISTURBANCE, FOR THE WORKSITE AREA, BASED ON THE ANALYSIS 414
MACHINE RUT 442
WASHOUT AREA 444
SOIL EROSION 446
TERRAIN DELTA 448
OTHER 450
IDENTIFY A PARTICULAR SUB-AREA OF THE WORKSITE THAT REQUIRES REPAIR 416
SELECT A CORRECTIVE ACTION TO BE IMPLEMENTED AT THE PARTICULAR SUB-AREA OF THE WORKSITE 418
MOBILE MACHINE ACTION 452
PLANNED PATH UPDATE ACTION 454
TRACTION-ASSSIST ACTION 456
UAV ACTION 458
OTHER 460
OUTPUT AN INDICATION OF THE CORRECTIVE ACTION TO REPAIR THE PARITCULAR SUB-AREA 420
UPDATE THE GROUND DISTURBANCE MAPPING. BASED AT LEAST IN PART ON THE CORRECTIVE ACTION SELECTED 422
END

FIG. 4

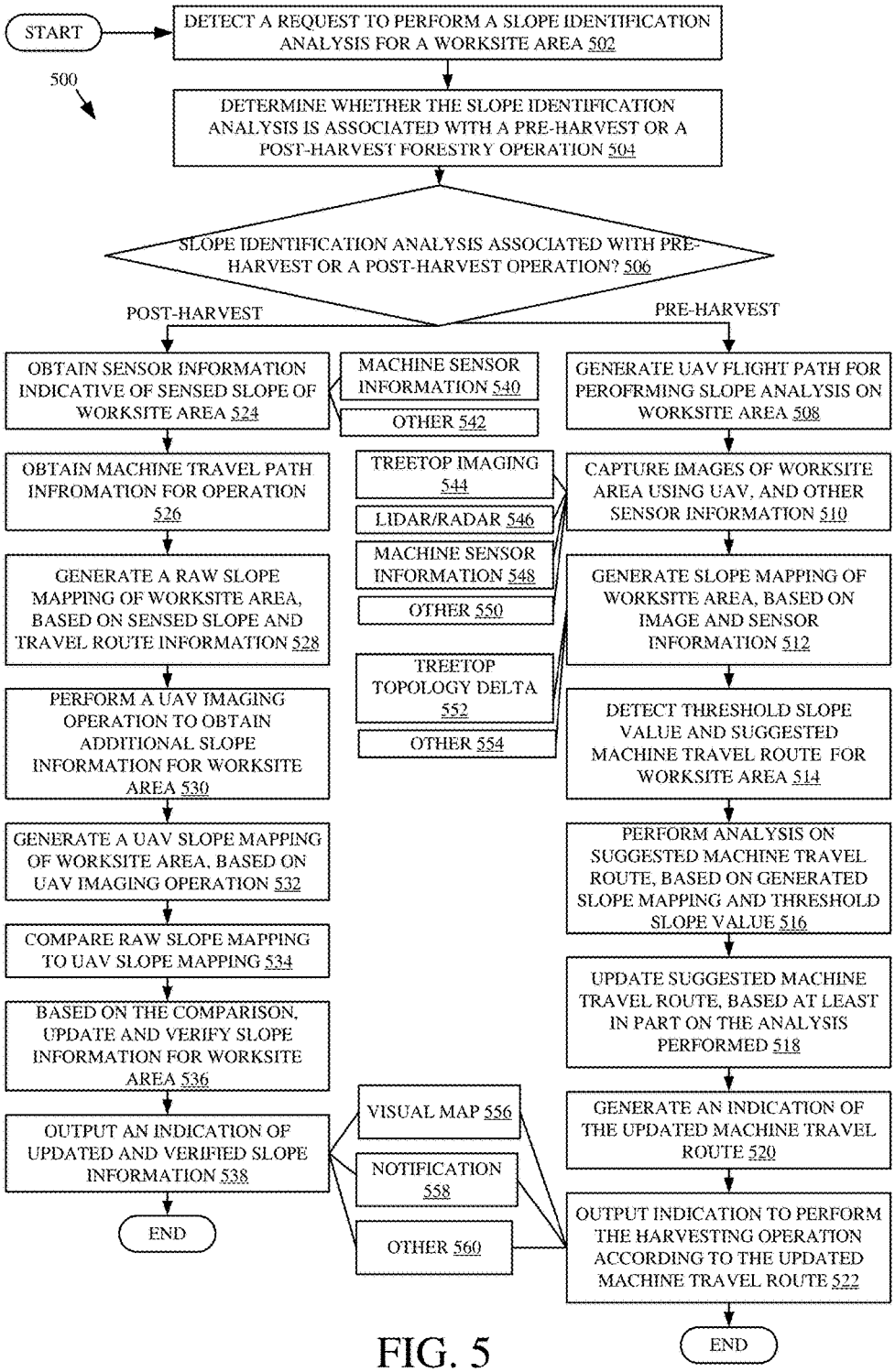

START
DETECT A REQUEST TO PERFORM A SLOPE IDENTIFICATION ANALYSIS FOR A WORKSITE AREA 502
500
DETERMINE WHETHER THE SLOPE IDENTIFICATION ANALYSIS IS ASSOCIATED WITH A PRE-HARVEST OR A POST-HARVEST FORESTRY OPERATION 504
SLOPE IDENTIFICATION ANALYSIS ASSOCIATED WITH PRE-HARVEST OR A POST-HARVEST OPERATION? 506
POST-HARVEST
PRE-HARVEST
OBTAIN SENSOR INFORMATION INDICATIVE OF SENSED SLOPE OF WORKSITE AREA 524
MACHINE SENSOR INFORMATION 540
OTHER 542
OBTAIN MACHINE TRAVEL PATH INFROMATION FOR OPERATION 526
GENERATE A RAW SLOPE MAPPING OF WORKSITE AREA, BASED ON SENSED SLOPE AND TRAVEL ROUTE INFORMATION 528
PERFORM A UAV IMAGING OPERATION TO OBTAIN ADDITIONAL SLOPE INFORMATION FOR WORKSITE AREA 530
GENERATE A UAV SLOPE MAPPING OF WORKSITE AREA, BASED ON UAV IMAGING OPERATION 532
COMPARE RAW SLOPE MAPPING TO UAV SLOPE MAPPING 534
BASED ON THE COMPARISON, UPDATE AND VERIFY SLOPE INFORMATION FOR WORKSITE AREA 536
OUTPUT AN INDICATION OF UPDATED AND VERIFIED SLOPE INFORMATION 538
END
TREETOP IMAGING 544
LIDAR/RADAR 546
MACHINE SENSOR INFORMATION 548
OTHER 550
TREETOP TOPOLOGY DELTA 552
OTHER 554
VISUAL MAP 556
NOTIFICATION 558
OTHER 560
GENERATE UAV FLIGHT PATH FOR PEROFRMING SLOPE ANALYSIS ON WORKSITE AREA 508
CAPTURE IMAGES OF WORKSITE AREA USING UAV, AND OTHER SENSOR INFORMATION 510
GENERATE SLOPE MAPPING OF WORKSITE AREA, BASED ON IMAGE AND SENSOR INFORMATION 512
DETECT THRESHOLD SLOPE VALUE AND SUGGESTED MACHINE TRAVEL ROUTE FOR WORKSITE AREA 514
PERFORM ANALYSIS ON SUGGESTED MACHINE TRAVEL ROUTE, BASED ON GENERATED SLOPE MAPPING AND THRESHOLD SLOPE VALUE 516
UPDATE SUGGESTED MACHINE TRAVEL ROUTE, BASED AT LEAST IN PART ON THE ANALYSIS PERFORMED 518
GENERATE AN INDICATION OF THE UPDATED MACHINE TRAVEL ROUTE 520
OUTPUT INDICATION TO PERFORM THE HARVESTING OPERATION ACCORDING TO THE UPDATED MACHINE TRAVEL ROUTE 522
END

FIG. 5

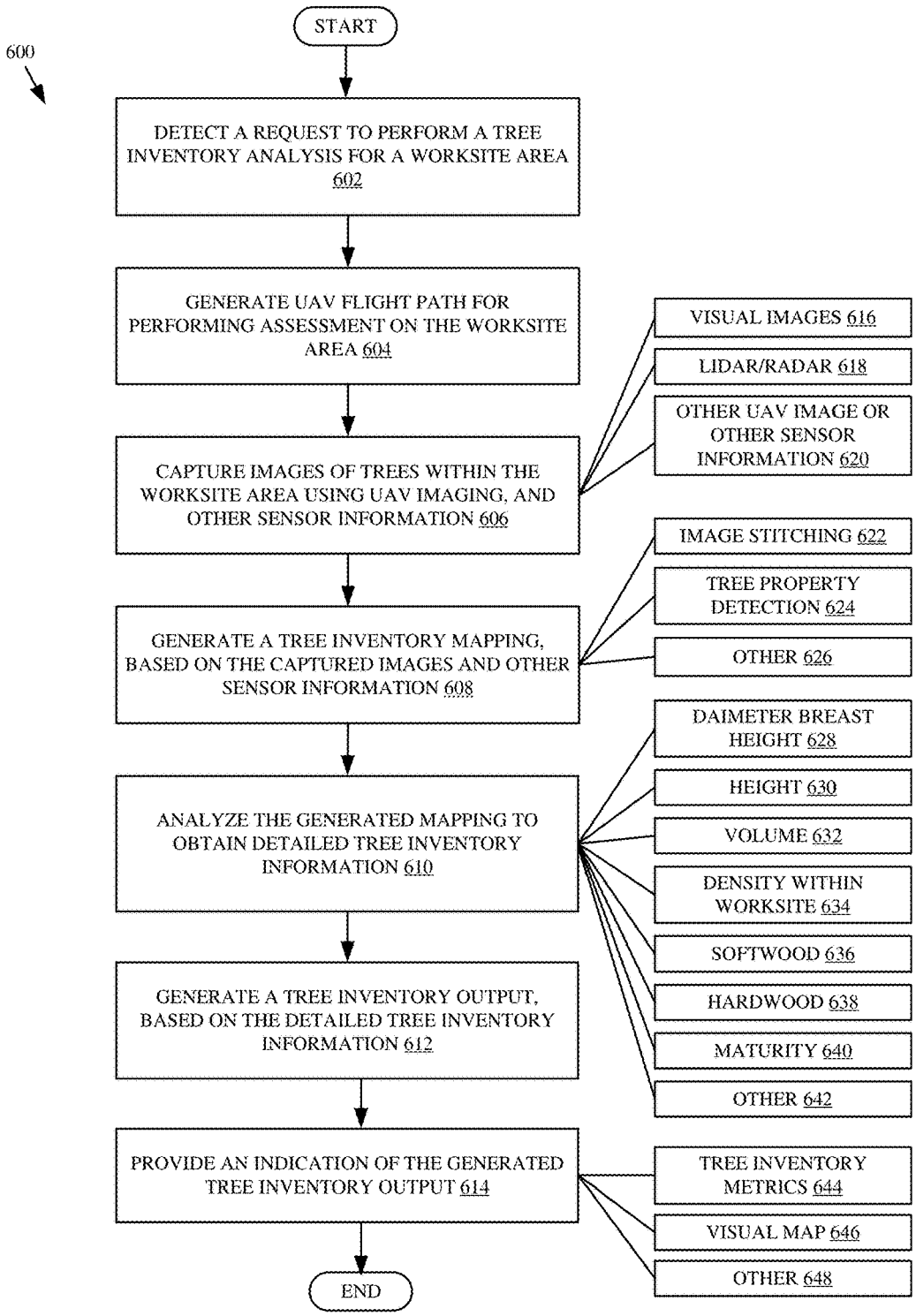

600
START
DETECT A REQUEST TO PERFORM A TREE INVENTORY ANALYSIS FOR A WORKSITE AREA 602
GENERATE UAV FLIGHT PATH FOR PERFORMING ASSESSMENT ON THE WORKSITE AREA 604
CAPTURE IMAGES OF TREES WITHIN THE WORKSITE AREA USING UAV IMAGING, AND OTHER SENSOR INFORMATION 606
VISUAL IMAGES 616
LIDAR/RADAR 618
OTHER UAV IMAGE OR OTHER SENSOR INFORMATION 620
GENERATE A TREE INVENTORY MAPPING, BASED ON THE CAPTURED IMAGES AND OTHER SENSOR INFORMATION 608
IMAGE STITCHING 622
TREE PROPERTY DETECTION 624
OTHER 626
ANALYZE THE GENERATED MAPPING TO OBTAIN DETAILED TREE INVENTORY INFORMATION 610
DAIMETER BREAST HEIGHT 628
HEIGHT 630
VOLUME 632
DENSITY WITHIN WORKSITE 634
SOFTWOOD 636
HARDWOOD 638
MATURITY 640
OTHER 642
GENERATE A TREE INVENTORY OUTPUT, BASED ON THE DETAILED TREE INVENTORY INFORMATION 612
PROVIDE AN INDICATION OF THE GENERATED TREE INVENTORY OUTPUT 614
TREE INVENTORY METRICS 644
VISUAL MAP 646
OTHER 648
END

FIG. 6

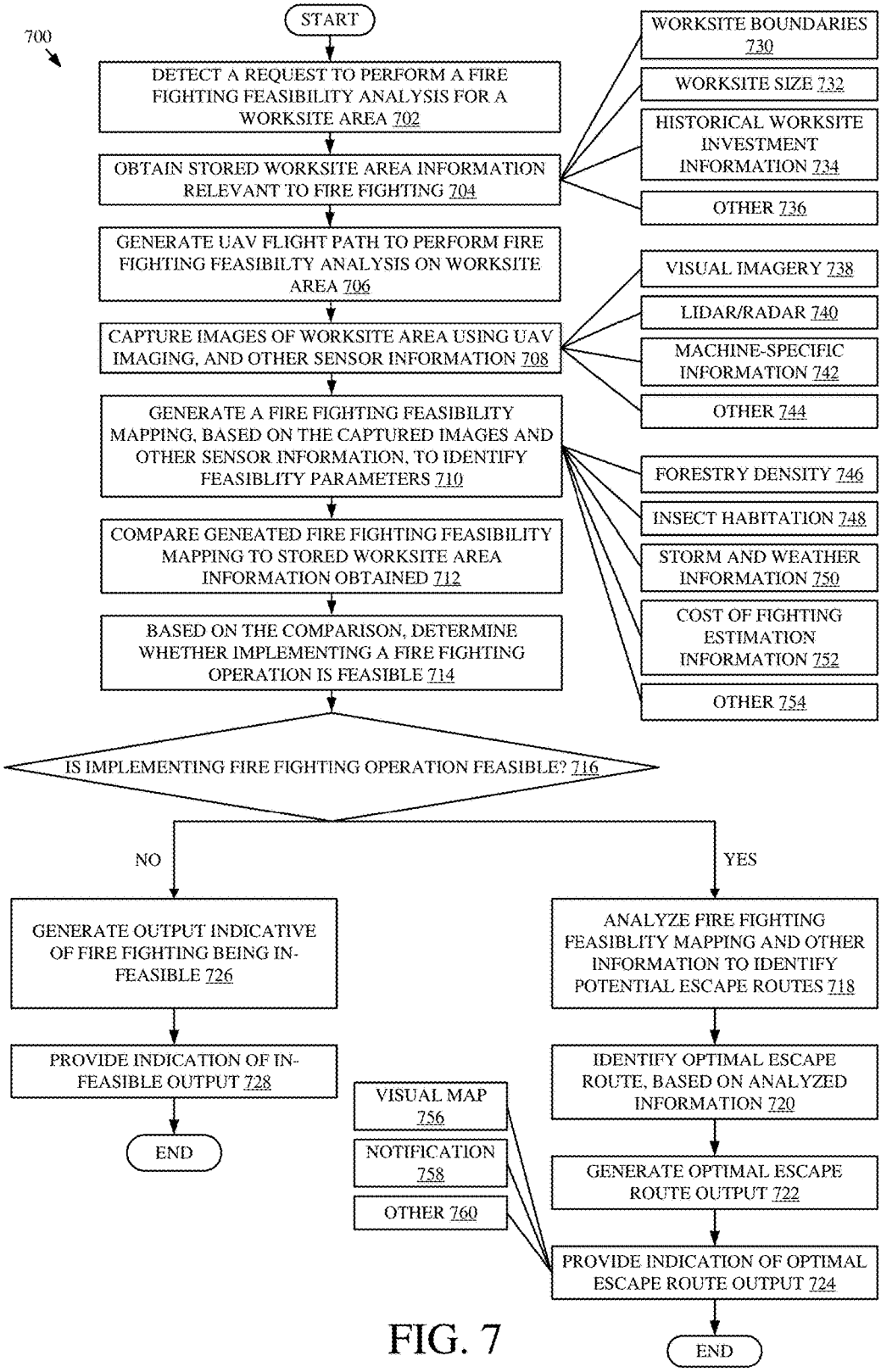

700
START
DETECT A REQUEST TO PERFORM A FIRE FIGHTING FEASIBILITY ANALYSIS FOR A WORKSITE AREA 702
OBTAIN STORED WORKSITE AREA INFORMATION RELEVANT TO FIRE FIGHTING 704
GENERATE UAV FLIGHT PATH TO PERFORM FIRE FIGHTING FEASIBILTY ANALYSIS ON WORKSITE AREA 706
CAPTURE IMAGES OF WORKSITE AREA USING UAV IMAGING, AND OTHER SENSOR INFORMATION 708
GENERATE A FIRE FIGHTING FEASIBILITY MAPPING, BASED ON THE CAPTURED IMAGES AND OTHER SENSOR INFORMATION, TO IDENTIFY FEASIBLITY PARAMETERS 710
COMPARE GENEATED FIRE FIGHTING FEASIBILITY MAPPING TO STORED WORKSITE AREA INFORMATION OBTAINED 712
BASED ON THE COMPARISON, DETERMINE WHETHER IMPLEMENTING A FIRE FIGHTING OPERATION IS FEASIBLE 714
WORKSITE BOUNDARIES 730
WORKSITE SIZE 732
HISTORICAL WORKSITE INVESTMENT INFORMATION 734
OTHER 736
VISUAL IMAGERY 738
LIDAR/RADAR 740
MACHINE-SPECIFIC INFORMATION 742
OTHER 744
FORESTRY DENSITY 746
INSECT HABITATION 748
STORM AND WEATHER INFORMATION 750
COST OF FIGHTING ESTIMATION INFORMATION 752
OTHER 754
IS IMPLEMENTING FIRE FIGHTING OPERATION FEASIBLE? 716
NO
YES
GENERATE OUTPUT INDICATIVE OF FIRE FIGHTING BEING IN-FEASIBLE 726
PROVIDE INDICATION OF IN-FEASIBLE OUTPUT 728
END
ANALYZE FIRE FIGHTING FEASIBLITY MAPPING AND OTHER INFORMATION TO IDENTIFY POTENTIAL ESCAPE ROUTES 718
IDENTIFY OPTIMAL ESCAPE ROUTE, BASED ON ANALYZED INFORMATION 720
GENERATE OPTIMAL ESCAPE ROUTE OUTPUT 722
PROVIDE INDICATION OF OPTIMAL ESCAPE ROUTE OUTPUT 724
VISUAL MAP 756
NOTIFICATION 758
OTHER 760
END

FIG. 7

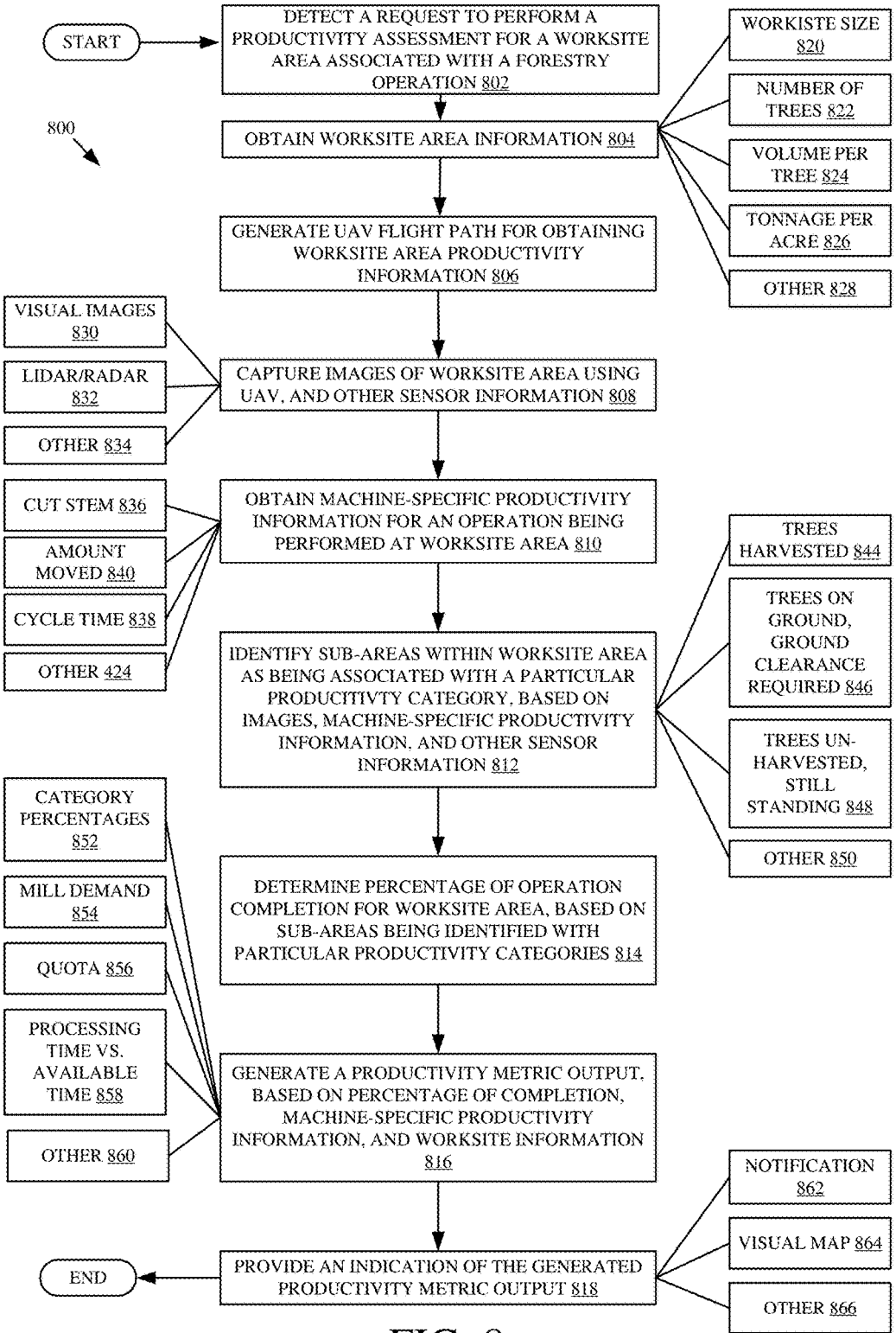

START
DETECT A REQUEST TO PERFORM A PRODUCTIVITY ASSESSMENT FOR A WORKSITE AREA ASSOCIATED WITH A FORESTRY OPERATION 802
800
OBTAIN WORKSITE AREA INFORMATION 804
WORKISTE SIZE 820
NUMBER OF TREES 822
VOLUME PER TREE 824
TONNAGE PER ACRE 826
OTHER 828
GENERATE UAV FLIGHT PATH FOR OBTAINING WORKSITE AREA PRODUCTIVITY INFORMATION 806
VISUAL IMAGES 830
LIDAR/RADAR 832
OTHER 834
CAPTURE IMAGES OF WORKSITE AREA USING UAV, AND OTHER SENSOR INFORMATION 808
CUT STEM 836
AMOUNT MOVED 840
CYCLE TIME 838
OTHER 424
OBTAIN MACHINE-SPECIFIC PRODUCTIVITY INFORMATION FOR AN OPERATION BEING PERFORMED AT WORKSITE AREA 810
TREES HARVESTED 844
TREES ON GROUND, GROUND CLEARANCE REQUIRED 846
TREES UN-HARVESTED, STILL STANDING 848
OTHER 850
IDENTIFY SUB-AREAS WITHIN WORKSITE AREA AS BEING ASSOCIATED WITH A PARTICULAR PRODUCTITVTY CATEGORY, BASED ON IMAGES, MACHINE-SPECIFIC PRODUCTIVITY INFORMATION, AND OTHER SENSOR INFORMATION 812
CATEGORY PERCENTAGES 852
MILL DEMAND 854
QUOTA 856
PROCESSING TIME VS. AVAILABLE TIME 858
OTHER 860
DETERMINE PERCENTAGE OF OPERATION COMPLETION FOR WORKSITE AREA, BASED ON SUB-AREAS BEING IDENTIFIED WITH PARTICULAR PRODUCTIVITY CATEGORIES 814
GENERATE A PRODUCTIVITY METRIC OUTPUT, BASED ON PERCENTAGE OF COMPLETION, MACHINE-SPECIFIC PRODUCTIVITY INFORMATION, AND WORKSITE INFORMATION 816
NOTIFICATION 862
VISUAL MAP 864
OTHER 866
PROVIDE AN INDICATION OF THE GENERATED PRODUCTIVITY METRIC OUTPUT 818
END

FIG. 8

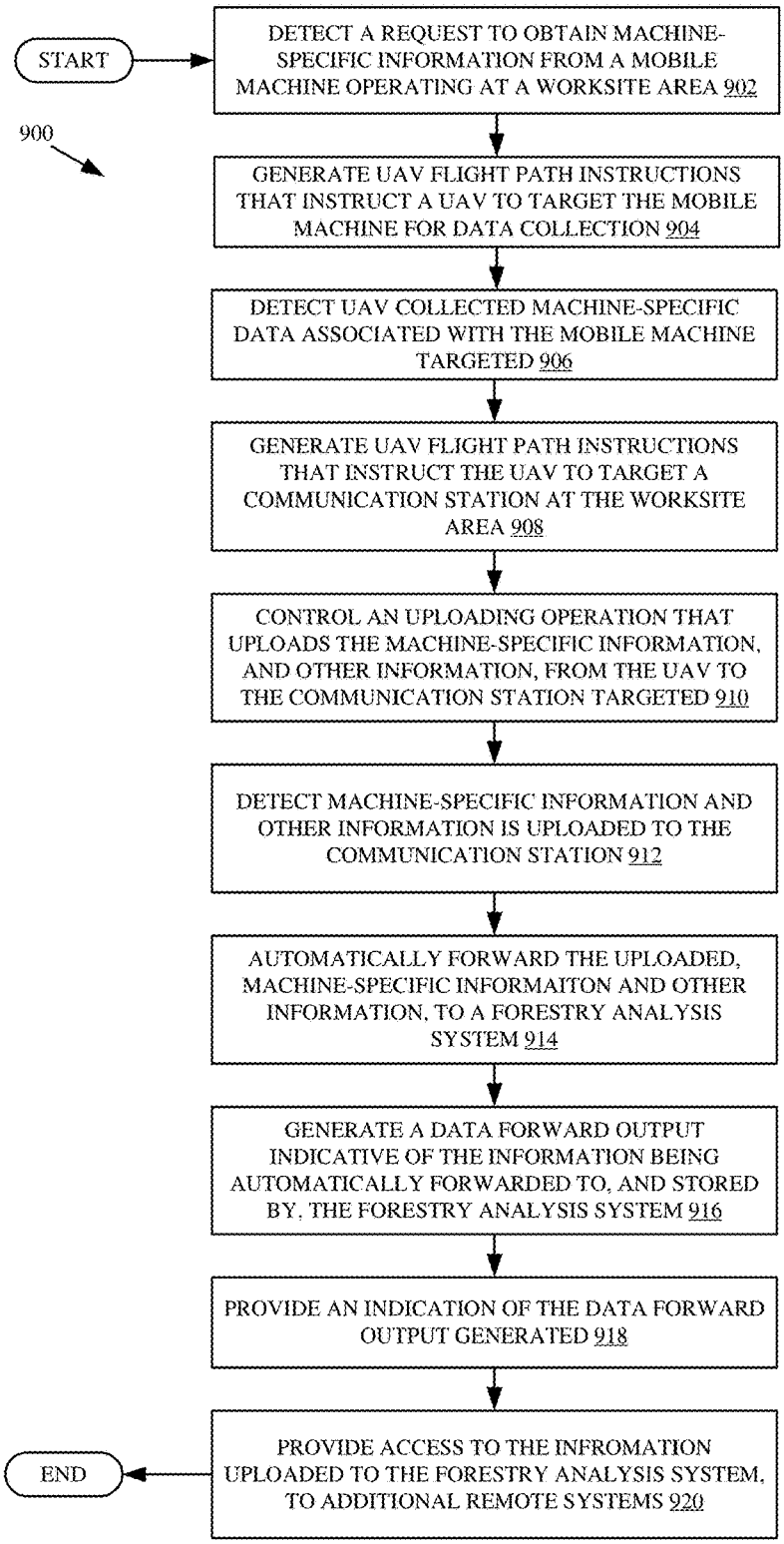

START
900
DETECT A REQUEST TO OBTAIN MACHINE-SPECIFIC INFORMATION FROM A MOBILE MACHINE OPERATING AT A WORKSITE AREA 902
GENERATE UAV FLIGHT PATH INSTRUCTIONS THAT INSTRUCT A UAV TO TARGET THE MOBILE MACHINE FOR DATA COLLECTION 904
DETECT UAV COLLECTED MACHINE-SPECIFIC DATA ASSOCIATED WITH THE MOBILE MACHINE TARGETED 906
GENERATE UAV FLIGHT PATH INSTRUCTIONS THAT INSTRUCT THE UAV TO TARGET A COMMUNICATION STATION AT THE WORKSITE AREA 908
CONTROL AN UPLOADING OPERATION THAT UPLOADS THE MACHINE-SPECIFIC INFORMATION, AND OTHER INFORMATION, FROM THE UAV TO THE COMMUNICATION STATION TARGETED 910
DETECT MACHINE-SPECIFIC INFORMATION AND OTHER INFORMATION IS UPLOADED TO THE COMMUNICATION STATION 912
AUTOMATICALLY FORWARD THE UPLOADED, MACHINE-SPECIFIC INFORMAITON AND OTHER INFORMATION, TO A FORESTRY ANALYSIS SYSTEM 914
GENERATE A DATA FORWARD OUTPUT INDICATIVE OF THE INFORMATION BEING AUTOMATICALLY FORWARDED TO, AND STORED BY, THE FORESTRY ANALYSIS SYSTEM 916
PROVIDE AN INDICATION OF THE DATA FORWARD OUTPUT GENERATED 918
PROVIDE ACCESS TO THE INFROMATION UPLOADED TO THE FORESTRY ANALYSIS SYSTEM, TO ADDITIONAL REMOTE SYSTEMS 920
END

FIG. 9

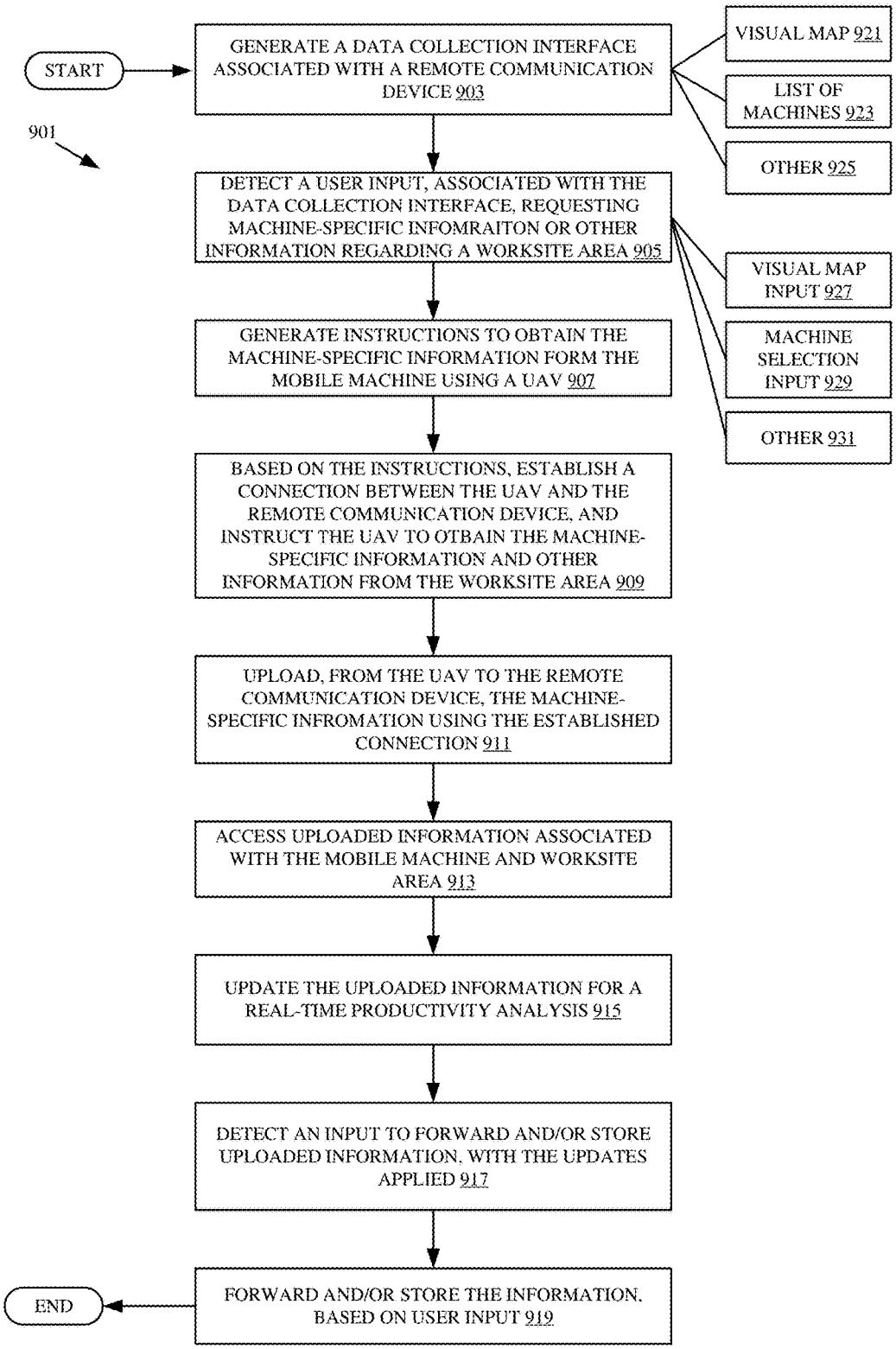

START
901
GENERATE A DATA COLLECTION INTERFACE ASSOCIATED WITH A REMOTE COMMUNICATION DEVICE 903
VISUAL MAP 921
LIST OF MACHINES 923
OTHER 925
DETECT A USER INPUT, ASSOCIATED WITH THE DATA COLLECTION INTERFACE, REQUESTING MACHINE-SPECIFIC INFOMRAITON OR OTHER INFORMATION REGARDING A WORKSITE AREA 905
VISUAL MAP INPUT 927
MACHINE SELECTION INPUT 929
OTHER 931
GENERATE INSTRUCTIONS TO OBTAIN THE MACHINE-SPECIFIC INFORMATION FORM THE MOBILE MACHINE USING A UAV 907
BASED ON THE INSTRUCTIONS, ESTABLISH A CONNECTION BETWEEN THE UAV AND THE REMOTE COMMUNICATION DEVICE, AND INSTRUCT THE UAV TO OTBAIN THE MACHINE-SPECIFIC INFORMATION AND OTHER INFORMATION FROM THE WORKSITE AREA 909
UPLOAD, FROM THE UAV TO THE REMOTE COMMUNICATION DEVICE, THE MACHINE-SPECIFIC INFROMATION USING THE ESTABLISHED CONNECTION 911
ACCESS UPLOADED INFORMATION ASSOCIATED WITH THE MOBILE MACHINE AND WORKSITE AREA 913
UPDATE THE UPLOADED INFORMATION FOR A REAL-TIME PRODUCTIVITY ANALYSIS 915
DETECT AN INPUT TO FORWARD AND/OR STORE UPLOADED INFORMATION, WITH THE UPDATES APPLIED 917
FORWARD AND/OR STORE THE INFORMATION, BASED ON USER INPUT 919
END

FIG. 10

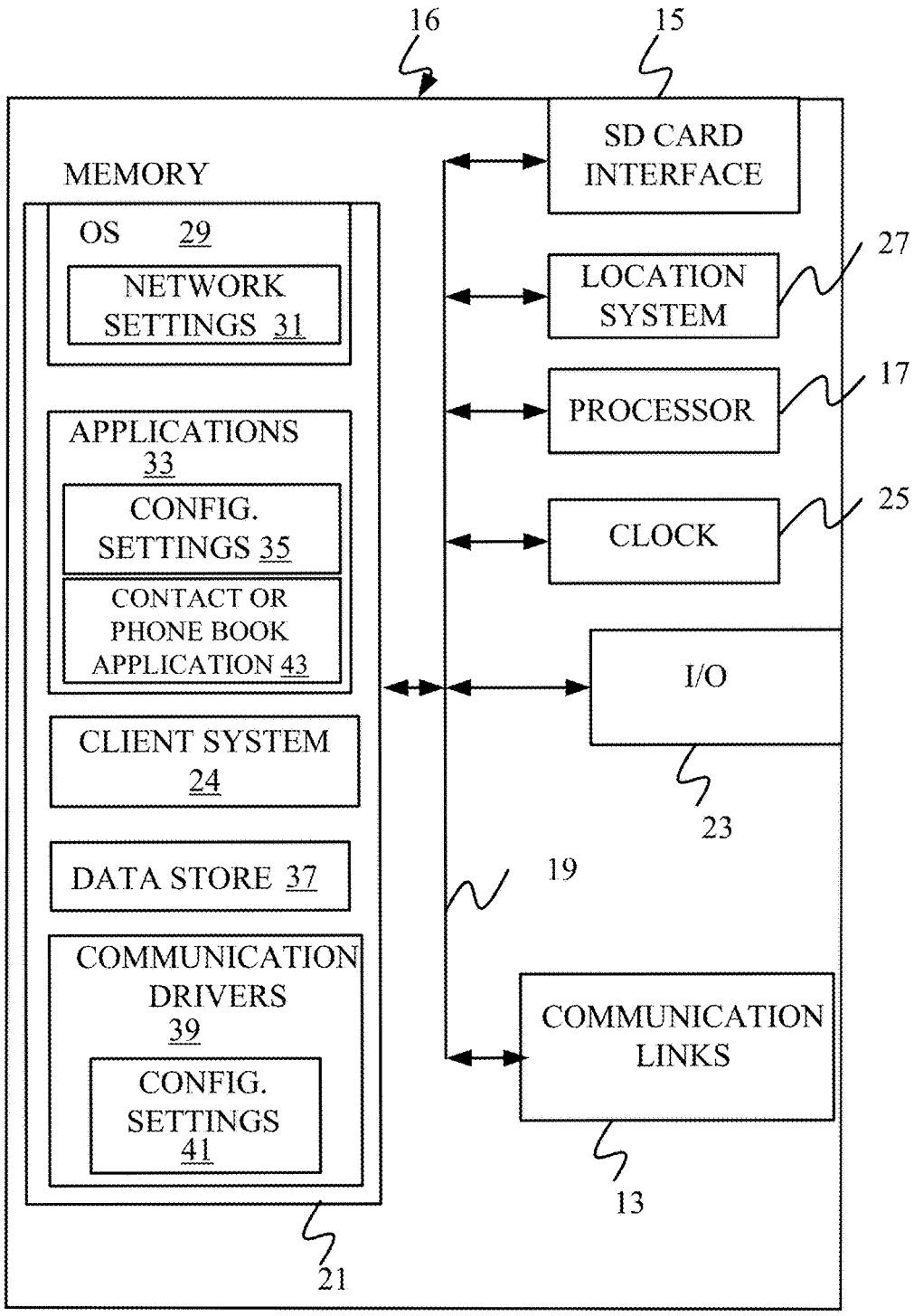

16
15
SD CARD INTERFACE
MEMORY
OS 29
NETWORK SETTINGS 31
27
LOCATION SYSTEM
17
PROCESSOR
APPLICATIONS 33
CONFIG. SETTINGS 35
25
CLOCK
CONTACT OR PHONE BOOK APPLICATION 43
I/O
CLIENT SYSTEM 24
23
19
DATA STORE 37
COMMUNICATION DRIVERS 39
CONFIG. SETTINGS 41
COMMUNICATION LINKS
13
21

FIG. 11

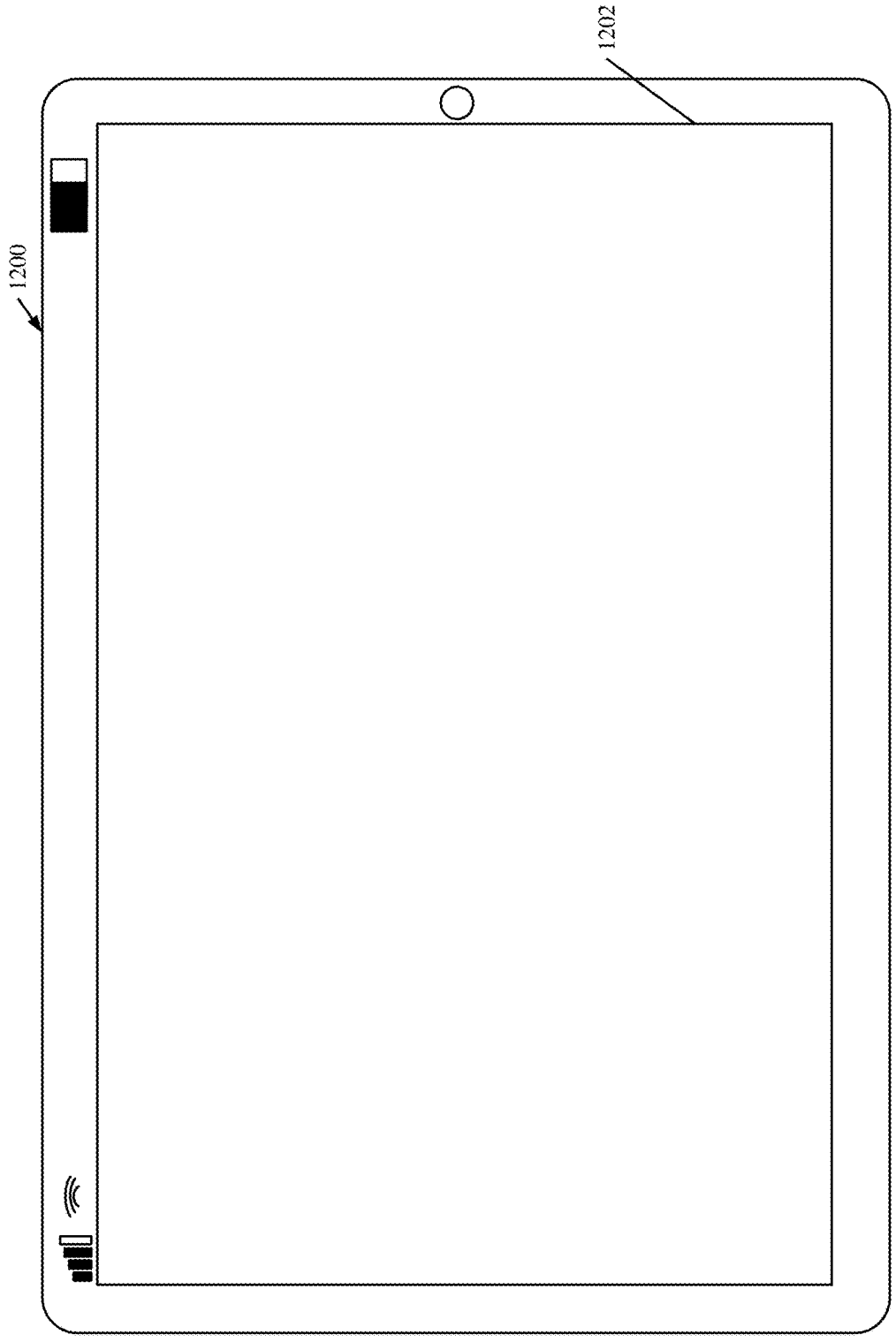


FIG. 12

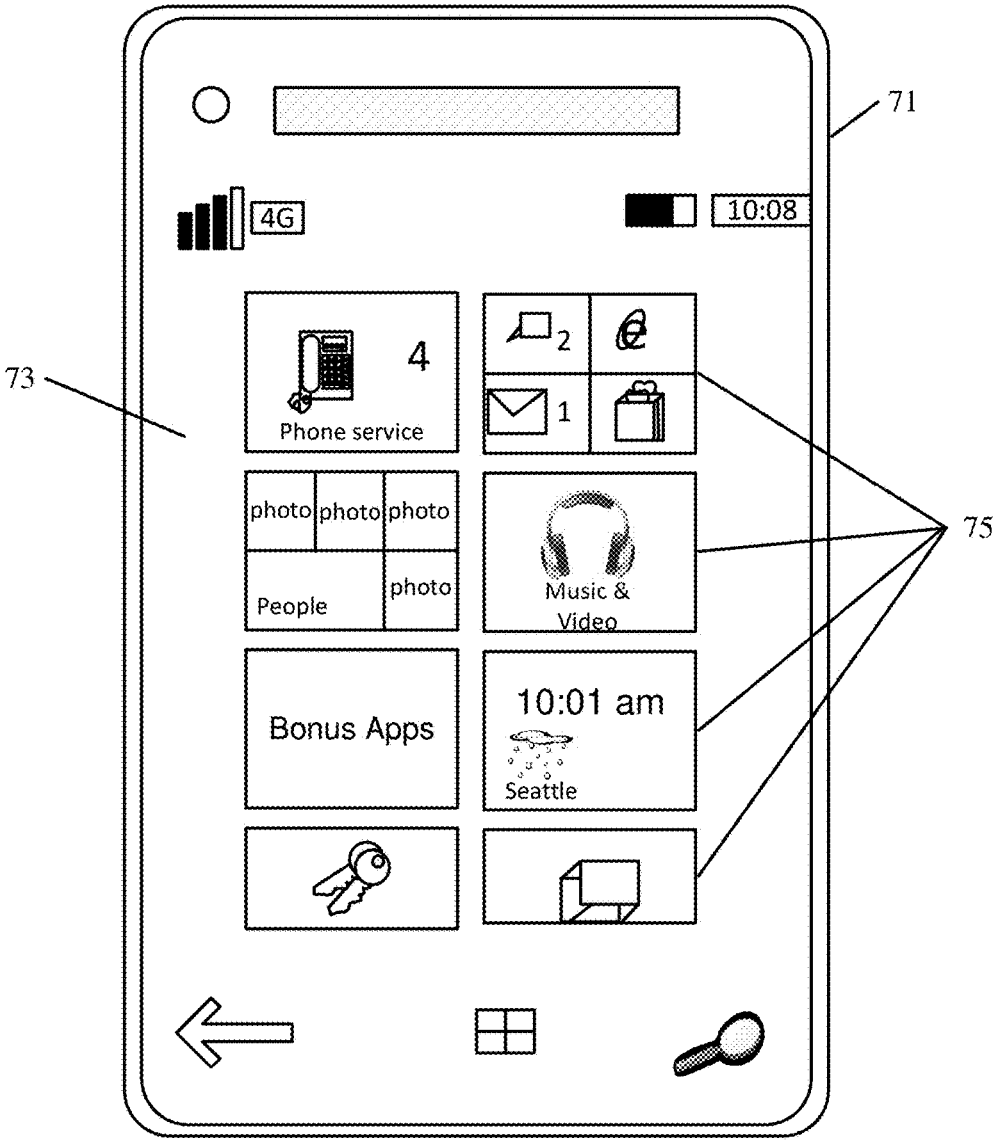

71
4G
10:08
73
4
Phone service
2
1
75
photo
photo
photo
People
photo
Music &
Video
Bonus Apps
10:01 am
Seattle

FIG. 13

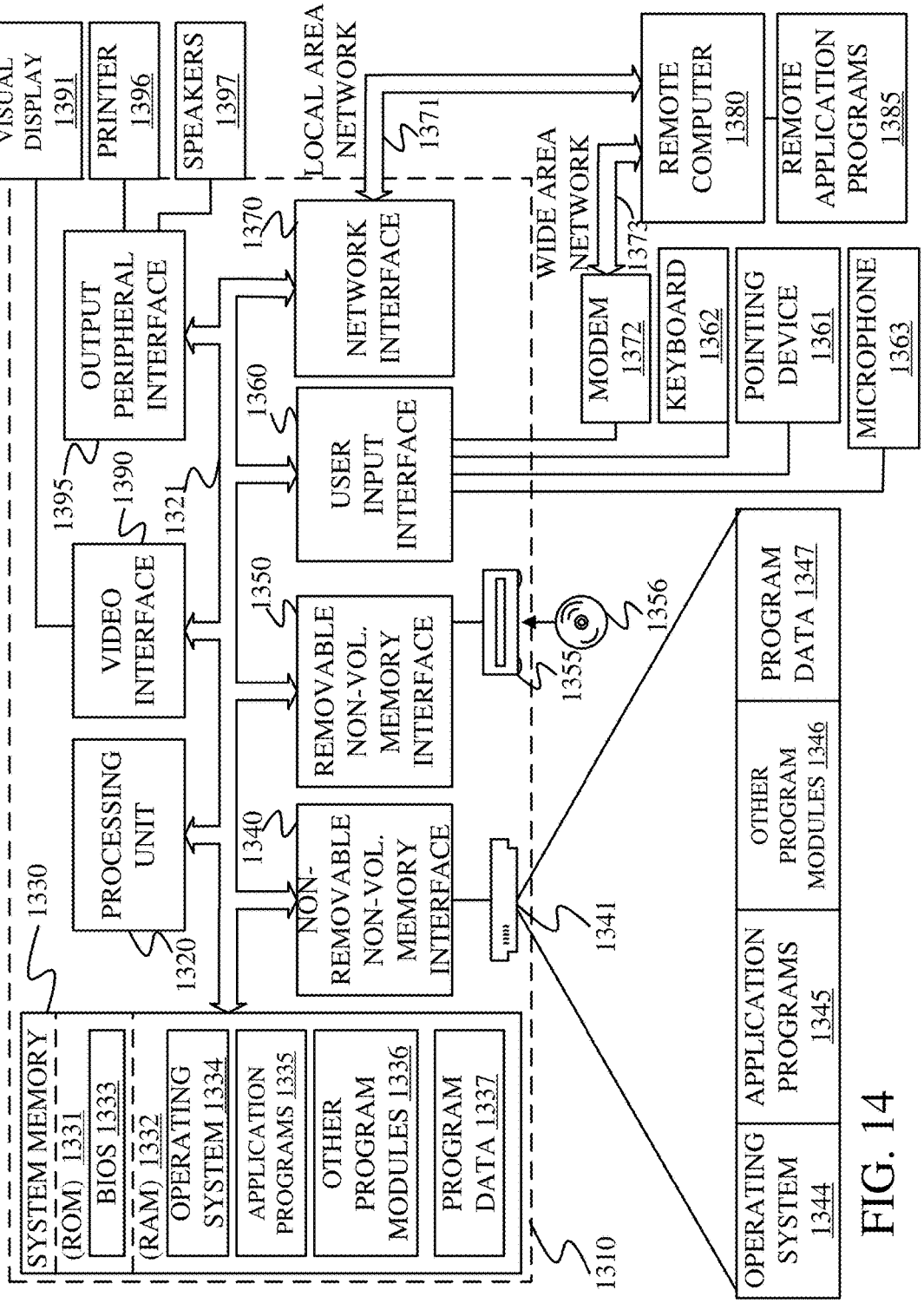

VISUAL DISPLAY 1391
PRINTER 1396
SPEAKERS 1397
LOCAL AREA NETWORK
1371
OUTPUT PERIPHERAL INTERFACE
NETWORK INTERFACE
1370
1360
1395
1390
1321
VIDEO INTERFACE
USER INPUT INTERFACE
WIDE AREA NETWORK
MODEM 1372
KEYBOARD 1362
POINTING DEVICE 1361
MICROPHONE 1363
REMOTE COMPUTER 1380
REMOTE APPLICATION PROGRAMS 1385
1373
1350
REMOVABLE NON-VOL. MEMORY INTERFACE
1340
NON-REMOVABLE NON-VOL. MEMORY INTERFACE
PROCESSING UNIT
1320
1330
SYSTEM MEMORY (ROM) 1331
BIOS 1333
(RAM) 1332
OPERATING SYSTEM 1334
APPLICATION PROGRAMS 1335
OTHER PROGRAM MODULES 1336
PROGRAM DATA 1337
1310
1341
1355
1356
OPERATING SYSTEM 1344
APPLICATION PROGRAMS 1345
OTHER PROGRAM MODULES 1346
PROGRAM DATA 1347

FIG. 14

USING UNMANNED AERIAL VEHICLES (UAVS OR DRONES) IN FORESTRY PRODUCTIVITY AND CONTROL APPLICATIONS

CROSS-REFERENCE TO RELATED APPLICATION

The present application is based on and claims the benefit of U.S. provisional patent application Ser. No. 62/565,863, filed Sep. 29, 2017, the content of which is hereby incorporated by reference in its entirety.

FIELD OF THE DESCRIPTION

The present description relates to the use of drones in forestry applications. More specifically, the present description relates to the use of drones in improving performance and data analysis for forestry applications within a variety of worksite operations.

BACKGROUND

There are a wide variety of different types of equipment, such as construction equipment, turf care equipment, agricultural equipment, and forestry equipment. These types of equipment are often operated by an operator and are communicatively connected to other machines.

Forestry equipment can include a wide variety of machines such as harvesters, skidders, feller bunchers, forwarders, and swing machines, among others. Forestry equipment can be operated by an operator, and have many different mechanisms that are controlled by the operator in performing an operation. The equipment may have multiple different mechanical, electrical, hydraulic, pneumatic, electromechanical (and other) subsystems, some or all of which can be controlled, at least to some extent, by the operator.

Current systems may experience difficulty in acquiring information, communicating the acquired information with other machines, and utilizing the acquired information to control machines so as to improve performance of machines to increase productivity measures of forestry operations. These difficulties experienced by current forestry systems can be exacerbated because of the complex nature of forestry operations, including complex terrain and environmental conditions of forestry worksites.

The discussion above is merely provided for general background information and is not intended to be used as an aid in determining the scope of the claimed subject matter.

SUMMARY

A method includes generating an unmanned aerial vehicle (UAV) control signal to fly the UAV over a worksite and capture imagery information at different geographic locations. The imagery information is used to generate a tree inventory metric that indicates a tree inventory at the worksite, or is used to generate a productivity metric that identifies a productivity category for a geographic location at the worksite. The method also generates an action signal based on the tree inventory metric or productivity metric, such as an action signal to deploy machines to different geographic location, or an action signal to update a worksite completion metric.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. The claimed subject matter is not limited to implementations that solve any or all disadvantages noted in the background.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a pictorial illustration of a worksite using a forestry analysis system with drones.

FIGS. **2**A and **2**B (collectively referred to herein as FIG. **2**) show a block diagram of one example of a computing architecture that includes the forestry analysis system illustrated in FIG. **1**.

FIG. **3**A is a block diagram of one example of a portion of the forestry analysis system illustrated in FIG. **1** in further detail.

FIG. **3**B is a block diagram of one example of a portion of the forestry analysis system illustrated in FIG. **1** in further detail.

FIG. **4** illustrates a flow diagram showing one example of controlling a UAV to perform a ground disturbance assessment.

FIG. **5** illustrates a flow diagram showing one example of controlling a UAV to perform a slope identification analysis.

FIG. **6** illustrates a flow diagram showing one example of controlling a UAV to perform a tree inventory analysis for a worksite area.

FIG. **7** illustrates a flow diagram showing one example of controlling a UAV to perform a fire-fighting feasibility analysis for a worksite area.

FIG. **8** illustrates a flow diagram showing one example of controlling a UAV to perform a productivity and control assessment for a worksite area associated with a forestry operation.

FIG. **9** illustrates a flow diagram showing one example of controlling a UAV to perform automatically obtain machine-specific information of a mobile machine operating in a worksite area.

FIG. **10** illustrates a flow diagram showing one example of controlling a UAV to obtain machine-specific information of a mobile machine operating in a worksite by using user input.

FIGS. **11-13** show examples of mobile devices that can be used in the architectures shown in the previous figures.

FIG. **14** is a block diagram showing one example of a computing environment that can be used in the architectures shown in the previous figures.

DETAILED DESCRIPTION

A wide variety of different forestry operations can be performed within a worksite. Some example forestry operations include preparing a worksite, gathering information about the worksite, harvesting a planted material, fighting a fire, and repairing damage to the environment, among others. Many such forestry operations utilize machinery that can perform a variety of functions.

Forestry machines (also referred to herein as a machine, a mobile machine, and a vehicle) often have a wide variety of sensors that sense a variety of different variables such as machine operating parameters, worksite characteristics, environmental parameters, etc. Sensor signals are communicated over a controller area network (CAN) bus (or another network, such as an Ethernet network, WiFi etc.) to various systems that process the sensed variables to generate

output signals (such as control signals or other outputs) based on the sensed variables.

However, it might be difficult for some current forestry systems to not only obtain accurate and valuable sensed variables, but to also analyze the sensed variables along with other worksite information to produce meaningful results. Further, it might be difficult for some systems to use the analyzed information to improve worksite productivity. There are a variety of different factors that can exacerbate this difficulty for forestry operations.

One particular factor that makes it especially difficult for some current forestry systems to obtain and utilize information is the widely varying characteristics of forestry worksites themselves. For example, forestry worksites often have characteristics such as a high density of trees and other vegetation, large differences in topology such as steep, naturally-occurring slopes, and areas of ruts or soil erosion (e.g., large ruts produced by operation of heavy machinery). Also, forestry worksites are often large, spanning hundreds or thousands of acres. These and other forestry worksite characteristics make it difficult for land vehicles to traverse the area when performing an operation or otherwise attempting to obtain valuable information for the worksite.

To further illustrate these difficulties, a brief overview of several example forestry operations will be provided below. A forestry harvesting operation, for example, can be difficult when a feller buncher is operating parallel to a steep slope and experiences a loss of traction. In such a situation, it might be valuable to obtain and analyze worksite slope information that can be used to better control the feller buncher and reduce slippage experienced by the vehicle. As another example, a feller buncher might be less productive (e.g., take more time to harvest an area) if it starts harvesting at an area having a high density of tree population, compared to if it starts harvesting at an area of less density. Similarly, a machine might have difficulty traversing a worksite or efficiently performing an operation if it follows a travel route over laid trees (e.g., cut trees that have not been moved from the worksite area and are laying on the ground). Thus, it might be valuable for forestry systems to obtain and utilize tree inventory information as well as worksite productivity information such as the level of completeness of specific worksite areas.

In another example situation, a contractor might remove machines from the worksite when a harvesting or other operation is complete. However, the worksite might have damage from the machines that is not easily detected in some current systems. In this example, machines will then be transported back to the worksite (to repair the damage), which costs the contractor time and money. In view of this, it might be beneficial to obtain and utilize information about ground disturbance caused by the machines.

It might also be difficult for some current systems to determine whether a forest fire within a worksite is worth fighting. For instance, characteristics of the environment in and around the worksite such as insect habitation and information about the feasibility of performing a fire fighting operation may bear on whether the fire should be fought at that location. This type of information can be valuable in making fire fighting decisions.

Another factor that makes it especially difficult for some current forestry systems to obtain and utilize information is the geographic location of forestry worksites themselves. Forestry worksites are often located in remote areas, distant from populated cities or towns, and are therefore remote from cellular connectivity towers or other communication stations. Because of this, it can be especially difficult to collect and share valuable data for the worksite. For example, it can be difficult to obtain valuable information (e.g., sensor information) from machines operating on the ground. Once the information is obtained from the machines, it can also be difficult to forward the data to an analysis service or storage location (e.g., a cloud storage service provider via a satellite connection), or otherwise provide an operator with the data. That is, even if the information is obtained, some current systems face difficulties in providing the data to a system for analysis such that the analyzed data can be used to assist an operator, for instance, in making management decisions for the forestry worksite.

An additional factor that makes it especially difficult for some current forestry systems to obtain and utilize information to improve productivity is the complex nature of the control operations needed to operate a machine. For example, it might be beneficial for some control operations to be automated or semi-automated processes that are generated by considering information about, for example, the worksite, the machine, and the environment. These complications can make it very difficult to optimize performance of forestry machines for improving productivity of a forestry worksite operation.

To address at least some of these and other difficulties faced within forestry worksites, the present description provides a forestry analysis system. As will be discussed in further detail below, one example forestry analysis system addresses these challenges by controlling an unmanned aerial vehicle (UAV) to obtain images of a worksite along with other valuable information (e.g., machine-specific sensor information), such that the forestry analysis system can generate outputs, based on the images and other information, to control machines or otherwise influence operations within the worksite.

FIG. **1** is a pictorial illustration **100** of a worksite **102** having a worksite area **106** that includes one or more mobile machine(s) **108** operating to perform one or more forestry operations. FIG. **1** illustratively shows that UAV **104** includes an image capture component **122**. UAV **104** travels along a flight path within worksite **102** and uses image capture component **122** (and other sensors) to capture images (and other sensor information). Image capture component **122** can capture information indicative of worksite area **106** and mobile machines **108**. UAV **104** is also configured to communicate with mobile machines **108** to obtain sensor information sensed by sensors positioned on each of the machines (e.g., machine-specific sensor information). Once UAV **104** has obtained the imaging information and/or the machine-specific sensor information, UAV **104** can communicate with a communication station **110** and a communication device **114** to store the information and forward the information to a forestry analysis system **116**. Forestry analysis system **116** receives the information and is generally configured to perform data analysis on the information. Based on the analyses performed, forestry analysis system **116** generates outputs that can control communication device **114**, communication station **110**, UAV **104**, and mobile machine **108**, or otherwise represent the analyzed information, such as by generating a user interface for interaction by operator **112**. Worksite **102** also illustratively includes additional worksites **118** and one or more additional remote systems **120**.

FIGS. **2**A and **2**B (collectively referred to herein as FIG. **2**) show a block diagram of one example of a forestry computing architecture **200** that includes forestry analysis system **116** illustrated in FIG. **1**. Prior to discussing the

features of UAV **104** and forestry analysis system **116** in further detail, a brief overview of the other features illustrated in FIG. **2** will be provided.

FIG. **2** illustratively shows that mobile machine(s) **108**, UAV system **104** (hereinafter UAV, UAV system), forestry analysis system **116**, communication station **110**, remote systems **120**, worksites **118**, worksite area **106**, and communication device **114**, among other components **248**, are connected by network **286**. Thus, forestry computing architecture operates in a networked environment, where network **286** includes any of a wide variety of different logical connections such as a local area network (LAN), wide area network (WAN), near field communication network, satellite communication network, cellular networks, or a wide variety of networks or combination of networks.

Communication device **114** illustratively includes one or more processor(s) **282**, one or more data store(s) **284**, and a user interface component **286**. User interface component **286** is configured to generate user interfaces on a display screen, the user interfaces having user input mechanisms for detecting user interaction by operator **112**. In one example, communication device **114** includes a tablet computing device or a laptop computing device, or any of the other devices discussed with respect to FIGS. **11-13** below.

FIG. **2** illustratively shows that mobile machine **108** (hereinafter mobile machine, machine, or forestry machine) includes a positioning system **202**, a user interface device **204**, user interface logic **206**, one or more sensors **208**, a control system **210** including a communication system **212** and a control signal generator **214**, controllable subsystems **218** including a propulsion system **220**, one or more processors **222**, one or more data stores **224**, and other mobile machine components **203**. While the present description will primarily focus on an example in which mobile machine **108** includes a forestry machine that performs forestry operations, it is noted that mobile machine **108** can include any of a wide variety of different machines.

In one example, mobile machine **108** uses user interface logic **206** to generate operator interface displays having user input mechanisms for display output on a user interface device **204** and for interaction by operator **112**. Operator **112** can be a local operator of mobile machine **108** in an operator's compartment of mobile machine **108**, and can interact with user input mechanisms to control and manipulate mobile machine **108**. Operator **112** can also be a remote operator of mobile machine **108**, interacting with mobile machine **108**, for example, via communication device **114** over network **286**. User input mechanisms can include one or more display devices (e.g., user interface device **204**), one or more audio devices, one or more haptic devices, and other items, such as a steering wheel, joysticks, pedals, levers, buttons, keypads, etc.

Sensor(s) **208** can generate a wide variety of different sensor signals representing a wide variety of different sensed variables. For instance, sensor(s) **208** generate signals indicative of slope angle, soil moisture, proximity, acceleration, hydraulic actuator movement or position, a geographic location (e.g., where sensors **208** include a global positioning system (GPS) receiver or other positioning system), among others.

Positioning system **202** illustratively generates one or more signals indicative of a position of mobile machine **108** at any given time during an operation. Generally, positioning system **202** receives sensor signals from one or more sensor(s) **208**, such as a GPS receiver, a dead reckoning system, a LORAN system, or a wide variety of other systems or sensors, to determine a position of mobile machine **108** across a worksite. Positioning system **202** can also access data store **224** to retrieve stored positioning information that indicates positions of mobile machine **108** in performing historical operations, as well as the paths and/or patterns of travel of mobile machine **108** during performance of the historical operations.

Control system **210** includes communication system **212**, which illustratively includes UAV communication component **216** among a wide variety of other communication components **201**, and is generally configured to allow mobile machine **108** to communicate with remote systems including a remote analytics computing system, such forestry analysis system **116**, a remote manager computing system, communication device **114**, mobile machine **108**, remote systems **120**, among others. Thus, communication system **212** illustratively communicates over communication networks discussed above. In one example, UAV communication component **216** is configured to communicate with UAV **104** over a wireless local area networking such as WiFi. Control signal generator **214** generates control signals for controlling a variety of different controllable subsystems **218** based on sensor signals generated by sensor(s) **208**, based on information received through communication system **212** (e.g., information received from forestry analysis system **116**), based on user inputs received through user input mechanisms detected via user interface logic **206**, based on positioning information obtained from positioning system **202**, and/or it can generate control signals in a wide variety of other ways as well.

Controllable subsystems **218** illustratively include propulsion system **220** among a wide variety of other controllable subsystems **205**, such as a grapple, circular saw or shear, hydraulic implements, etc. Propulsion system **220** generally includes an engine that drives ground engaging wheels or tracks via a powertrain mechanism.

FIG. **2** further illustratively shows that UAV **104** includes controllable UAV subsystems **226** having a propulsion system **228**, one or more attribute sensor(s) **230**, a UAV control system **232** having a communication component **234** and a UAV control signal generator **250**, a UAV positioning system **240**, image capture component **122** having a visual imaging component **242** and a light detection and ranging (LIDAR)/Radar imaging component **244**, user interface logic **280**, one or more processors **246**, one or more data stores **248**, and a wide variety of other UAV components **207**.

Attribute sensors **230** can generate a wide variety of different sensor signals representing a wide variety of different sensed variables regarding UAV **108**. For instance, attribute sensors **230** can generate signals indicative of acceleration and orientation of UAV **108**. Attribute sensors **230** can include, as an example only, but not by limitation, range finders, inertial navigation systems, payload sensors, etc.

UAV positioning system **240** can include logic and illustratively generates one or more signals indicative of a position of UAV **104** at any given time during an operation. Generally, UAV positioning system **240** receives sensor signals from one or more attribute sensor(s) **230**, such as a global positioning system (GPS) receiver, a dead reckoning system, a LORAN system, range finder, inertial navigation system, laser range finder, or image capture component **122**, or a wide variety of other systems or sensors, to determine positions of UAV **104** across a worksite. UAV positioning system **240** can also access data store **248** to retrieve stored positioning information that indicates positions of UAV **104** in performing historical operations, as well as the flight

paths and/or patterns of flight of UAV **104** during performance of the historical operations.

UAV control system **232** can include communication component **234**, which illustratively includes a mobile machine connectivity component **236** and a forestry analysis connectivity component **238**, among other components **209**. Communication component **234** is generally configured to allow UAV **104** to communicate with mobile machines **108**, remote systems including a remote analytics computing system such forestry analysis system **116**, a remote manager computing system, communication device **114**, communication station **110**, as well as other remote systems **120**, among others. Mobile machine connectivity component **236**, for example, establishes a secure connection and communicates directly with UAV communication component **216** of mobile machine **108**, and is thus configured to communicate with mobile machine **108** over WiFi or other communication networks such as a near field communication network. Thus, UAV **104** can transmit and receive data and other information from mobile machine **108** via mobile machine connectivity component **236**.

Forestry analysis connectivity component **238**, for example, establishes a secure connection and communicates with forestry analysis system **116** through communication device **114**, communication station **110**, or a variety of other communication devices or interfaces. Thus, UAV **104** transmits and receives data and other information from forestry analysis system **116** via forestry analysis connectivity component **238**. As will be discussed in further detail below, UAV **104** transmits information, such as data obtained from sensors **208** or machine **108**, as well as attribute sensors **230**, image capture component **122**, or UAV **104**, to forestry analysis system **116**. UAV **104** also receives output information such as productivity measures from forestry analysis system **116**. This communication architecture can be especially useful in examples where forestry analysis system **116** is a remote cloud computing service requiring communication via a satellite connection.

UAV control system **232** also illustratively includes UAV control signal generator **250** that generates control signals for controlling a variety of different controllable UAV subsystems **226**. This can be done based on sensor signals generated by attribute sensors **230**, based on information received through communication component **238**, based upon user inputs received through user input mechanisms detected via user interface logic **280** (e.g., user inputs provided from communication device **114**, as will be discussed in further detail below), or it can generate control signals in a wide variety of other ways as well.

Controllable UAV subsystems **226** illustratively include propulsion system **228** among a wide variety of other controllable systems. Propulsion system **228** generally includes a motor that drives one or more propellers or turbines (among others) to generate lift and to propel UAV **104** along a flight path.

Image capture component **122** is configured to obtain images or other sensor information indicative of a wide variety of different items in worksite area **106**. For example, image capture component **122** can identify worksite area **106** and capture images that indicate a wide variety of different worksite characteristics and/or properties such as, but not limited to, particular areas of interest, trees, tree properties, ground surface properties, ground surface and tree top topography, insect habitation, etc.

Specifically, in one example, visual imaging component **242** can include any of a wide variety of different digital still cameras or video cameras that capture high resolution digital representations of worksite area **106**. LIDAR/radar imaging component **244** scans worksite area **106** with pulsed laser light and measures the reflected pulses with one or more sensors to generate a series of data representations that indicate a model of the landscape. This can be used for generating, for example, a three-dimensional model of worksite area **106**. Visual imaging component **242** and LIDAR/radar imaging component **244** can also capture information indicative of a location of mobile machines **108**, communication station **110**, operator **112**, communication device **114**, and/or other machines or items of interest positioned in worksite **102**.

FIG. **2** illustratively shows that forestry analysis system **116** includes a mapping system **252**, area of interest identification logic **254**, UAV interaction logic **256**, machine interaction logic **258**, ground disturbance identification logic **260**, fire-fighting deployment decision logic **262**, slope identification logic **264**, productivity control system logic **260**, tree inventory logic **268**, machine connectivity logic **270**, one or more processors and/or servers **272**, a communication system **274**, user interface logic **276**, and one or more data stores **278**, among a wide variety of other components **209**. Again, before describing the operation of the entire architecture in more detail, a brief description of some of the items on forestry analysis system **116** will first be provided.

Communication system **274** allows forestry analysis system **116** to communicate with a remote manager computing system. This can be done using communication device **114**, UAV **104**, mobile machines **108**, communication station **110**, and remote systems **120**, among others. Communication system **274** communicates over communication networks discussed above. In one example, forestry analysis system **116** is remote from mobile machines **108**, UAV **104**, communication station **110**, communication device **114**, and the other features of computing system architecture **200**. For instance, it may be implemented as a computing service that receives information, obtained by mobile machines **108** and/or UAV system **104**, via communication station **110** and/or communication device **114**.

Generally, forestry analysis system **116** is configured to receive a wide variety of information, such as information indicative of characteristics and properties of worksite area **106** as well as information indicative of performance of a forestry operation. This information can be captured by UAV system **104** (such as information captured by using image capture component **122**) or it can be captured by machine **108**. As will be further detailed with respect to FIGS. **3**A and **3**B, forestry analysis system **116** performs a wide variety of different data analyses on the information to generate outputs. The outputs generated by forestry analysis system **116** can be provided to any of the systems discussed with respect to forestry computing architecture **200**.

FIGS. **3**A and **3**B are block diagrams of one example of forestry analysis system **116** illustrated in FIG. **1** in further detail. FIGS. **3**A and **3**B will now be discussed in conjunction with one another.

Mapping system **252** illustratively includes coordinate positioning logic **300**, image stitching logic **302**, LIDAR/radar positioning logic **304**, and visual map output logic **306**. Mapping system **252** generally obtains the images captured by UAV **104** information regarding various positions of worksite **102**, such as the various positions of UAV **104** as it travels along a flight path within worksite area **106** or positions of mobile machine **108**. Based on the position information, mapping system **252** generates a mapped representation of worksite **102** (e.g., worksite area **106**). That

representation can be stored at data store **278**, accessed for correlating sensed information or image information to a real-world location within worksite **102**, and utilized to generate a visual representation of worksite **102**. The visual representation can be output, for example, to interfaces displayed on user interface device **204** or user interface component **286** for interaction by operator **112**.

Coordinate positioning logic **300** receives or otherwise accesses positioning information from any of positioning system **202** and UAV positioning system **240**. In one example, coordinate positioning logic **300** generates a data structure that retains coordinate positions, such as latitude and longitude, corresponding to sensor or image information received for a forestry operation.

Image stitching logic **302** receives or otherwise accesses images captured by visual imaging component **242** and combines the images into a spatial representation of worksite area **106**. For example, image stitching logic **302** stitches images captured by UAV **104** into a digital image model of worksite area **106** based on the image information itself and a corresponding coordinate data structure generated by coordinate positioning logic **300**. LIDAR/radar stitching logic **304** can receive or otherwise access distance data points scanned or otherwise detected by LIDAR/radar imaging component **244**. LIDAR/radar stitching logic **304** can generate a three-dimensional point cloud model or other data point model representation of worksite area **106** based on the distance data points. LIDAR/radar stitching logic **304** utilizes a corresponding coordinate data structure, generated by coordinate positioning logic **300**, to generate the point cloud model as a representation of worksite area **106**.

Visual map output logic **306** generates a visual map that represents worksite area **106** with high detail. For example, a visual map generated by visual map output logic **306** can illustratively identify a machine rut in a worksite within several centimeters of accuracy. Visual map output logic **306** generates a visual map based on any of a coordinate data structure generated by coordinate positioning logic **300**, a digital image model generated by image stitching logic **302**, and/or a data point model generated by LIDAR/radar stitching logic **304**. The visual map generated by visual map output logic **306** can be rendered for display on a device such as user interface component **286** and user interface device **204**.

In addition, in one example, visual map output logic **306** can use analysis results generated by forestry analysis system **116** to include visual indications of the analysis results within a rendered visual map. For instance, in an example where forestry analysis system **116** generates a planned travel route for machine **108**, visual map output logic **306** generates a visual representation of the planned path as it corresponds to real-world locations represented on the display of the visual map.

Area of interest identification logic **254** illustratively includes forestry analysis-type input logic **308** and historic area of interest identification logic **310**. Area of interest identification logic **254** identifies one or more areas of interest within worksite **102**. For example, area of interest identification logic **254** can identify worksite area **106** as an area within worksite **102** that is of particular interest to a current operation being performed. Forestry analysis-type input logic **308** can identify a current analysis to be performed by forestry analysis system **116** and accordingly select an area of interest for that assessment. For example, forestry-analysis type input logic **308** identifies a ground disturbance assessment to be performed. Forestry analysis-type input logic **308** can identify the assessment to be performed based on an indication of a user input that selects an analysis, automatically based on obtained information, or in a variety of other ways as well.

Once the type of assessment to be performed is identified, forestry analysis-type input logic **308** identifies a particular area within worksite **102**, such as worksite area **106**, for which logic (e.g., disturbance identification logic **330**) is to perform the assessment. Accordingly, forestry-analysis type input logic **308** also identifies data obtained for worksite area **106** as being relevant to the assessment. It can do this by accessing a mapped representation of worksite **106** generated by mapping system **252**, and providing an indication of the relevant data to ground disturbance identification logic **330**. Of course, it is noted that forestry-analysis type input logic **308** can include other features, such as identifying a series or workflow of assessments to be performed or identifying an entire boundary of worksite area **102**, among others.

Historic area of interest identification logic **310** is configured to access information pertaining to prior assessments performed on worksite **102** (e.g., historical analysis information stored in association with data store **278**) and identify relationships between particular areas within worksite **102** and the prior operations performed for each area, respectively.

UAV interaction logic **256** interacts with UAV **104** in a wide variety of different ways for facilitating transfer of information between UAV **104** and forestry analysis system **116**. UAV interaction logic **256** illustratively includes machine identification logic **312**, image and data collection input logic **314**, worksite consideration logic **316**, and flight path interface logic **318**. Machine identification logic **312** identifies a wide variety of machines in worksite **102** and provides UAV **104** with instructions to utilize a unique machine identification code for communicating information with a particular machine. Machine identification logic **312** can generate information that can be used by UAV **104** to communicate with forestry analysis system **116**, a particular mobile machine **108**, a particular communication station **110**, etc. It can do this by providing a unique identification code for the machine or system that UAV **104** is to communicate with, or along with geolocation information associated with the unique identification code.

Image and data collection input logic **314** generates instructions that indicate to UAV **104** the particular type of information it is to collect. For instance, it may instruct UAV **104** to collect data or one or more images for an analysis to be performed by forestry analysis system **116**. In one example, image and data collection input logic **314** may instruct UAV **104** to collect information, such as machine-specific sensor information from machine **108** (e.g., by identifying the relevant machine in worksite area **106** with machine identification logic **312**) and digital images or distance point data for worksite area **106**. These are examples only.

Worksite consideration logic **316** considers a wide variety of information regarding worksite area **102** to generate or modify instructions for collecting information with UAV **104**. In one example, worksite consideration logic **316** interacts with area of interest identification logic **254** to receive an indication of a particular worksite (e.g., worksite area **106**) for which an analysis is to be performed, and based on this indication, generates instructions that instruct UAV **104** to fly and obtain data based on geographical information for worksite area **106**. For example, worksite consideration logic **316** can generate instructions that instruct UAV **104** to use input values regarding worksite boundaries, tree height,

machine deployment, resource allocation, etc. when performing a data collection operation for a particular analysis being performed.

Flight path interface logic **318** generates flight path instructions that instruct UAV **104** to travel along a defined aerial path to perform data collection and sharing operations, according to a particular analysis to be performed. For example, flight path interface logic **318** may generate a first set of instructions that specify a first flight path for UAV **104** to travel in collecting information corresponding to a ground disturbance assessment, and generate a second set of instructions that specify a second flight path for UAV **104** to travel in collecting information corresponding to a slope assessment.

Machine interaction logic **258** interacts with mobile machine **108** in a wide variety of different ways for facilitating control of mobile machine **108** according to analysis results obtained by forestry analysis system **116**. Machine interaction logic **258** illustratively includes machine operation identification logic **320**, and machine control system output logic **322** having steering and header logic **324**, traction assist logic **326**, and operator-assist logic **328**. It can have a wide variety of other items as well.

Machine operation identification logic **320** receives data obtained for analysis by forestry analysis system **116** and identifies an operation, performed by machine **108**, corresponding to the data. For example, machine operation identification logic **320** receives indications of sensor data, obtained by machine **108**, indicating soil moisture content and identifies that the sensor data was obtained during performance of a harvesting operation by machine **108**.

Results of analyses performed at forestry analysis system **116** can be provided to machine control system output logic **322**. Machine control system output logic **322** receives analysis results or other indications of an analysis (e.g., indication of an output signal generated by an analysis) and uses the results to generate output signals that are provided to machine **108**. Steering and header logic **324**, for example, generates an output control signal that instructs mobile machine **108** to adjust steering parameters or a heading setting and thereby control directional travel of mobile machine **108**. This information can be displayed to assist in operator control of machine **108** or it can be used to control machine **108** automatically. For instance, based on a slope assessment, steering and header logic **324** can generate instructions used to move machine **108** to a directional heading that allows machine **108** to perform a current harvesting operation along a less steep slope. Steering and header logic **324** can generate control signals that are provided to machine **108** to automatically move machine **108**, given the directional heading.

Traction assist logic **326** obtains analysis results and generates instructions that control machine **108** to use traction assist mechanisms. For example, based on receiving analysis information indicating a steep slope, traction assist logic **326** can generate instructions used to automatically use traction-assist equipment or to perform traction-assist techniques with mobile machine **108**.

Operator-assist logic **328** can identify whether machine **108** is operating under full or partial operator **112** control or whether it is operating independently of operator **112** (e.g., it can identify whether machine **108** is operating in a fully manual mode, a partial autonomous mode, or a fully autonomous mode). It can also generate instructions, based on analysis information, that provide information specifically useful to operator **112** for controlling machine **108**. In an example where analysis information is used to update a travel route prescribed for mobile machine **108**, operator-assist logic **328** can generate instructions to provide indications to operator **112** to move machine **108** accordingly (e.g., the instructions can be used to generate user interface notifications with user interface logic **206** that show operator **112** a suggested travel path).

Tree inventory logic **268** is configured to analyze information obtained by image capture component **122** to determine characteristics of a tree population within worksite area **106**. Tree inventory logic **268** illustratively includes tree metric image processing logic **368** and processed tree metric output component **382**. Tree metric image processing logic **368** can measure a wide variety of tree properties for trees in worksite area **106**, based on visual data obtained by visual imaging component **242** and/or LIDAR/radar imaging component **244**. For example, tree metric image processing logic **368** can determine a wide variety of metrics, such as an average, mean, deviation, or other statistical metric, corresponding to a measured tree property value for trees in worksite area **106**. Tree metric image processing logic **368** illustratively includes diameter breast height logic **370** that can determine metrics indicative of a measured tree diameter at breast height. Height logic **372** can determine metrics indicative of a measured tree height. Volume logic **374** can determine metrics indicative of a measured volume of a tree population. Density per area logic **376** can determine metrics indicative of a density of trees per worksite area **106**. Softwood logic **378** can determine metrics indicative of areas of softwood (e.g., conifer) trees. Hardwood logic **380** can determine metrics indicative of areas of hardwood (e.g., deciduous) trees.

Processed tree metric output component **382** can generate output signals indicating any of the determined tree metrics, as well as an action signal. For example, processed tree metric output component **382** can generate an output that is provided to user interface component **286** and/or user interface device **204** to inform operator **112** of the determined tree metrics for worksite area **106**. For instance, worksite area **106** can be visualized, according to functionality of mapping system **252** discussed above, to incorporate visual representations of tree metrics on a generated map. An action signal generated by processed tree metric output component **382** can, for example, include machine deployment signals to control deployment of a forestry machine at worksite area **106**, or at specific geographic locations based on the tree inventory metrics.

Ground disturbance identification logic **260** is generally configured to analyze any of machine-specific information and/or image information captured by image capture component **122** to perform a ground disturbance assessment. "Ground disturbance" as used herein can refer to any deviation in ground surface properties, such as soil erosion, rut formation, material overlaying the ground surface, etc. Particularly, "ground disturbance" can refer to these and other deviations from naturally occurring ground surface properties that are caused by the operation of machinery within worksite **102**. Ground disturbance identification logic **260** illustratively includes ground disturbance threshold logic **330**, ground disturbance image processing logic **332**, and ground disturbance correction logic **334** having area of correction identification component **336** and corrective action selection component **338**. Ground disturbance threshold logic **330** generates a threshold value of ground disturbance. A threshold value of ground disturbance can include, for example, but not by limitation, a level of soil erosion, a measure of rut depth, a measure of amount of material (e.g., cut trees, leaves, other material) overlaying a ground sur-

face, among a wide variety of others. Ground disturbance image processing logic **332** uses one or more sets of rules to process images obtained by image capture component **122** (e.g., and/or information processed by mapping system **252**) to generate a mapping of the determined ground disturbance for worksite area **106**, and identify particular sub-areas within worksite area **106** having a level of ground disturbance that exceeds the threshold value of ground disturbance. For example, ground disturbance image processing logic **332** can identify a machine rut located within worksite area **106** and having a depth greater than a threshold machine rut depth. Thus, ground disturbance image processing logic **332** can generate a set of ground disturbance metrics, each having a value indicative of a ground disturbance at a different geographic location, based on the imagery information. From the imagery information, a given location that has a ground disturbance indicator indicative of likely ground disturbance can be identified. The value of the ground disturbance metric might include a difference in a smoothness of the ground at the geographical location, relative to a smoothness of the ground at other, proximate locations.

Area of correction identification component **336** includes logic that identifies an area, such as a geographical area surrounding the machine rut, to be operated on by mobile machine **108** for correcting the disturbed ground. Corrective action selection component **338** selects a particular corrective action, from a plurality of available corrective actions, to be implemented by machine **108** for correcting the disturbed ground at the identified area of worksite area **106**. In one example, a corrective action includes obtaining and delivering additional soil to the identified area, as well as smoothing the ground surface of soil with mobile machine **108**. Ground disturbance correction logic **334** can thus be utilized to generate instructions, such as an action signal, for automatically, semi-automatically, or manually controlling mobile machine **108** to perform an operation that reduces or otherwise mediates undesired disturbance of a ground surface in worksite area **106** (e.g., at the location of identified ground disturbance), based on the ground disturbance metrics.

Slope identification logic **264** is configured to analyze any of machine-specific information and/or image information captured by image capture component **122** to perform a slope identification assessment for worksite **102**. Slope identification logic **264** illustratively includes slope threshold logic **348**, slope image processing logic **350**, slope verification logic **352**, machine path and slope consideration logic **354**, and slope visualization logic **356**. Slope threshold logic **348** generates a threshold value of ground slope. A threshold value of ground slope can include, for example, but not by limitation, a ratio of vertical rise to horizontal run, an angle of ground surface, or any other value that can be compared to a sensed or otherwise obtained measure of slope (e.g., gradient or pitch) of worksite area **106**. Slope image processing logic **350** one or more sets of rules to process images obtained by image capture component **122**, and/or information processed by mapping system **252**, to identify particular sub-areas within worksite area **106** having a slope that exceeds the threshold value of slope. Slope image processing logic **350** can generate a set of slope metrics, each having a value indicative of a measure of slope at a different location in the forestry worksite, based on the imagery information. For example, slope image processing logic **350** can identify a slope within worksite area **106** having an angle greater than 12 degrees. Slope verification logic **352** is configured to verify a measured slope by performing a verification analysis. For example, machine **108** utilizes one or more sensors **208** to sense a slope of worksite area **106**. Slope verification logic **352** obtains slope sensor signals and measures a slope value for worksite area **106**, based on the slope sensor signals. Slope verification logic **352** compares the measured slope value to an identified slope, as identified by slope image processing logic **250**. Slope verification logic **352** can thus be utilized to verify and/or calibrate the aerial image processing operations performed by slope image processing logic **350** by utilizing comparisons against slope data sensed by sensors **208** on machines **108** operating on the ground.

Machine path and slope consideration logic **354** uses slope measurements obtained by slope identification logic **264** to generate instructions, such as an action signal, that can update or otherwise control a prescribed machine path. For example, where a particular sub-area within worksite area **106** has been identified as having a slope that exceeds the threshold value of slope, machine path and slope consideration logic **354** can first determine that a prescribed travel route of machine **108** includes travel over or within that sub-area. Machine path and slope consideration logic **354** can then instruct machine interaction logic **258** to provide an output or control signal to machine **108** for avoiding the particular sub-area with the steep slope. Thus, machine path and slope consideration logic **354** can control communication logic to communicate the route signal to machine **108**.

Slope visualization logic **356** can generate a visual representation of measured slope data. For example, slope visualization logic **356** can generate a cross-sectional map of worksite area **106** representing the measured slope data. Slope visualization logic **356** can provide the visual representation to mapping system **252** for further incorporation with, for example, visual maps of worksite **102**.

Fire fighting deployment decision logic **262** illustratively includes fire fighting feasibility analysis logic **340** and escape route identification logic **346**. Generally, fire fighting feasibility analysis logic **262** analyzes any of machine-specific information and/or image information captured by image capture component **122** to perform an analysis for determining whether it is feasible to perform a fire fighting operation. For example, information obtained by image capture component **122** can be analyzed by fire fighting feasibility analysis logic **262** to determine terrain characteristics at worksite area **106**, determine that a level of insect habitation, such as a measured population of an invasive species (e.g., gypsy moth, among other invasive species specific to tree survival), is present within worksite area **106**, and determine other items. Based on this analysis, fire fighting feasibility analysis logic **262** might determine that it is not feasible or recommended to fight a fire at that location. In another example, fire fighting feasibility analysis logic **262** analyzes obtained information to determine that a wind speed is relatively low, and thus determine that it is feasible to fight a fire at that location. Of course, fire fighting feasibility analysis logic **262** can analyze other obtained information such as, but not limited to, a size of worksite area **106**, a wind speed and direction, soil moisture levels, cloud coverage, among others, for performing a fire fighting feasibility analysis and generating an action signal, based on the analysis.

Escape route identification logic **346** generates a travel route or other route that is determined to be safe for fire fighters, machine **108**, UAV **104**, and/or operator **112** to travel along to escape a fire. For example, based on fire fighting feasibility analysis logic **262** determining that a fire

fighting operation is to be performed, escape route identification logic **346** analyzes any of machine-specific information and/or image information captured by image capture component **122** to plan an escape path for the machines that are utilized in performing the fire fighting operation. As such, a prescribed travel route of a machine can be updated to represent an escape path for safely removing items within forestry worksite **102** to an area of safety, relative to a current forest fire. The escape route can be continuously or intermittently updated based on changing conditions as they are sensed by UAV **104** and other items. Escape route identification logic **348** can instruct machine interaction logic **258** to provide an output or control signals to machine **108** and/or other items, to control them to avoid the forest fire while performing a fire fighting or other operation. The control can be automatic, semi-automatic, or manual.

Productivity control system logic **266** illustratively includes worksite input logic **358**, machine productivity input logic **360**, UAV flight path logic **362**, categorical productivity image processing logic **364**, and categorical productivity output logic **366**. Productivity control system logic **266** performs a productivity analysis to determine levels of productivity with respect to specific sub-areas within worksite area **106**. As an example only, but not by limitation, productivity control system logic **266** will be described in further detail with respect to a tree harvesting operation. For example, productivity control system logic **266** differentiates between a harvested area, a work in progress area, or an unharvested area within worksite area **106**. A harvested area has been harvested of its trees. A work in progress area is partially harvested or has trees that have been cut but are laid on the ground (e.g, trees still required to be removed from the work area). An unharvested area has all trees still standing. Of course, a wide variety of other areas can be identified for determining productivity of an operation being performed at worksite area **106**.

More specifically, in one example, image capture component **122** is utilized by productivity control system logic **266** to analyze imagery of worksite area **106**, and based on the analyzed imagery, differentiate between the various levels of productivity within worksite area **106**. UAV flight path logic **362** can load a map of worksite area **106** and generates a flight path with respect to boundaries of worksite area **106**. In one example, UAV flight path logic **362** interacts with UAV interaction logic **256** (e.g., flight path interface logic **318**) to generate a flight path that UAV **104** travels to obtain aerial imagery that will be utilized to determine productivity. Worksite input logic **358** utilizes a wide variety of information regarding worksite **106** (such as the imagery information obtained by image capture component **122** along the generated flight path, information obtained by mapping system **252**, tree inventory logic **268**, among others) to determine worksite characteristics that will be used in analyzing productivity measures. For example, worksite input logic **358** can determine a jobsite size (e.g., acres), tree population such as a number of trees per acre, and tree volume such as a number of pounds per tree. Machine productivity input logic **360** determines a wide variety of information regarding machines **108**, such as a measure of uptime of each machine (e.g., amount of time machine is working in the area), number of trees cut, moved, or otherwise harvested by machines **108**, etc. This can be obtained by interacting with machine information obtained by machine interaction logic **258**, as described above.

Categorical productivity image processing logic **364** uses any of the image information obtained by image capture component **122** along the generated flight path, worksite characteristics determined by worksite input logic **358**, machine productivity characteristics determined by machine productivity input logic **358**, among other information, to determine the level of productivity for each respective sub-area within worksite area **106**. For example, where worksite area **106** has a size of 100 acres, categorical productivity image processing logic **364** identifies a first geographical sub-area of 25 acres that corresponds to a harvested area, a second geographical sub-area of 25 acres that corresponds to a work in progress area, and a third geographical sub-area of 50 acres that corresponds to an unharvested area, respectively, within worksite area **106**. To further illustrate this example, categorical productivity image processing logic **364** can identify the second sub-area based on imagery information, obtained by image capture component **122**, that identifies trees bundled on the ground, and also based on machine information such as a location of a skidder and a current harvesting operation being performed by that skidder in the second sub-area. Thus, this information is used to determine that this particular geographical area, having boundaries that make it a sub-area of 25 acres, is still being harvested.

Categorical productivity output logic **366** can generate an output, such as an action signal, or control signal indicative of the identified productivity categories and their corresponding geographical areas. For instance, categorical productivity output logic **366** can generate an output indicative of an equipment demand for worksite area **106**, such as a number of trucks (e.g., carrying harvested trees) that are moved from the worksite per day. In one example, categorical productivity output logic **366** can load and generate a map that visually represents the first sub-area, second sub-area, and third sub-areas identified within worksite area **106**, and/or percentages of the three categories within worksite area **106**. Categorical productivity output logic **366** can provide a map representation that visually distinguishes between the sub-areas, such as by shading the areas differently (e.g., hashing, coloring, etc.). Categorical productivity output logic **366** can thus interact with mapping system **252** to generate an output that is provided to user interface component **286** and/or user interface device **204** to provide operator **112** with a visual representation of the productivity analysis (e.g., the shaded map). Categorical productivity output logic **366** can also generate one or more reports, based on the determined completeness of each sub-area, reporting productivity metrics such as a total process time, a total available time to complete a process, a mill demand (e.g., trucks per day, a number of tons of harvested material loaded per truck, etc.), and a comparison of these calculated metrics to a quota for the worksite. In this way, productivity control system logic **266** utilizes aerial imaging of worksite area **106** by UAV system **104**, in combination with additional information pertaining to a worksite operation, to accurately determine and report how much of an operation has been completed, as well as estimated jobsite process efficiency (e.g., based on productivity metrics noted above). Categorical productivity output logic **366** can also generate an action signal that can control forestry analysis system **116** to update worksite completion metrics, generating a UAV control signal that controls UAV **104** (e.g., to obtain machine-specific information), a machine control signal to control machine **108**, among other action signals.

Machine connectivity logic **270** illustratively includes network connectivity identification logic **384**, network connectivity strength analysis logic **386**, automated UAV data collection logic **388**, partial-assist UAV data collection logic **390**, and connectivity trouble code logic **392**. It can include

other items as well. The variety of analyses discussed above can provide valuable information, and often use data that is otherwise difficult to obtain, especially considering the difficulties presented by forestry worksites. As mentioned above, forestry worksites are often located in remote areas, and some current forestry systems have poor connection capabilities. Thus, while data might be obtained at the machine-level, it can be difficult to upload or otherwise share this data for using the data with, for example, forestry application analyses that generate meaningful information. In accordance with one example, UAV system **104** is utilized to address these challenges by functions as a data collection and forwarding system for machines **108** operating at worksite area **106**.

Network connectivity identification logic **384** identifies a network connection, for instance network **286** being a local area network (LAN), wide area network (WAN), or WiFi, among others. In one example, network connectivity identification logic **384** identifies a WiFi network connection between UAV system **104** and machine **108**, and identifies a satellite network connection between communication station **110** and remote systems **120**, where forestry analysis system **116** is a remote system **120** implemented, for instance, as a cloud computing service. Network connectivity strength analysis logic **386** determines a strength of any of these network connections. Based on the identified network connections and their determined connectivity strength, automated UAV data collection logic **388**, partial-assist UAV data collection logic **390** select a particular network for performing data collection and forwarding.

Automated UAV data collection logic **388** illustratively includes machine data collection logic **394**, communication station upload logic **396**, and data forwarding logic **398**. Machine data collection logic **388** can generate instructions that control UAV system **104** to target machines **108** for data collection. Specifically, machine data collection logic **388** can allow UAV system **104** to fly to machines **108**, within a certain proximity and according to worksite area **106** boundaries and other worksite information such as tree top height, and hover above each machine **108** to establish a communication connection to collect data. In one example, machine data collection logic **388** can include instructions that allow UAV system **104** to establish a WiFi connection with machine **108** for collecting machine-specific information obtained by machine **108**. The instructions identify a particular machine, identify a travel route to the machine, and identify how to collect data from the machine via a communication connection. The instructions can be wholly or partially stored or otherwise provided to UAV **104** prior to a data forwarding operation occurring. Thus, UAV system **104** can be in communication with a remote forestry analysis system **116** to receive instructions of machine connectivity logic **270** during, for example, a data collection calibration operation.

Communication station upload logic **396** generates instructions that control UAV system **104** to target communication station **110** for data upload. Specifically, communication station upload logic **396** can allow UAV system **104** to fly to communication station **110**, within a certain proximity (e.g., according to worksite area **106** boundaries and other worksite information such as tree top height, etc.) and hover above communication station **110** to establish a communication connection. The established communication connection is used to upload the collected machine-specific information and a wide variety of other information (such as imagery data obtained by image capture component **122**) to communication station **110**. Communication station **110** can be located at a worksite headquarters within worksite **102** and therefore serve as a base for UAV system **104**.

Upon the collected data being uploaded to communication station **110**, data forwarding logic **398** forwards the uploaded data to a remote system. For example, data forwarding logic **398** can forward the collected data to a satellite connection that communicates with forestry analysis system **116** executing at a remote cloud computing service.

Partial-assist UAV data collection logic **390** operates similarly to the features described above with respect to automated UAV data collection logic **388**. However, partial-assist UAV data collection logic **390** can incorporate user interactions to perform specific data collection, uploading, storing, and forwarding functions. Partial-assist UAV data collection logic **390** illustratively includes communication device data connectivity logic **301**, machine data targeting logic **303**, real time productivity interface logic **305**, and data storage and forwarding logic **307**.

Communication device data connectivity logic **301** controls interaction with communication device **114**. This can be used to allow operator **112** to interact with, for example, user interfaces displayed by user interface component **286** in order to select parameters of a data collection operation. Thus, communication device data connectivity logic **301** can allow operator **112** to select particular machines **108**, particular data to be obtained by machines **108** (e.g., specific types of sensor data obtained by particular sensors **208**) or UAV system **104**, a particular flight path for collecting data from machines **108**, and particular mechanisms for storing and forwarding the collected data, among other parameters. Operator **112** can therefore utilize a tablet computer or other mobile device (e.g., communication device **114**) to interact with user interfaces for customizing a data collection operation, and to interact with data storage and forward functions for providing valuable information to other remote systems **120** (e.g., forestry analysis system **116**).

Based at least in part on user input identified with communication device data connectivity logic **301**, machine data targeting logic **303** can identify selected machines **108** to be targeted for data collection. Machine data targeting logic **303** can generate instructions that control UAV system **104** to fly to locations of selected machines **108**, within a certain proximity (and according to worksite area **106** boundaries and other worksite information such as tree top height), and hover above each machine **108** to establish a communication connection for collecting data. Machine data targeting logic **303** can also control UAV system **104** to obtain specific types of machine information and/or imagery information by image capture component **122**, as indicated by a user input provided by operator **112**.

In an example where communication device **114** is a tablet computer used by operator **112** within worksite **102**, real time productivity interface logic **305** can provide updates and changes to relevant data while an operation is being performed. Real time productivity interface logic **305** can serve as an interface between a data collection operation being executed by partial-assist UAV data collection logic **390** and a productivity analysis being executed by productivity control system logic **266**. Thus, as data is collected by machine data targeting logic **303**, real time productivity interface logic **305** can generate instructions that update productivity metrics with productivity control system logic **266**, and in return control forestry analysis system **116** (e.g., mapping system **252**) to update visual maps that are surfaced or displayed by communication device **114**. Map changes are therefore made in real time from a management stand-

point (e.g., during operation, while data is continuously collected) and updates can be provided to all machines during an operation. Updates during an operation can include updates to points of interest, areas to be harvested, production track history, among other things.

Based at least in part on user input identified with communication device data connectivity logic **301**, data storage and forwarding logic **307** can generate instructions that control how data is stored at data store **284** and forwarded to, for example, other remote systems **120** (e.g., forestry analysis system **116**). In one example, data storage and forwarding logic **307** can determine that communication device **114** does not have connection to a cellular network for communicating with a remote system **120**, and therefore stores the obtained data at communication device **114** until, for example, a communication connection is established, Thus, at least some functionality of forestry analysis system **116** that is executed locally at communication device **114**, is utilized to provide real-time, meaningful information to operator **112**.

Connectivity trouble code logic **392** illustratively includes trouble code identification logic **309**, trouble code notification generator logic **311**, and trouble code interface logic **313**. Based on connectivity information determined by connectivity strength analysis logic **386**, and based on information regarding attempted data storage, upload, and forward techniques of machine connectivity logic **270**, among other information, trouble code identification logic **309** can identify a wide variety of trouble codes. For example, where a limited connection is established between mobile machine **108** and UAV system **104**, such as a connection having a low bandwidth of data transfer available, trouble code identification logic **309** can identify a trouble code corresponding to limited connection status. Trouble codes identified by trouble code identification logic **309** can also include, for example, codes indicating poor connectivity strength, a distance between communication station **114** and worksite area **106**, a travel issue with UAV system **104** (e.g., tree tops are too tall, resulting in a UAV being too far to communicate with mobile machine **108**), among others.

Trouble code notification generator logic **311** can generate a notification of the identified trouble code. In one example, trouble code notification generator logic **311** can provide the notification for display at an interface generated with user interface component **286** at communication device **114**. Thus, operator **112** can be notified of issues regarding attempted connection establishment, data upload, data forward, and data storage, among other things.

Trouble code interface logic **313** can interface with any of the other items discussed with respect to forestry analysis system **116**, and/or computing architecture **200**, and can provide instructions for control, based on an identified trouble code. For instance, trouble code interface logic **313** may generate instructions to stop performance of a current operation, or otherwise change or update a machine path or flight path, based on a trouble code indicating a current issue.

FIG. **4** illustrates a flow diagram showing one example **400** of controlling a UAV to perform a ground disturbance assessment **400**. At block **402**, ground disturbance identification logic **260** detects a request to perform a ground disturbance assessment for a worksite area **106**. Ground disturbance assessments can be performed for a wide variety of reasons and at various times during an operation or once an operation is completed. For example, ground disturbance identification logic **260** can determine that a ground disturbance assessment is to be performed for post-forestry processing, as indicated at block **424**, post-timber removal, as indicated at block **426**, data verification, as indicated at block **428**, and a wide variety of others, as indicated at block **430**.

Post-forestry processing, as indicated at block **424**, includes a ground disturbance assessment that is to be performed after a forestry operation has been fully completed, and thus can be utilized to assess ground surface damage caused by machines utilized in the entirety of a completed forestry operation. Post-timber removal, as indicated at block **426**, includes a ground disturbance assessment that is to be performed after a forestry operation has been partially completed (e.g., after some amount of trees have been cut and/or removed but prior to all fallen trees being removed), and therefore can be utilized to assess ground surface damage caused by machines utilized until a current state of an operation. While harvesting is used as an example, it is noted that post-timber removal, as indicated at block **426**, can include assessments performed after partial completion of any forestry operation. Data verification, as indicated at block **428**, includes a comparison between one set of obtained ground disturbance data (e.g., machine-specific sensor information sensed by sensors **208** on machine **108**) to another set of obtained ground disturbance data (e.g., imagery information obtained by image capture component **122** or UAV system **104**) to verify ground disturbance for an operation performed at worksite area **106**.

At block **404**, ground disturbance identification logic **260** generates a flight path for performing the ground disturbance assessment on worksite area **106**. For example, ground disturbance identification logic **260** can generate instructions that instruct flight path interface logic **318** to create a flight path for performing the ground disturbance assessment on worksite area **106**.

At block **406**, ground disturbance identification logic **260** obtains captured images of worksite area **106**. For example, ground disturbance identification logic **260** can obtain images captured by image capture component **122** of UAV system **104**, and other sensor information. Captured images representing ground disturbance of worksite area **106** illustratively include visual images captured by visual imaging component **242**, as indicated at block **432**, lidar or radar data representations captured by lidar/radar imaging component **244**, as indicated at block **434**, and other image information obtained by image capture component **122**. Sensor information representing ground disturbance of worksite area **106** can also be obtained by ground disturbance identification logic **260**, and can illustratively include machine-specific sensor information sensed by sensors **208** on machine **108**, as indicated by block **436**, among other information, as indicated at block **440**.

At block **408**, ground disturbance image processing logic **332** generates a ground disturbance mapping of worksite area **106**. For example, ground disturbance image processing logic **332** interfaces with mapping system **252** (e.g., image stitching logic **302**) to stitch together images captured by image capture component **122**. This is used to generate a mapped representation of worksite area **106** having a measured ground disturbance.

At block **410**, ground disturbance threshold logic **330** identifies a threshold value of ground disturbance, such as a measure of soil erosion or washout, a measure of rut depth, a measure of an amount of material (e.g., cut trees, leaves, other material) overlaying a ground surface, among a wide variety of other threshold values.

At block **412**, ground disturbance image processing logic **332** analyzes the generated ground disturbance mapping (or

mapped representation) of worksite area **106**, based at least in part on the threshold value of ground disturbance generated by ground disturbance threshold logic **330**. That is, ground disturbance image processing logic **332** can compare a measured value of ground disturbance, for each area within worksite area **106** having some detected ground disturbance and represented on the mapped representation, to a threshold value of ground disturbance. AT block **412**, ground disturbance image processing logic **332** can generate a set of ground disturbance metrics, each having a value indicative of a ground disturbance at a different geographic location, based on the imagery information. The value of the ground disturbance metric might include a difference in a smoothness of the ground at the geographical location, relative to a smoothness of the ground at other, proximate locations.

At block **414**, ground disturbance image processing logic **332** detects that a level of ground disturbance is beyond the threshold value of ground disturbance for an area, based at least in part on the analysis performed at block **412**. For example, the analysis indicated at block **412** can be used to determine that a measured ground disturbance, such as a measured rut depth (where the rut was caused by operation of machine **108** within worksite area **106**) at a given location on the mapped representation of worksite area **106** exceeds a threshold value of rut depth (e.g., measured rut depth value of 3 inches exceeds a threshold rut depth value of 1 inch). Ground disturbance image processing logic **332** can detect that a level of ground disturbance is beyond a threshold value of ground disturbance for a wide variety of different types of ground disturbances, such as a machine rut disturbance, as indicated at block **442**, a washout area, as indicated at block **444**, a level of soil erosion, as indicated at block **446**, a difference in terrain characteristics such as a terrain delta, as indicated at block **448**, among other types of ground disturbances shown at block **450**. For instance, from the imagery information, a given location that has a ground disturbance indicator indicative of likely ground disturbance can be identified.

At block **416**, area of correction identification component **336** identifies a particular sub-area of the worksite area **106** that requires repair and generates an action signal. For instance, ground disturbance image processing logic **332** can identify points on the mapped representation of worksite area **106** where measured ground disturbance exceeds the threshold level of ground disturbance, and can also identify how the identified points correspond to respective geographical positions of worksite area **106**. Area of correction identification component **336** can thus identify sub-areas or geographical regions in worksite area **106** that correspond to the identified points indicating excessive ground disturbance. Area of correction identification component **336** thus identifies one or more geographical areas of worksite area **106** that experience an unacceptable level of ground disturbance and thus that require repair. As an example, where a measured rut depth exceeds a threshold value of rut depth at a position on the ground disturbance map, area of correction identification component **336** can identify a geographical area of 100 square feet that corresponds to the disturbance by the rut (and some boundary area around the rut) and that is to be repaired.

At block **418**, corrective action selection component **338** selects a particular corrective action to be implemented at the particular sub-area of worksite area **106**. For instance, based at least in part on the measured ground disturbance, and the identified sub-area to be repaired, corrective action selection component **338** can automatically select the most appropriate corrective action to be implemented at the particular sub-area. Corrective action selection component **338** can select the most appropriate corrective action to be implemented based on a variety of different criteria, such as the type of disturbance, the types of machines **108** in the area, the cost of different operations, the time to perform different operations, the safety of different operations, etc. In one example, corrective action selection component **338** can select the most appropriate corrective action to be implemented based on an indication of a user input that selects a particular action. The particular action selected by corrective action selection component **338** can include any of a mobile machine action, as indicated at block **452**, a planned path update action, as indicated at block **454**, a traction-assist action, as indicated at block **456**, a UAV action, as indicated at block **458**, among other actions as shown at block **460**.

A mobile machine action, as indicated at block **452**, can include instructions to control mobile machine **108** to perform a ground disturbance correction (e.g., instructions to perform an operation that fills a machine-induced rut). A planned path update action, as indicated at block **454**, can include instructions to modify a prescribed travel route of machine **108** to reduce additional ground disturbance. A traction-assist action, as indicated at block **456**, can include instructions to implement traction-assist features with mobile machine **108** to reduce further ground disturbance. A UAV action, as indicated at block **458**, can include instructions to obtain additional imagery by image capture component **122**, or for instance, instructions to control UAV **104** to obtain the additional images.

At block **420**, ground disturbance correction logic **334** generates and outputs an indication of the corrective action selected to repair the particular sub-area. For example, ground disturbance correction logic **334** can output a notification for notifying operator **112** (e.g., by user interface component **246** and/or user interface device **204**) of the selected action, a control signal to control any of the machines or vehicles **108** at worksite **102**, and a wide variety of other outputs.

At block **422**, ground disturbance identification logic **260** updates the ground disturbance mapping, based at least in part on the corrective action that was selected. For example, ground disturbance identification logic **260** can perform additional ground disturbance assessments once a corrective action has been selected and/or performed, to determine if any further corrective action is required to reduce ground disturbance at worksite area **106**. In one example, an action signal is output.

FIG. **5** illustrates a flow diagram showing one example **500** of controlling a UAV to perform a slope identification analysis. At block **502**, slope identification logic **264** detects a request to perform a slope identification analysis for worksite area **106**. Again, this can be an automated request or a request from any operators or individuals.

At block **504**, slope identification logic **264** determines whether the slope identification analysis, to be performed, is associated with a pre-harvest or a post-harvest forestry operation. Slope identification logic **264** can differentiate between a slope analysis for a pre-harvest or a post-harvest forestry operation based on, for example, information received from machine operation identification logic **258**. For example, machine operation identification logic **258** can be used to determine whether one or more machines **108** are currently performing a harvesting operation. Slope identification logic **264** can also use forestry analysis-type input logic **308** to determine whether the requested analysis is selected (e.g., automatically or manually by user input) to be pre-harvest or post-harvest analysis. A pre-harvest slope

analysis can use aerial imagery to measure slope of worksite area **106**. A post-harvest slope analysis can use aerial imagery in combination with other sensor-specific information from machines **108** to verify a measured slope of worksite area **106**.

At decision block **506**, slope identification logic **264** can select that the slope analysis is associated with either of a pre-harvest operation or a post-harvest operation. At block **508**, where slope identification logic **264** selects a pre-harvest operation, slope identification logic **264** generates a UAV flight path to obtain imagery information indicative of a slope of worksite area **106** by using image capture component **122**. For example, slope identification logic **264** can generate instructions that interface with flight path interface logic **318** for controlling UAV system **104** according to a generated flight path.

At block **510**, slope image processing logic **350** instructs UAV system **104** to capture images of worksite area **106** using image capture component **122** and/or obtain other information (such as information using attribute sensors **230**). As indicated at block **544**, slope image processing logic **350** can instruct UAV system **104** to capture treetop or other worksite area **106** imagery information using visual imaging component **242**. As indicated at block **546**, slope image processing logic **350** can instruct UAV system **104** to capture lidar/radar information indicating slope of worksite area **106** by using lidar/radar imaging component **244**. Of course, slope image processing logic **350** can instruct UAV system **104** to obtain other information as well, as indicated at block **550**.

At block **512**, slope image processing logic **350** generates a slope mapping of worksite area **106**, based on the captured images and other information obtained at block **510**. For example, slope image processing logic **350** can interface with mapping system **252** (e.g., image stitching logic **302**) to stitch together images captured by image capture component **122** into a mapped representation of worksite area **106** having measured slope values. A mapping of slope for worksite area **106** can indicate various sub-areas and their corresponding measured slope values, such that sub-areas can be identified for avoidance by machine **108**, or as areas machine **108** should work in, as it performs an operation. As indicated at block **552**, the generated slope mapping can represent a treetop topology delta (such as a difference in measured height of trees according to analysis performed on treetops within worksite area **106**). For example, slope image processing logic **350** can determine differences in a height of trees, and uses the differences to measure slope changes for worksite area **106**. The generated slope mapping can indicate other slope measures as well, as indicated at block **554**.

At block **514**, slope threshold logic **348** identifies a threshold value of ground slope, and machine path and slope consideration logic **354** identifies a suggested machine travel route for worksite area **106**. For example, machine path and slope consideration logic **354** identifies a prescribed travel route of machine **108** for performing an operation within worksite area **106**, based on slope.

At block **516**, machine path and slope consideration logic **354** performs a slope analysis with respect to the suggested machine travel route, based on the generated slope mapping and the identified threshold value of ground slope. At block **516**, slope image processing logic **350** can generate a set of slope metrics, each having a value indicative of a measure of slope at a different location in the forestry worksite, based on the imagery information. In one example, machine path and slope consideration logic **354** can identify the particular sub-areas within worksite area **106** having a measured slope value that exceeds the threshold value of ground slope. If any of the particular sub-areas are also geographical regions in which machine **108** is prescribed to travel over, according to the prescribed machine travel route, then machine path and slope consideration logic **354** can identify these sub-areas as problem areas that require machine path correction.

At block **518**, machine path and slope consideration logic **354** updates the suggested machine travel route, based at least in part on the analysis performed at block **516**. Updating the suggested machine travel route at block **518** can include modifying the suggested travel route to avoid the problem areas (e.g., areas where the slope is too large) or, for example, generate a new prescribed machine path.

At block, **520**, machine path and slope consideration logic **354** generates an indication of the updated machine path. At block **522**, slope identification logic **264** outputs the indication. The indication can be used to control machine **108** to perform the harvesting operation along the updated travel route. In one example, slope visualization logic **356** provides an output of the updated machine travel route with a visual map, as indicated at block **556**. As indicated at block **558**, slope identification logic **264** can generate a notification for notifying operator **112** (e.g., by user interface component **246** and/or user interface device **204**) of the updated machine travel route. Other outputs can be provided as well, as indicated at block **560**.

Thus, it can be seen that slope identification logic **264** can, prior to an operation being performed, utilize UAV system **104** to measure slope of worksite **106**, and thus identify areas having a slope greater than a threshold slope to update a machine travel route for avoiding large slopes. This can be used to improve machine efficiency, because machines **108** experience less slippage and produce less damage to worksite area **106**, thereby also improving productivity of a harvesting operation.

Turning to block **524**, where slope identification logic **264** selects a post-harvest operation rather than a pre-harvest operation at decision block **506**, slope identification logic **264** obtains sensor information indicative of sensed slope of worksite area **106**. At block **540**, slope identification logic **264** obtains machine-specific sensor information, such as information sensed by sensors **208** or by one or more machines **108**. For example, while machines **108** are performing a harvesting operation, sensors **208** can sense slope of worksite area **106**. This sensed slope can be verified by slope identification logic **264** to improve accuracy of further slope measurements.

At block **526**, slope identification logic **264** obtains machine travel path information for the harvesting operation (e.g., machine travel path traveled for a completed harvesting operation or machine travel path currently in progress for a current harvesting operation). Machine travel path information can generally include a geographical location at which machine **108** is positioned during the harvesting operation. At block **528**, slope identification logic **264** generates a raw mapping of worksite area **106**, based on the sensed slope and geographical location information. For instance, slope identification logic **264** can interface with mapping system **252** to generate a raw mapping of measured slope values across worksite area **106**, and in particular across sub-areas in which machine **108** travels. The raw mapping can be used to verify the accuracy of raw slope sensing techniques, such as to calibrate sensors **208** or verify accuracy of slope identification logic **264**.

At block **530**, slope identification logic **264** controls UAV **104** to perform an imaging operation to obtain additional

slope information for worksite area **106**. For example, block **530** includes any of the features discussed above with respect to blocks **508** and **510**.

At block **532**, slope identification logic **264** generates a UAV slope mapping of worksite area **106**, based on the UAV imaging information captured by image capture component **122** and other sensor information (e.g., and in accordance with the features discussed with respect to block **512**).

At block **534**, slope verification logic **352** compares the raw slope mapping generated at block **528** to the UAV slope mapping generated at block **532**. Slope verification logic **352** can identify differences between raw slope data of the raw slope mapping and the imaged slope data of the UAV slope mapping. Slope verification logic **352** can also generate a metric indicative of a degree of difference between the two types of measured slope information.

At block **536**, slope verification logic **352** updates and verifies the slope information for worksite area **106**, based on the comparison. In one example, where a raw slope value conflicts with an imaged slope value, slope verification logic **352** can use one or more rules to select a prevailing measured slope value. If slope verification logic **352** determines that the conflicting values are relatively close to one another (e.g., small degree of difference), slope verification logic **352** might select a particular one of the values as being a prevailing value based on one or more rules. If, however, slope verification logic **352** determines that the conflicting values are not relatively close to one another (e.g., large degree of difference), slope verification logic **352** can take an average of the two values or generate a new, accurate slope value in other ways.

At block **538**, slope identification logic **264** outputs the indication of the updated and/or verified slope information. For instance, slope visualization logic **356** can provide an output of the updated slope information with a visual map, as indicated at block **556**. Outputs provided with a visual map can suggest "no go" areas such as wetlands, sink holes, very steep terrain, etc. As indicated at block **558**, slope identification logic **264** generates a notification for notifying operator **112** (e.g., by user interface component **246** and/or user interface device **204**) of the updated and/or verified slope information. Outputs provided as a notification can include operator assistance features that suggest a most efficient route of travel based on the updated and/or verified slope information. Other outputs of the updated and/or verified slope information can be provided as well, as indicated at block **560**. In one example, an action signal is output.

Thus, operation **500** illustratively improves travel of machine **108**, and therefore improves productivity of worksite **102**, by identifying problem-areas of worksite **106** (e.g., having steep slope above a threshold) and updating travel routes of machine **108**, based on verified slope information.

FIG. **6** illustrates a flow diagram showing one example **600** of controlling a UAV to performing a tree inventory analysis for a worksite area. At block **602**, tree inventory logic **268** detects a request to perform a tree inventory analysis for worksite area **106**. This request can be automated or manual or a combination of both.

At block **604**, tree inventory logic **268** generates a UAV flight path for performing the tree inventory analysis on worksite area **106**. For example, tree inventory logic **268** can generate instructions that interface with flight path interface logic **318** for controlling UAV **104** according to a generated flight path. The flight path generated by tree inventory logic **268** can be particular to obtaining imagery information, indicating tree properties of worksite **106**, with image capture component **122**.

At block **606**, tree inventory logic **268** instructs UAV **104** to capture images of worksite area **106** using image capture component **122** and/or obtain other information using attribute sensors **230**. As indicated at block **616**, tree inventory logic **268** can instruct UAV **104** to capture visual images of trees using visual imaging component **242**. As indicated at block **618**, tree inventory logic **268** can instruct UAV **104** to capture lidar/radar information indicating tree properties by using lidar/radar imaging component **244**. Tree inventory logic **268** can instruct UAV **104** to obtain other information as well, as indicated at block **620**.

At block **608**, tree metric image processing logic **368** generates a tree inventory mapping, based on the captured images and other sensor information. For example, as indicated at block **622**, tree metric image processing logic **368** can interface with mapping system **252** (e.g., image stitching logic **302**) to stitch together images captured by image capture component **122** into a mapped representation of worksite area **106** having tree information. In one example, as indicated at block **624**, tree metric image processing logic **368** can use tree property detection techniques to generate the mapped representation of worksite area **106** for representing tree information. For example, specific measures of tree properties can be determined from the mapping. Of course, tree metric image processing logic **368** can generate the tree inventory map in other ways as well, as indicated at block **626**.

At block **610**, tree metric image processing logic **368** analyzes the generated mapping, including the measured tree properties, to obtain detailed tree inventory information. Detailed tree inventory information can include metrics pertaining to each type of measured tree property. At block **628**, diameter breast height logic **370** generates metrics indicative of a measured diameter breast height. At block **630**, height logic **372** generates metrics indicative of a measured tree height. At block **632**, volume logic **374** generates metrics indicative of a measured volume of a tree population. At block **634**, density per area logic **376** generates metrics indicative of a density of trees per worksite area **106**. At block **636**, softwood logic **378** generates metrics indicative of softwood (e.g., identifies tree type as conifer). At block **638**, hardwood logic **380** generates metrics indicative of hardwood (e.g., identifies tree type as deciduous). As a further example, tree metric image processing logic **368** can be configured to generate metrics pertaining to tree maturity, such as age and health, or other items.

At block **612**, processed tree metric output component **382** generates a tree inventory output based on the detailed tree inventory information. Outputs can include values indicating the metrics themselves, comparisons of metrics, and a wide variety of other outputs. Processed tree metric output component **382** can generate output signals indicating any of the determined tree metrics, as well as an action signal. An action signal generated by processed tree metric output component **382** can, for example, include machine deployment signals to control deployment of a forestry machine at worksite area **106**, or at specific geographic locations based on the tree inventory metrics.

At block **614**, processed tree metric output component **382** provides an indication of the tree inventory output. Processed tree metric output component **382** can provide an indication of the output to indicate the tree inventory metrics **644**. For example, tree inventory metrics can be provided to operator **112** as notifications indicating the numerical values

of tree inventory metrics. Processed tree metric output component **382** can provide an indication of the tree inventory output as a visual map, as indicated at block **646**. Thus, worksite area **106** can be visualized, according to functionality of mapping system **252** discussed above, with visual representations of the tree metrics. Of course, the tree inventory output can be provided in other ways as well, as indicated at block **648**. In one example, an action signal is provided as an output.

FIG. **7** illustrates a flow diagram showing one example **700** of controlling a UAV to perform a fire-fighting feasibility analysis for a worksite area. At block **702**, fire fighting deployment decision logic **262** detects a request to perform a fire fighting feasibility analysis for worksite area **106**. As with other requests, this can be automated, manual, or a combination of both.

At block **704**, fire fighting deployment decision logic **262** obtains information regarding worksite area **106** that is relevant to fire fighting operations. For instance, fire fighting deployment decision logic **262** can obtain stored information regarding worksite area **106**, such as worksite boundaries **730**, worksite size **732**, and historical worksite investment information **734**. In one example, fire fighting deployment decision logic **262** can interface with historic area of interest identification logic **310** to identify worksite boundaries **730**, worksite size **732**, and investment information (e.g., hours invested, money invested, start date of forestry operations, end date of operations, etc.) **734**, among other information **736**.

At block **706**, fire fighting deployment decision logic **262** generates a UAV flight path for performing the fire fighting feasibility analysis on worksite area **106**. For example, fire fighting deployment decision logic **262** can generate instructions that interface with flight path interface logic **318** for controlling UAV **104** according to a generated flight path. The flight path generated by fire fighting deployment decision logic **262** can control UAV **104** to obtain imagery information indicative of fire fighting parameters for worksite **106** by using image capture component **122**.

At block **708**, fire fighting deployment decision logic **262** instructs UAV **104** to capture images of worksite area **106** using image capture component **122** and/or obtain other information using attribute sensors **230**. As indicated at block **738**, fire fighting deployment decision logic **262** instructs UAV **104** to capture visual imagery using visual imaging component **242**. As indicated at block **740**, fire fighting deployment decision logic **262** can instruct UAV **104** to capture LIDAR/radar information indicating fire fighting parameters of worksite area **106** by using lidar/radar imaging component **244**. Fire fighting deployment decision logic **262** can instruct UAV **104** to obtain machine specific information, as indicated at block **742**, and other information, as indicated at block **744**.

At block **710**, fire fighting deployment decision logic **262** generates a fire fighting feasibility mapping of worksite area **106**, based on the captured images and other information obtained at block **708**. For example, fire fighting deployment decision logic **262** can interface with mapping system **252** (e.g., image stitching logic **302**) to stitch together images captured by image capture component **122** into a mapped representation of worksite area **106**, such that the mapping also represents a feasibility of fighting a fire in worksite area **106**. Fire fighting feasibility logic **262** can generate the mapping to indicate that particular sub-areas, of worksite area **106** as being either feasible or not feasible for performing a fire fighting operation. The fire fighting feasibility mapping can represent a wide variety of measured parameters for determining whether it is feasible to fight a fire, such as forestry density **746**, insect habitation **748** (e.g., pest infestation), storm and weather impact information **750**, and cost of fighting estimation information **752**, among other information **754**.

At block **712**, fire fighting feasibility analysis logic **340** compares the fire fighting feasibility mapping generated at block **710** to the stored worksite area information obtained at block **704**. For example, fire fighting feasibility analysis logic **340** compares a size of worksite area **732** to a density of forestry material **744**. This comparison can be used to determine terrain characteristics at worksite area **106**, generate a metric that indicates worksite area **106** is too large, too steep, and/or too dense for stopping a forest fire. As another example, fire fighting feasibility analysis logic **340** compares insect habitation **746** (e.g., invasive species habitation) to an amount of investment (e.g., number of hours spent harvesting in worksite area **106**). This comparison can be used to generate a metric that indicates worksite area **106** has not invested enough and has too many invasive species of insects to be valuable enough for implementing a fire fighting operation. Of course, these are just examples and fire fighting feasibility analysis logic **340** can compare a wide variety of different types of information to perform a fire fighting feasibility analysis.

At block **714**, fire fighting feasibility analysis logic **340** determines whether implementing a fire fighting operation is feasible, based the comparison discussed above with respect to block **712**. As similarly mentioned above, fire fighting feasibility analysis logic **340** can determine that a fire fighting operation is not feasible when worksite area **106** is determined to have characteristics that, for example, increase a risk of implementing a fire fighting operation, reduce a value of worksite **106** beyond a level that would warrant implementing a fire fighting operation, or that require excessive costs to implement a fire fighting operation, among others. Fire fighting feasibility analysis logic **340** can determine that a fire fighting operation is feasible when worksite area **106** is determined to have characteristics that, for example, reduce risk of implementing a fire fighting operation, increase the value of worksite **106**, or otherwise do not require excessive costs to implement a fire fighting operation. Of course, other characteristics can be considered by fire fighting feasibility analysis logic **340**.

At decision block **716**, fire fighting feasibility analysis logic **340** can determine whether it is feasible to implement a fire fighting operation. At block **718**, where fire fighting feasibility analysis logic **340** determines that it is feasible to implement a fire fighting operation, an action signal is generated, for example where escape route identification logic **346** can analyze the fire fighting feasibility mapping and other information (such as machine-specific sensor information) to identify potential escape routes. Potential escape routes can include travel routes for firefighters, operator **112**, machine **108**, and for other items in worksite **102**.

At block **720**, escape route identification logic **346** selects a particular one of the potential escape routes, based on the analyzed fire fighting feasibility mapping and other information. Escape route identification logic **346** can select the most safe or most efficient escape route as an optimal escape route. At block **722**, escape route identification logic **346** generates an output indicating the optimal escape route selected.

At block **724**, escape route identification logic **346** provides an indication of the optimal escape route output generated at block **722**. Escape route identification logic **346**

can provide the output as a visual map **756**, a notification **758**, or another output **760**. For example, escape route identification logic **346** can identify a travel route through worksite area **106** that operator **112** and or machines **108** travel to be safely removed from danger presented by a forest fire. In such an example, escape route identification logic **346** can provide an output indicating a travel route according to the optimal escape route to mapping system **252** for incorporation with a visual map of worksite area **106**. Escape route identification logic **346** can provide an output indicating a notification that is presented to operator **112** (e.g., by user interface component **246** and/or user interface device **204**), the escape route can be continuously updated based on new aerial imagery, weather changes, and other things.

At block **726**, where fire fighting feasibility analysis logic **340** determines that it is not feasible to implement a fire fighting operation, an action signal is generated, for example where fire fighting deployment decision logic **340** generates an output indicating the fire fighting operation is not feasible. At block **728**, fire fighting feasibility analysis logic **340** provides an indication of the infeasible output (e.g., action signal). The indication of the fire-fighting operation being infeasible can be provided as a notification to operator **112** or in a variety of other ways as well. For example, operator **112** can receive a notification at communication device **114** indicating that fire fighting feasibility analysis logic **340** has determined that a particular fire fighting operation is not feasible for a location at worksite area **106**. This is just one example.

FIG. **8** illustrates a flow diagram showing one example **800** of controlling a UAV to perform a productivity and control assessment for a worksite area associated with a forestry operation. At block **802**, productivity control system logic **266** detects a request to perform a productivity assessment for worksite area **106**. This request can be automatic, manual, or a combination of both.

At block **804**, worksite input logic **358** obtains information regarding worksite area **106** that is relevant to performing a productivity assessment. For instance, worksite input logic **358** can interface with area of interest identification logic **254** and mapping system **252** to obtain information regarding characteristics of worksite area **106**. Based on the obtained information, worksite input logic **358** can identify particular characteristics that will be used in performing a worksite productivity and control assessment for worksite area **106**. Worksite input logic **358** thus can identify any of worksite size **820**, a number of trees **822**, a volume per tree **824**, a tonnage per acre **826**, and a wide variety of other worksite characteristic information **828**.

At block **806**, UAV flight path logic **362** generates a UAV flight path for obtaining worksite productivity information. Based on the worksite characteristics obtained at block **804**, UAV flight path logic **362** generates instructions that control UAV **104** (e.g., by interfacing with flight path interface logic **318**) to travel along a defined flight path, where the flight path is defined to allow UAV **104** to obtain imagery information that is specific to a productivity and control assessment for worksite area **106**.

At block **808**, productivity control system logic **266** instructs UAV **104** to capture images of worksite area **106** using image capture component **122**, and/or to obtain other information using attribute sensors **230**. Productivity control system logic **266** can instruct UAV system **104** to capture visual imagery **830** using visual imaging component **242**, LIDAR/radar information **832** using lidar/radar imaging component **244**, and other information, as indicated at block **834**. Images of worksite area **106** can be analyzed to determine where an operation has been completed, and where an operation is currently in progress. Thus, by using aerial imagery information captured by UAV **104**, an entire worksite area **106** can be examined for obtaining detailed productivity information.

At block **810**, machine productivity input logic **360** obtains machine-specific productivity information for an operation performed at worksite area **106**. For instance, machine productivity input logic **360** obtains information sensed or otherwise collected by machine **108** and is indicative of how machine **108** is performing a current operation (e.g., indicative of performance of a harvesting operation). Information obtained by machine productivity input logic **360** can indicate productivity metrics specific to a machine, such as cut stem information **840** (e.g., number of stems cut, frequency of cutter being used, etc.), a cycle time **842** (e.g., amount of time machine **108** has been in use for performing a harvesting operation, etc.), an amount of material moved **840** (e.g., number of trees moved from ground pile to vehicle for transport, etc.), among other productivity information **842**.

At block **812**, categorical productivity image processing logic **364** identifies sub-areas within worksite area **106** as being associated with a particular productivity category, based on the imagery and machine-specific information. That is, categorical productivity image processing logic **364** can use aerial imagery captured by UAV system **104** and productivity information of machine **108** to determine which geographical regions of worksite area **106** are completed, are currently being worked in, or have not yet been worked in. For example, categorical productivity image processing logic **364** identifies sub-areas of worksite area **106** where trees are harvested **844**, identifies sub-areas where trees are on the ground but require clearance **846**, identifies sub-areas where trees are unharvested and thus still standing **848**, and identifies other sub-areas of operation progress **850**.

At block **814**, categorical productivity image processing logic **364** determines a percentage of completion of an operation being performed at worksite area **106**, based on the identified sub-areas (e.g., by aggregating the productivity categories). For example, where there is a large number of sub-areas identified as having trees harvested **844**, and there is a small number of sub-areas identified as having trees on the ground **846** (e.g., cut, yet need to be removed from worksite area **106**), then categorical productivity image processing logic **364** might determine a percentage of completion that indicates that a majority (or a specific percentage) of a harvesting operation for worksite area **106** is already complete. As another example, where there is a small number of sub-areas identified as having trees harvested **844**, and there is a large number of sub-areas identified as having trees still standing **848**, then categorical productivity image processing logic **364** might determine a percentage of completion that indicates that a harvesting operation for worksite area **106** has just been started, and that a majority (or a specific percentage) of the operation is yet to be performed.

At block **816**, categorical productivity output logic **366** generates a productivity output, based on the percentage of operation completed, the machine-specific information, and the worksite information. The percentage completion can be utilized, along with other information, by categorical productivity output logic **366** to generate a measured value of productivity obtained in performing the operation at worksite area **106**. In one example, categorical productivity output logic **366** can generate a productivity measure as a

percentage of each category **852** identified in the entire worksite area **106**. That is, productivity of worksite area **106** can be identified as 25 percent harvest complete, 20 percent harvest in progress, and 55 percent not yet harvested, as one example. Also, in one example, categorical productivity output logic **366** can generate a productivity output indicating a mill demand **854**, such as a number of trucks per day (e.g., the number of trucks, hauling loads of cut trees, will be identified for worksite area **106** for the harvesting operation). Categorical productivity output logic **366** can also generate an estimated productivity metric such as a quota, an estimated tonnage of material (e.g., harvested trees) that will be produced from the harvesting operation, and other estimated metrics, according to the determined metrics of productivity. Further, in one example, categorical productivity output logic **366** can generate a productivity metric as a comparison of total operation time to total available time for the operation, or such as a determined operation efficiency for worksite area **106**. Categorical productivity output logic **366** can generate other productivity metrics **860**. In accordance with block **816**, categorical productivity output logic **366** can also generate such as an action signal to control forestry analysis system **116** to update worksite completion metrics, control UAV **104** (e.g., to obtain machine-specific information), control machine **108**, among other action signals.

At block **818**, categorical productivity output logic **366** provides an indication of the productivity metric output generated. Categorical productivity output logic **366** can provide the output as a notification, as indicated at block **862**. For example, categorical productivity output logic **366** generates a notification for notifying operator **112** (e.g., by user interface component **246** and/or user interface device **204**) of the productivity metric, such as the percentages of each category of completion for the operation being performed at worksite area **106**. Categorical productivity output logic **366** can also provide the output with a visual map, as indicated at block **864**. Outputs provided with a visual map, for example, can represent the varying sub-areas of completion level, among other information such as a processing time versus available time for each machine **108** currently operating within worksite area **106**. Of course, outputs (e.g., action signals) of the productivity assessment can be provided in other ways as well, as indicated at block **866**.

FIG. **9** illustrates a flow diagram showing one example **900** of controlling UAV **104** to automatically obtain machine-specific information of a mobile machine operating in a worksite area. Operation **900** includes a mechanism that allows UAV **104** to collect information from machines **108**, positioned across a worksite area **106**, and upload the collected information to remote systems **120** for analysis automatically.

At block **902**, automated UAV data collection logic **388** detects a request to obtain machine-specific information from a mobile machine operating in a worksite area. Automated UAV data collection logic **388** can detect a request for obtaining such information at regularly scheduled intervals, for example, or in response to a determination that an operation is initiated or completed, for example, or in other ways.

At block **904**, machine data collection logic **395** generates a UAV flight path that controls UAV **104** to target particular machines **108** and obtain information from those particular machines **108**. More specifically, machine data collection logic **395** can generate instructions that control UAV **104** (e.g., by interfacing with flight path interface logic **318**) to travel along a defined flight path, where the flight path is defined to allow UAV **104** to hover above each machine **108**, within a certain distance, to establish a communication connection (e.g., over a WiFi connection, near field communication connection, etc.). The established communication connection can allow UAV **104** to obtain machine-specific information. Machine data collection logic **395** can thus identify particular machines **108** by a unique identifier, and interface with flight path interface logic **318** to direct travel of UAV **104** to each identified machine.

At block **906**, machine data collection logic **394** detects that UAV **104** collected machine specific data associated with the mobile machines **108** targeted in accordance with block **904**.

At block **908**, communication station upload logic **396** generates a UAV flight path that controls UAV **104** to travel to communication station **110**. In one example, communication station upload logic **396** generates the UAV flight path based on machine data collection logic **394** detecting that UAV **104** has collected the machine specific data. That is, once machine specific data is obtained, communication station upload logic **396** generates instructions that control UAV **104** (e.g., by interfacing with flight path interface logic **318**) to travel along a defined flight path, where the flight path is defined to allow UAV **104** to hover above communication station **110**, within a certain distance, to establish a communication connection (e.g., over a WiFi connection, near field communication connection, etc.).

At block **910**, communication station upload logic **396** controls an uploading operation that instructs UAV **104** to upload the obtained machine-specific information, among other information (such as imagery information obtained by image capture component **122**) to communication station **110** (e.g. to a satellite communication station remote from UAV **104**) via the established communication connection (e.g., satellite communication connection). For example, where communication station **110** is positioned remotely from machines **108**, UAV **104** is instructed, by communication station upload logic **396**, to travel from a location near machine **108** to a location near communication station **110** such that communication station **110** can receive the information captured by UAV **104** over the connection established between UAV **104** and communication station **110**.

At block **912**, communication station upload logic **396** detects that UAV **104** has uploaded the information to communication station **110**.

At block **914**, data forwarding logic **398** automatically forwards the uploaded, machine specific data and other information to a forestry analysis system. In one example, data forwarding logic **398** can automatically forward the information based on communication station upload logic **396** detecting that the information was uploaded from UAV **104**. Data forwarding logic **398** can forward the information to, for example, a remote forestry analysis system via a communication connection (e.g., satellite connection that allows communication between communications station **110** and a remote, cloud computing service executing some or all of forestry analysis system **116**).

At block **916**, data forwarding logic **398** generates a data forward output indicative of the information being automatically forwarded to and stored by forestry analysis system **116**. At block **918**, data forwarding logic **398** outputs an indication of the data forward output. For example, data forwarding logic **398** can provide an indication of the data forward output to UAV **104**, such that UAV **104** is released to perform other data collection and upload operations or other operations. In one example, data forwarding logic **398** provides an indication of the data forward output being

performed to operator **112**, such as via user interface component **246** and/or user interface device **204**.

At block **920**, automated UAV data collection logic **388** provides remote systems **120** with access to the information uploaded to forestry analysis system **116**. For example, automated UAV data collection logic **388** can generate instructions that allow remote systems **120** to access and use the data uploaded to forestry analysis system **116** according to the automated collection and upload operation **900**.

FIG. **10** illustrates a flow diagram showing one example **901** of controlling a UAV to obtain machine-specific information of a mobile machine operating in a worksite based on a user input. At block **903**, communication device connectivity logic **301** generates a data collection interface that can be displayed or otherwise provided to communication device **114**. Communication device connectivity logic **301** can generate instructions that control communication device **114** to display a representation of a visual map **921**, a list **923** of available mobile machines **108**, and a wide variety of other interfaces **925** that display other information that can be used by operator **112** to select parameters for collecting and uploading relevant information about worksite area **106**.

At block **905**, communication device connectivity logic **301** detects a user input, for example associated with the interface generated, that requests machine specific information or other information regarding worksite area **106**. For example, communication device connectivity logic **301** can detect a user input received with a visual map representation **927** (e.g., selecting location for UAV system **104** to travel to), detect a user input received to select a particular machine **929** (e.g., the user input selects a machine from a list of available machines **108** operating in worksite area **106**), and detect a wide variety of other inputs **931** that initiate a data collection and upload operation.

At block **907**, machine data targeting logic **303** generates a UAV flight path that controls UAV **104** to target particular machines **108** and obtain information from those particular machines. Machine data targeting logic **303** can generate a UAV flight path according to any of the features described with respect to block **908** of FIG. **9** (e.g., machine data collection logic **394**).

At block **909**, communication device connectivity logic **301** establishes a communication connection between UAV **104** and communication device **114**. Communication device connectivity logic **301** can instruct UAV **104** to, via the established communication connection, obtain machine specific information and other information from worksite area **106**. For instance, communication device connectivity logic **301** can establish a WiFi connection between communication device **114** and UAV **104**, and transfer the flight path instructions generated by machine data targeting logic **303** to UAV **104**. Based on the operator input that selects particular machines **108** and/or locations of worksite area **106**, operator **112** can thus utilize partial-assist UAV data collection logic **390** to instruct UAV system **104** to collect specific information.

At block **911**, communication device connectivity logic **301** uploads data obtained by UAV **104** to communication device **114** using the established connection. That is, once UAV **104** has traveled along the flight path and captured relevant information, communication device connectivity logic **301** instructs UAV **104** to report back to a location in worksite area **106** that is near communication device **114**, and accordingly upload the captured information to communication device **114**.

At block **913**, real time productivity interface logic **305** accesses some of the information uploaded to communication device **114** and associated with mobile machine **108** and/or worksite area **106**. That is, real time productivity interface logic **305** selects particular uploaded information that can be utilized in updating a productivity status for an operation being performed at worksite area **106**.

At block **915**, real time productivity interface logic **307** updates the uploaded information for providing a real time productivity update. For example, where UAV **104** captured machine specific information that indicates a number of hours that machine **108** has been harvesting in worksite area **106**, real time productivity interface logic **307** can update a current productivity measure, based on this captured information, and provide an indication of the updated productivity measure to operator **112** using communication device **114**. As such, in accordance with block **915**, operator **112** can receive updates to a productivity measure of an operation for worksite area **106** as information is obtained from UAV system **104** and uploaded to communication device **114**, in real time.

At block **917**, data storage and forward logic **307** detects an input to forward and/or store the uploaded information, with the updates applied. For instance, communication device **114** provides an interface that allows operator **112** to provide a user input to select a storage location, such as a remote storage location at forestry analysis system **116** or local location at communication device **114**. At block **919**, data storage and forward logic **307** generates instructions that forward and/store the information according to the user input. That is, at block **919**, data storage and forward logic **307** generates instructions that forward the information from communication device **114** to forestry analysis system **116**, or otherwise store the information at communication device **114** for further control locally with operator **112** interaction.

It is noted that while forestry harvesting machines have been particularly discussed with respect to the examples described herein, other machines can also be implemented with said examples, and thus the present disclosure is not limited to use of the systems and processes discussed with merely forestry harvesting machines.

The present discussion has mentioned processors and servers. In one example, the processors and servers include computer processors with associated memory and timing circuitry, not separately shown. They are functional parts of the systems or devices to which they belong and are activated by, and facilitate the functionality of the other components or items in those systems.

Also, a number of user interface displays have been discussed. They can take a wide variety of different forms and can have a wide variety of different user actuatable input mechanisms disposed thereon. For instance, the user actuatable input mechanisms can be text boxes, check boxes, icons, links, drop-down menus, search boxes, etc. They can also be actuated in a wide variety of different ways. For instance, they can be actuated using a point and click device (such as a track ball or mouse). They can be actuated using hardware buttons, switches, a joystick or keyboard, thumb switches or thumb pads, etc. They can also be actuated using a virtual keyboard or other virtual actuators. In addition, where the screen on which they are displayed is a touch sensitive screen, they can be actuated using touch gestures. Also, where the device that displays them has speech recognition components, they can be actuated using speech commands.

A number of data stores have also been discussed. It will be noted they can each be broken into multiple data stores. All can be local to the systems accessing them, all can be

remote, or some can be local while others are remote. All of these configurations are contemplated herein.

Also, the figures show a number of blocks with functionality ascribed to each block. It will be noted that fewer blocks can be used so the functionality is performed by fewer components. Also, more blocks can be used with the functionality distributed among more components.

The present discussion has mentioned processors and servers. In one example, the processors and servers include computer processors with associated memory and timing circuitry, not separately shown. They are functional parts of the systems or devices to which they belong and are activated by, and facilitate the functionality of the other components or items in those systems.

Also, a number of user interface displays have been discussed. They can take a wide variety of different forms and can have a wide variety of different user actuatable input mechanisms disposed thereon. For instance, the user actuatable input mechanisms can be text boxes, check boxes, icons, links, drop-down menus, search boxes, etc. They can also be actuated in a wide variety of different ways. For instance, they can be actuated using a point and click device (such as a track ball or mouse). They can be actuated using hardware buttons, switches, a joystick or keyboard, thumb switches or thumb pads, etc. They can also be actuated using a virtual keyboard or other virtual actuators. In addition, where the screen on which they are displayed is a touch sensitive screen, they can be actuated using touch gestures. Also, where the device that displays them has speech recognition components, they can be actuated using speech commands.

A number of data stores have also been discussed. It will be noted they can each be broken into multiple data stores. All can be local to the systems accessing them, all can be remote, or some can be local while others are remote. All of these configurations are contemplated herein.

Also, the figures show a number of blocks with functionality ascribed to each block. It will be noted that fewer blocks can be used so the functionality is performed by fewer components. Also, more blocks can be used with the functionality distributed among more components.

FIG. **11** is a simplified block diagram of one illustrative example of a handheld or mobile computing device that can be used as a user's or client's hand held device **16**, in which the present system (or parts of it) can be deployed. For instance, a mobile device can be deployed as computing architecture **200** in the operator compartment of machine **108** or for use in generating, processing, or displaying the information discussed herein and in generating a control interface. FIGS. **12-13** are examples of handheld or mobile devices.

FIG. **11** provides a general block diagram of the components of a client device **16** that can run some components shown in FIG. **2**, that interacts with them, or both. In the device **16**, a communications link **13** is provided that allows the handheld device to communicate with other computing devices and in some examples provide a channel for receiving information automatically, such as by scanning. Examples of communications link **13** include allowing communication though one or more communication protocols, such as wireless services used to provide cellular access to a network, as well as protocols that provide local wireless connections to networks.

In other examples, applications can be received on a removable Secure Digital (SD) card that is connected to an interface **15**. Interface **15** and communication links **13** communicate with a processor **17** (which can also embody processors or servers from previous FIGS.) along a bus **19** that is also connected to memory **21** and input/output (I/O) components **23**, as well as clock **25** and location system **27**.

I/O components **23**, in one embodiment, are provided to facilitate input and output operations. I/O components **23** for various embodiments of the device **16** can include input components such as buttons, touch sensors, optical sensors, microphones, touch screens, proximity sensors, accelerometers, orientation sensors and output components such as a display device, a speaker, and or a printer port. Other I/O components **23** can be used as well.

Clock **25** illustratively comprises a real time clock component that outputs a time and date. It can also, illustratively, provide timing functions for processor **17**.

Location system **27** illustratively includes a component that outputs a current geographical location of device **16**. This can include, for instance, a global positioning system (GPS) receiver, a LORAN system, a dead reckoning system, a cellular triangulation system, or other positioning system. It can also include, for example, mapping software or navigation software that generates desired maps, navigation routes and other geographic functions.

Memory **21** stores operating system **29**, network settings **31**, applications **33**, application configuration settings **35**, data store **37**, communication drivers **39**, and communication configuration settings **41**. Memory **21** can include all types of tangible volatile and non-volatile computer-readable memory devices. It can also include computer storage media (described below). Memory **21** stores computer readable instructions that, when executed by processor **17**, cause the processor to perform computer-implemented steps or functions according to the instructions. Processor **17** can be activated by other components to facilitate their functionality as well.

FIG. **12** shows one example in which device **16** is a tablet computer **700**. In FIG. **12**, computer **1200** is shown with user interface display screen **1202**. Screen **1202** can be a touch screen or a pen-enabled interface that receives inputs from a pen or stylus. It can also use an on-screen virtual keyboard. Of course, it might also be attached to a keyboard or other user input device through a suitable attachment mechanism, such as a wireless link or USB port, for instance. Computer **700** can also illustratively receive voice inputs as well.

FIG. **13** shows that the device can be a smart phone **71**. Smart phone **71** has a touch sensitive display **73** that displays icons or tiles or other user input mechanisms **75**. Mechanisms **75** can be used by a user to run applications, make calls, perform data transfer operations, etc. In general, smart phone **71** is built on a mobile operating system and offers more advanced computing capability and connectivity than a feature phone.

Note that other forms of the devices **16** are possible.

FIG. **14** is one example of a computing environment in which elements of FIG. **2**, or parts of it, (for example) can be deployed. With reference to FIG. **14**, an example system for implementing some embodiments includes a general-purpose computing device in the form of a computer **1310**. Components of computer **1310** may include, but are not limited to, a processing unit **1320** (which can comprise processors or servers from previous FIGS.), a system memory **1330**, and a system bus **1321** that couples various system components including the system memory to the processing unit **1320**. The system bus **1321** may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. Memory and programs

described with respect to FIG. **2** can be deployed in corresponding portions of FIG. **14**.

Computer **1310** typically includes a variety of computer readable media. Computer readable media can be any available media that can be accessed by computer **1310** and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer readable media may comprise computer storage media and communication media. Computer storage media is different from, and does not include, a modulated data signal or carrier wave. It includes hardware storage media including both volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by computer **1310**. Communication media may embody computer readable instructions, data structures, program modules or other data in a transport mechanism and includes any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal.

The system memory **1330** includes computer storage media in the form of volatile and/or nonvolatile memory such as read only memory (ROM) **1331** and random access memory (RAM) **1332**. A basic input/output system **1333** (BIOS), containing the basic routines that help to transfer information between elements within computer **1310**, such as during start-up, is typically stored in ROM **1331**. RAM **1332** typically contains data and/or program modules that are immediately accessible to and/or presently being operated on by processing unit **1320**. By way of example, and not limitation, FIG. **10** illustrates operating system **1334**, application programs **1335**, other program modules **1336**, and program data **1337**.

The computer **1310** may also include other removable/non-removable volatile/nonvolatile computer storage media. By way of example only, FIG. **14** illustrates a hard disk drive **1341** that reads from or writes to non-removable, nonvolatile magnetic media, an optical disk drive **1355**, and nonvolatile optical disk **1356**. The hard disk drive **1341** is typically connected to the system bus **1321** through a non-removable memory interface such as interface **1340**, and optical disk drive **1355** are typically connected to the system bus **1321** by a removable memory interface, such as interface **1350**.

Alternatively, or in addition, the functionality described herein can be performed, at least in part, by one or more hardware logic components. For example, and without limitation, illustrative types of hardware logic components that can be used include Field-programmable Gate Arrays (FPGAs), Application-specific Integrated Circuits (e.g., ASICs), Application-specific Standard Products (e.g., ASSPs), System-on-a-chip systems (SOCs), Complex Programmable Logic Devices (CPLDs), etc.

The drives and their associated computer storage media discussed above and illustrated in FIG. **14**, provide storage of computer readable instructions, data structures, program modules and other data for the computer **1310**. In FIG. **14**, for example, hard disk drive **1341** is illustrated as storing operating system **1344**, application programs **1345**, other program modules **1346**, and program data **1347**. Note that these components can either be the same as or different from operating system **1334**, application programs **1335**, other program modules **1336**, and program data **1337**.

A user may enter commands and information into the computer **1310** through input devices such as a keyboard **1362**, a microphone **1363**, and a pointing device **1361**, such as a mouse, trackball or touch pad. Other input devices (not shown) may include a joystick, game pad, satellite dish, scanner, or the like. These and other input devices are often connected to the processing unit **1320** through a user input interface **1360** that is coupled to the system bus, but may be connected by other interface and bus structures. A visual display **1391** or other type of display device is also connected to the system bus **1321** via an interface, such as a video interface **1390**. In addition to the monitor, computers may also include other peripheral output devices such as speakers **1397** and printer **1396**, which may be connected through an output peripheral interface **1395**.

The computer **1310** is operated in a networked environment using logical connections (such as a local area network—LAN, or wide area network WAN) to one or more remote computers, such as a remote computer **1380**.

When used in a LAN networking environment, the computer **1310** is connected to the LAN **1371** through a network interface or adapter **1370**. When used in a WAN networking environment, the computer **1310** typically includes a modem **1372** or other means for establishing communications over the WAN **1373**, such as the Internet. In a networked environment, program modules may be stored in a remote memory storage device. FIG. **14** illustrates, for example, that remote application programs **1385** can reside on remote computer **1380**.

It should also be noted that the different examples described herein can be combined in different ways. That is, parts of one or more examples can be combined with parts of one or more other examples. All of this is contemplated herein.

Example 1 is a computer-implemented method, comprising:

generating an unmanned aerial vehicle (UAV) control signal to control a UAV to fly over a forest site and capture imagery information, corresponding to different geographic locations in the forest site, with an image capture component on the UAV;

receiving the imagery information from the UAV;

generating a tree inventory metric indicative of a tree inventory at the forest site based on the imagery information; and

generating an action signal based on the tree inventory metric.

Example 2 is the computer-implemented method of any or all previous examples wherein generating the action signal comprises:

generating a machine deployment signal controlling deployment of a forestry machine at the forest site based on the tree inventory metric.

Example 3 is the computer-implemented method of any or all previous examples wherein generating a tree inventory metric comprises:

generating a set of tree inventory metrics, each one of the set of tree inventory metrics being generated for a corresponding one of the different geographic locations in the forest site.

Example 4 is the computer-implemented method of any or all previous examples wherein generating a machine deployment signal comprises:

generating the machine deployment signal to preferentially deploy the forestry machine to the different geographic locations in the forest site, based on the tree inventory metrics corresponding to the different geographic locations in the forest site.

Example 5 is the computer-implemented method of any or all previous examples wherein generating the tree inventory metric comprises:

generating a tree volume metric indicative of a lumber volume in trees in the different geographic locations based on the imagery information received from the UAV.

Example 6 is the computer-implemented method of any or all previous examples wherein generating the tree inventory metric comprises:

generating a tree population density metric indicative of a tree population density in the different geographic locations based on the imagery information received from the UAV.

Example 7 is the computer-implemented method of any or all previous examples wherein generating the tree inventory metric comprises:

generating a tree softwood/hardwood metric indicative of a quantity of softwood/hardwood trees in the different geographic locations based on the imagery information received from the UAV.

Example 8 is the computer-implemented method of any or all previous examples wherein generating the tree inventory metric comprises:

generating a tree diameter breast height metric indicative of a tree diameter breast height of trees in the different geographic locations based on the imagery information received from the UAV.

Example 9 is the computer-implemented method of any or all previous examples wherein generating the tree inventory metric comprises:

generating a tree height metric indicative of a height of trees in the different geographic locations based on the imagery information received from the UAV.

Example 10 is a computer-implemented method, comprising:

generating an unmanned aerial vehicle (UAV) control signal to control a UAV to fly over a forestry worksite and capture imagery information, corresponding to different geographic locations in the forestry worksite, with an image capture component on the UAV;

receiving the imagery information from the UAV;

identifying a productivity category corresponding to each of the different geographic locations at the forestry worksite, based on the imagery information; and

generating an action signal based on the productivity category corresponding to each of the geographic locations.

Example 11 is the computer-implemented method of any or all previous examples wherein generating an action signal comprises:

generating a computing system control signal to control an analysis system to update worksite completion metrics based on the productivity category corresponding to each of the different geographic locations at the forestry worksite.

Example 12 is the computer-implemented method of any or all previous examples wherein generating a UAV control signal comprises:

identifying a machine at one of the geographic locations at the forestry worksite;

Example 13 is the computer-implemented method of any or all previous examples wherein generating a UAV control signal comprises:

controlling the UAV to obtain machine-specific data generated from machine sensors on the identified machine at the one of the geographic locations at the forestry worksite.

Example 14 is the computer-implemented method of any or all previous examples and further comprising:

generating a productivity metric corresponding to the identified machine based on the imagery information and based on the machine-specific data.

Example 15 is the computer-implemented method of any or all previous examples wherein identifying a productivity category comprises:

aggregating the productivity categories corresponding to each of the different geographic locations at the forestry worksite, to obtain a worksite productivity category and wherein generating the action signal comprises generating the action signal based on the worksite productivity category.

Example 16 is the computer-implemented method of any or all previous examples wherein identifying the productivity category comprises:

identifying a state of completion of a forestry harvest operation being performed at each of the different geographic locations at the forestry worksite.

Example 17 is a computing system, comprising:

unmanned aerial vehicle (UAV) interaction logic that generates a control signal to control a UAV to fly over a forest site and capture imagery information, corresponding to different geographic locations in the forest site, with an image capture component on the UAV;

a communication system that receives the imagery information from the UAV;

tree inventory logic that generates a tree inventory metric indicative of a tree inventory at the forest site based on the imagery information; and

a processor that generates an action signal based on the tree inventory metric.

Example 18 is the computing system of any or all previous examples and further comprising:

productivity control system logic configured to identify a productivity category corresponding to each of the different geographic locations at the forestry worksite, based on the imagery information.

Example 19 is the computing system of any or all previous examples and further comprising:

machine interaction logic configured to identify a machine at one of the geographic locations at the forestry worksite wherein the UAV interaction logic is configured to control the UAV to obtain machine-specific data generated from machine sensors on the identified machine at the one of the geographic locations at the forestry worksite.

Example 20 is the computing system of any or all previous examples wherein the productivity control system is configured to generate a productivity metric corresponding to the identified machine based on the imagery information and based on the machine-specific data.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific

features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

What is claimed is:

1. A computer-implemented method, comprising:

generating an unmanned aerial vehicle (UAV) control signal to control a UAV to fly over a forest site and capture imagery information, corresponding to different geographic locations in the forest site, with an image capture component on the UAV;

controlling the UAV to obtain machine-specific data generated from machine sensors on each of a plurality of machines at the geographic locations at the forestry site;

receiving the imagery information and the machine-specific data from the UAV;

generating a tree inventory metric indicative of a tree inventory at the forest site based on the imagery information;

generating a productivity metric corresponding to each of the identified machines at the geographic locations at the forestry site indicative of a productivity level at the forestry site based on the imagery information and based on the machine-specific data;

generating an action signal based on the tree inventory metric.

2. The computer-implemented method of claim **1** wherein generating the action signal comprises:

generating a machine deployment signal controlling deployment of a forestry machine at the forest site based on the tree inventory metric.

3. The computer-implemented method of claim **2** wherein generating a tree inventory metric comprises:

generating a set of tree inventory metrics, each one of the set of tree inventory metrics being generated for a corresponding one of the different geographic locations in the forest site.

4. The computer-implemented method of claim **3** wherein generating a machine deployment signal comprises:

generating the machine deployment signal to preferentially deploy the forestry machine to the different geographic locations in the forest site, based on the tree inventory metrics corresponding to the different geographic locations in the forest site.

5. The computer-implemented method of claim **1** wherein generating the tree inventory metric comprises:

generating a tree volume metric indicative of a lumber volume in trees in the different geographic locations based on the imagery information received from the UAV.

6. The computer-implemented method of claim **1** wherein generating the tree inventory metric comprises:

generating a tree population density metric indicative of a tree population density in the different geographic locations based on the imagery information received from the UAV.

7. The computer-implemented method of claim **1** wherein generating the tree inventory metric comprises:

generating a tree softwood/hardwood metric indicative of a quantity of softwood/hardwood trees in the different geographic locations based on the imagery information received from the UAV.

8. The computer-implemented method of claim **1** wherein generating the tree inventory metric comprises:

generating a tree diameter breast height metric indicative of a tree diameter breast height of trees in the different geographic locations based on the imagery information received from the UAV.

9. The computer-implemented method of claim **1** wherein generating the tree inventory metric comprises:

generating a tree height metric indicative of a height of trees in the different geographic locations based on the imagery information received from the UAV.

10. A computer-implemented method, comprising:

generating an unmanned aerial vehicle (UAV) control signal to control a UAV to fly over a forestry worksite and capture imagery information, corresponding to different geographic locations in the forestry worksite, with an image capture component on the UAV;

identifying a machine at one of the geographic locations at the forestry worksite;

controlling the UAV to obtain machine-specific data generated from machine sensors on the identified machine at the one of the geographic locations at the forestry worksite;

receiving the imagery information and the machine-specific data from the UAV;

identifying a productivity category indicative of worksite completion state corresponding to each of the different geographic locations at the forestry worksite, based on the imagery information;

generating a productivity metric corresponding to the identified machine based on the imager information and based on the machine-specific data; and

generating an action signal based on the productivity category corresponding to each of the geographic locations, and the productivity metric corresponding to the identified machine.

11. The computer-implemented method of claim **10** wherein generating an action signal comprises:

generating a computing system control signal to control an analysis system to update worksite completion metrics based on the productivity category corresponding to each of the different geographic locations at the forestry worksite.

12. The computer-implemented method of claim **10** wherein identifying a productivity category comprises:

aggregating the productivity categories corresponding to each of the different geographic locations at the forestry worksite, to obtain a worksite productivity category and wherein generating the action signal comprises generating the action signal based on the worksite productivity category.

13. The computer-implemented method of claim **12** wherein identifying the productivity category comprises:

identifying a state of completion of a forestry harvest operation being performed at each of the different geographic locations at the forestry worksite.

14. A computing system, comprising:

unmanned aerial vehicle (UAV) interaction logic that generates a control signal to control a UAV to fly over a forest site and capture imagery information, corresponding to different geographic locations in the forest site, with an image capture component on the UAV;

machine interaction logic configured to identify each of a plurality of different machines at the geographic locations at the forestry site wherein the UAV interaction logic is configured to control the UAV to obtain machine-specific data generated from machine sensors on each of the identified machines at the geographic locations at the forestry site;

a communication system that receives the imagery information and machine-specific data from the UAV;

tree inventory logic that generates a tree inventory metric indicative of a tree inventory at the forest site based on the imagery information; and

a productivity control system configured to identify a different productivity category metric corresponding to each of the different geographic locations at the forestry site and indicative of a productivity of a forestry operation at each of the different geographic locations, based on the imagery information, and wherein the productivity control system is configured to generate a machine productivity metric corresponding to each of the identified machines, and being indicative of a productivity of the corresponding machine in performing the forestry operation, based on the imagery information and based on the machine-specific data; and

a processor that generates an action signal based on the tree inventory metric, and the machine productivity metric.

* * * * *